Demography and Economics

DEMOGRAPHY AND ECONOMICS

ANYA HAGEMAN AND PAULINE GALOUSTIAN

Queens University

CONTENTS

Intrinsic Population Change

Migration

Zooming In

Zooming Out

Acknowledgements:

Pauline Galoustian provided research support and copyright clearance support. Pauline also created many of the graphics, selected many of the images, and designed the overall look of the textbook.

Queen's University Library provided a grant and guidelines for creating an Open Textbook.

The **cover photo** was taken October 14, 2009 by barnyz. It's available on Flickr.com and the copyright is CC BY-NC-ND 2.0. It is called "Bratislava" and depicts a winding street in the old town.

Any errors, omissions or copyright issues are my responsibility.

Disclaimer

> This textbook deals with sensitive topics such as death, gender, birth control, and immigration. Any opinions, personal or religious values, or prejudices which may be correctly or incorrectly inferred from the way the material in this textbook is presented should not be thought to reflect the views of Pauline Galoustian or any part of Queen's University.

~ *Anya Hageman* (primary author)

Details and Conditions of Use:

RECOMMENDED CITATION

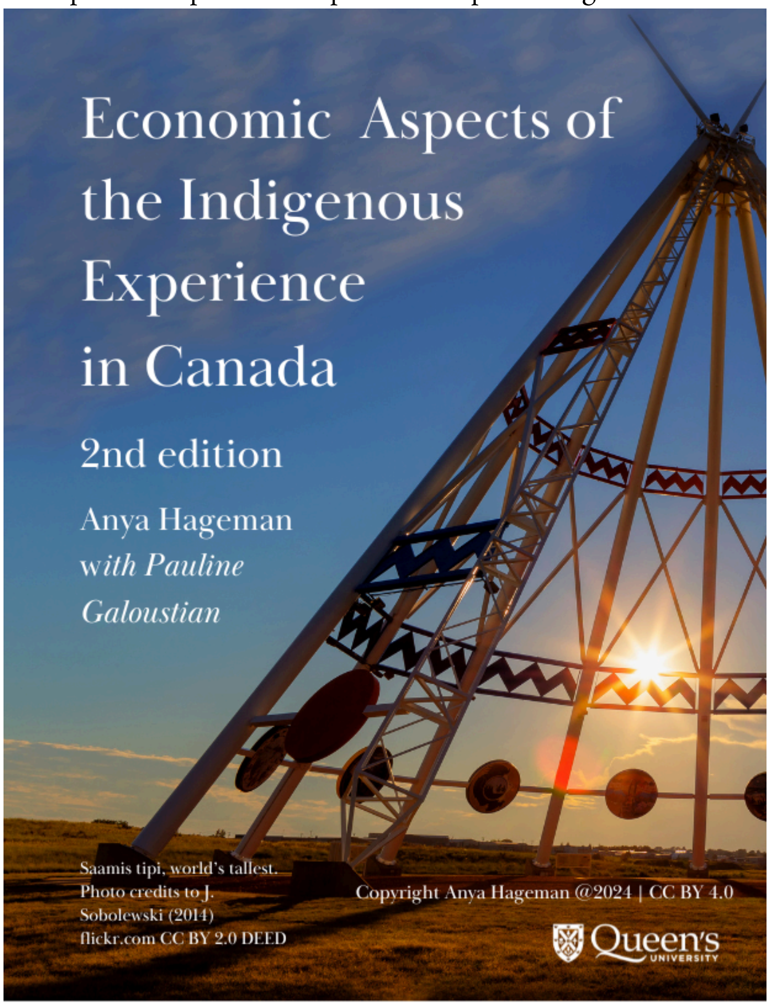
Hageman, Anya and Pauline Galoustian (2023). Demography and Economics. Kingston, Ontario: Queen's University Library. https://ecampusontario.pressbooks.pub/demographyandeconomics

OTHER BOOK BY AUTHORS

See also

Hageman, Anya and Pauline Galoustian (2024). Economic Aspects of the Indigenous Experience in Canada, 2nd edition. Kingston, Ontario: Queens University Library.

at https://ecampusontario.pressbooks.pub/indigenouseconomics244



INTRODUCTION TO POPULATION ECONOMICS

Chapter 1: What is Population Economics?

Economics is the study of material trade-offs, of costs and benefits.
Demography is the study of human population changes.

Can these social sciences be combined without producing a monster?

Photo by See-Ming Lee, 2009, flickr.com. CC BY-SA

Welcome to the economic study of us – the human population. How does the way we are born, grow, age, and die affect the economy, and how does the economy affect the way we are born, grow, age, and die?

These questions take a limited view of us as human beings. The approach is materialistic. To move forward without acknowledging the limitations of this view would be dangerous. Next thing you know, we would be pricing human life in dollars without batting an eye. We do actually discuss the dollar value of a decreased chance of dying, known as the "Value of a Statistical Life", in Chapter 10.

We can move forward with economics and demography if we understand that economics cannot provide ultimate, absolute, or intrinsic values for anything. Economics just measures the material trade-offs involved in decisions or policies. In economics, the value of something is what must be given up in exchange for one more unit of it. To be specific, **economics measures the value-in-trade of the marginal unit of a good or service to market participants at one point in time.**

The value-in-trade does not tell us what to buy or do; it tells us what it will cost to do so. It tells us what we have to give up to get what we want. *Economic demography provides us with some of the information we need to support those social outcomes we believe are best.*

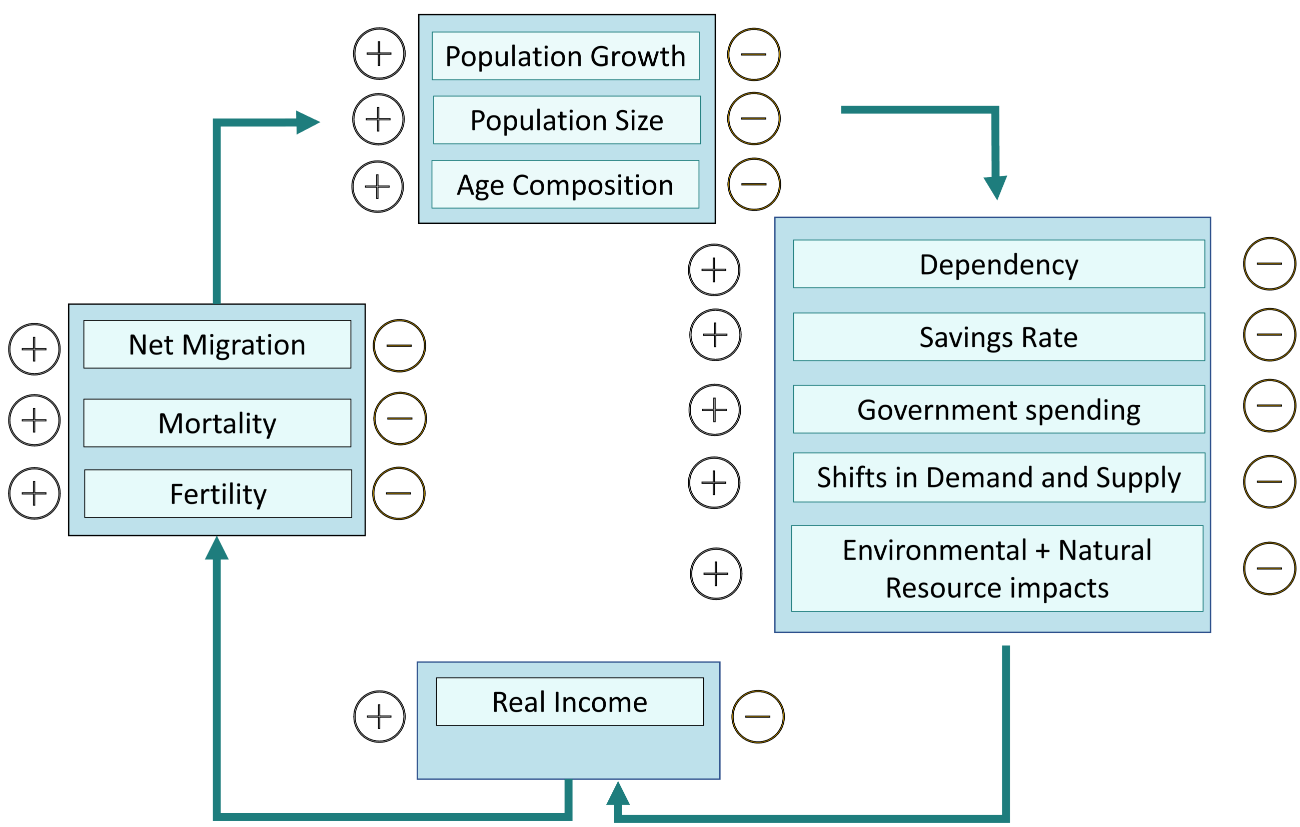
The interplay between economy and population

Figure 1.1 shows that the economy and the population's size, growth rate, and composition are mutually influential, as explained by J.R. Weeks (1989). Financial pressures, especially those that increase (+) or decrease (-) **real income**[1], may lead to increases or decreases in **fertility**, **mortality**, and **migration**. This is shown by the lower left arrow.

Fertility, mortality, and migration are the three drivers of population change. When they change, the population's growth rate, absolute size, and age or sex composition may change. This is shown by the upper left arrow.

Changes in the population's growth rate, absolute size, and age or sex composition affect the economy, for example by changing the supply of labour and the demand for resources. Prices and wages change, and real income is affected. Thus, as shown by the top right and lower right arrows, changes in the overall population increase or decrease real income. We come full circle.

Figure 1-1. Economics and demography



1. Real income equals income divided by the price index, thus real income is a measure of purchasing power.

Since economics and demography affect one another, there is the possibility of feedback loops. The population's growth could cause the economy to grow, which could cause the population to grow, and so on forever and ever without rest.

On the other hand, the causality between population and the economy could be such that an equilibrium emerges. An equilibrium is a resting place, a stable situation from which there is no tendency to move. If a randomly occurring phenomenon from outside economics or demography, that is to say, some phenomenon exogenous to the model, were to upset an equilibrium, the equilibrium would eventually re-emerge.

In our next chapter we'll examine the equilibrium described by the oldest model of population and economic change, the Malthusian model.

Exercises: Chapter 1

1. The cost of a loaf of bread is $3.99. The average wage is $12 per hour. What does this mean to an economist?
2. What determines value-in-trade?
3. Compare the benefits of the legal system to society with the benefits of the market-place to society.
4. What is an equilibrium?
5. Give an example of a positive feedback loop that involves war.
6. Give an example of a negative feedback loop that involves sleep.

Chapter 2: Population and Economic History

In Chapter 1 we discussed the possibility of combining Economics with Demography to form a monster. The Malthusian model is a bit of a monster.
The Malthusian model was the very first model of population change and the very first macroeconomic model as well.

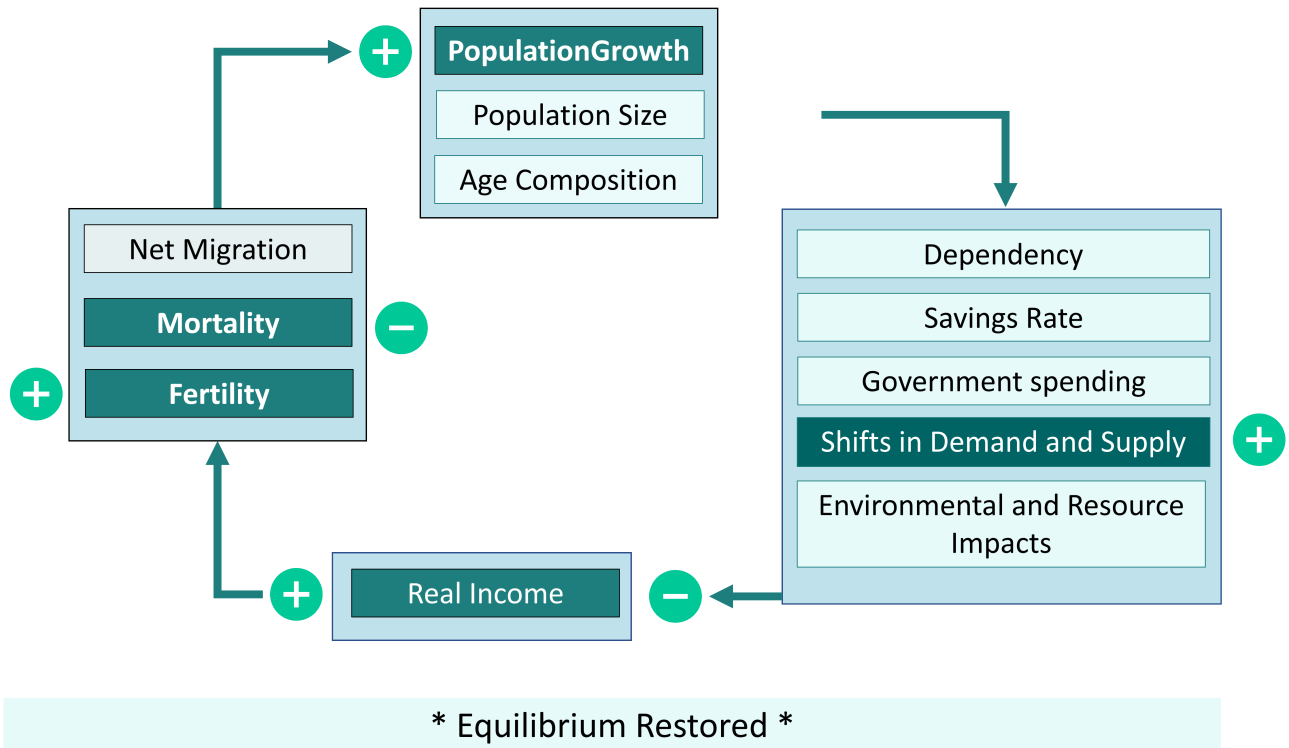
The Malthusian Equilibrium

Written by Thomas Robert Malthus in various editions, *An Essay on the Principle of Population as it Affects the Future Improvement of Society* (1798) is famous because it presents an equilibrium that is both credible and terrifying. Economists like Malthus gave Economics the reputation of being a "dismal science". On the basis of his model, Malthus predicted that the **standard of living** can never increase, and that it is useless to help the poor.

Malthus' model assumes two things: first, that food production can never grow as fast as the population can grow, and second, that the population grows whenever food becomes more plentiful. The model ignores a number of factors which will be discussed later.

Malthus' model achieves an equilibrium because population size affects the amount of food per person in a simplistic and rigid way, and the amount of food per person affects the population in a simplistic and rigid way that is exactly opposite. Since the forces are opposing, no positive or negative feedback loops can form.

Figure 2-1. The Malthusian Model



Let's begin our examination of the Malthusian model by looking at "**Real Income**" at the bottom of Figure 2-1. Malthus didn't actually talk about Real Income; he talked about "Food per Person", which is conceptually similar to real income per person or per household. Real Income per household is the average household's income divided by the overall price level. So it measures how much stuff households can afford to buy.

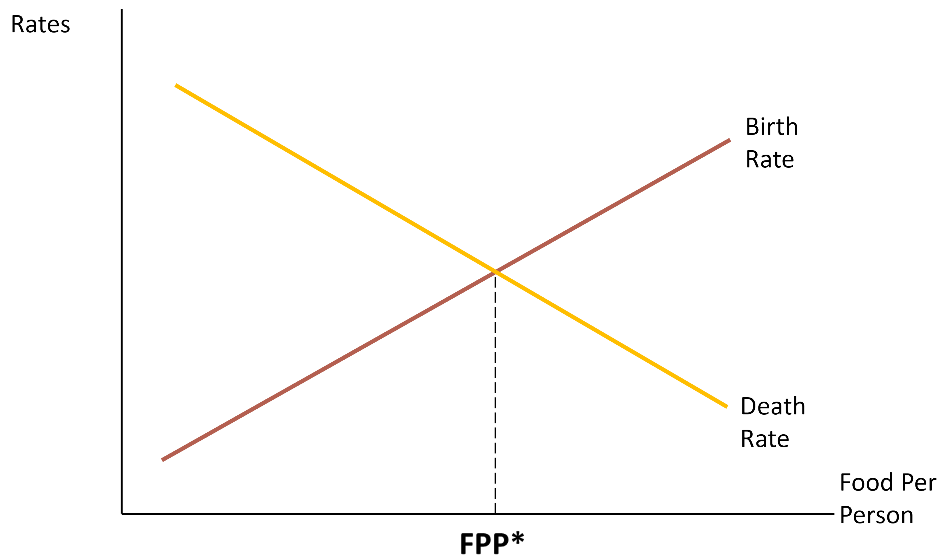
Malthus believed that if something happened to increase Food per Person/Household Real Income, then the **birth rate** would increase and the **death rate** would decrease. This is shown by the lower left arrow, although fertility and mortality are not exactly the same thing as births and deaths (as we will learn in later chapters).

The upper left arrow shows that an increase in fertility and a decrease in mortality cause the population to grow.

The population growth causes demand for food to increase. Malthus believed that agricultural supply could not keep up with the demand for food caused by population growth, so food per person/real income would decline as the population grew, as shown by the lower right arrow. We would end up at the original level of food-per-person/real income.

Figure 2-2 is a graphical depiction of how the Malthusian equilibrium is determined.

Figure 2-2. The "Malthusian Scissors"



In Figure 2-2 we have the birth rate as a positive function of food per person and the death rate as a negative function of food per person, in keeping with Malthus' assumptions. The point where they intersect is the Malthusian equilibrium level of food per person. Malthus assumed that this level of food per person would be low, just enough for survival or "subsistence". But that's not necessarily the case. The Malthusian model's predicted equilibrium level of food person is just whatever level of food per person coincides with zero population growth. That is to say, the equilibrium level of food per person is found where the birth rate is equal to the death rate.

So not only do we have an equilibrium level of food per person, we also have an equilibrium level of population growth, namely zero population growth ("ZPG").

Figure 2-2 shows us that if food per person were to be any higher than its equilibrium level, for example because of favourable weather, the birth rate would exceed the death rate. This means that the population would grow and cause food per person to come back down. As food per person declined, the birth rate and death rate would converge once again until the original equilibrium was restored. Similarly, if food per person were any lower than its equilibrium level, perhaps because of famine, the death rate would exceed the birth rate, and then the population would shrink. As the population shrank, food per person would increase again. Eventually, food per person would be at its original level, and the population would have stopped shrinking.

Note that, in Figure 2-2, the birth rate line is NOT like a supply curve. It does not shift to the right when the birth rate rises at every standard of living. It shifts up vertically in that case. The death rate line also shifts up vertically with an increase in death rates, and shifts down vertically when they fall.

What might cause the birth rate line to shift? Malthus noted that the age at which people get married affects the birth rate. Whatever the level of food per person, if social norms or personal choices mean that most people get married younger/older, then the birth rate will rise/fall.

What might cause the death rate line to shift? An outbreak of a new disease, for example, would cause the death rate to shift up, though it would likely shift up more for people who have less food per person than for people with higher incomes. The development or distribution of a vaccine would cause the death rate to shift down.

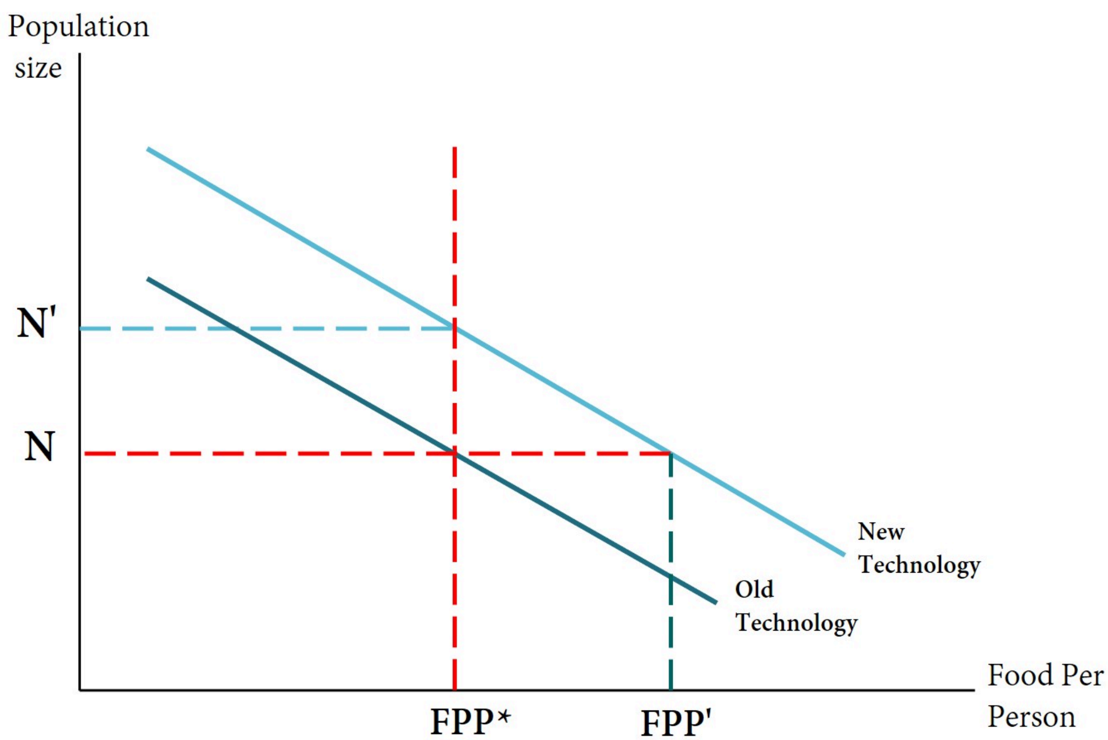
What happens to the equilibrium level of food per person if the death rate shifts down? You might be surprised. Trace it out and you will see that if the death rate line were to shift down, or if the birth rate line were to shift up, the original equilibrium level of food per person would now coincide with a birth rate that is higher than the death rate. There would be positive population growth at this level of food per person, stressing the food supply. The economy and the population would settle at a new equilibrium, an equilibrium consistent with a lower level of food per person.

Gregory Clark, in his 2007 book "A Farewell to Alms," notes that homes in medieval East Asia were likely a lot cleaner than they were in medieval Europe. In East Asia, cats and dogs were not permitted indoors, people took their shoes off when entering the house, and people's urine and defecation was removed from the home and used to create fertilizer. Because Europe didn't follow such practices, death rates were likely higher in Europe. Clark provides some data to back this up. The Malthusian model predicts that the higher death rates in Europe would result in a higher equilibrium level of food per person, ***ceteris paribus***. Accordingly, Clark believes that the lack of hygiene in Europe was a major reason for the higher standard of living in Europe.

Whether Clark's argument is historically accurate or not, the Malthusian model warns us that it is not enough to offer vaccinations and medical technology to poor societies. Everyone needs not only to survive, but to thrive. If peoples' lives are to be saved by vaccination or other means, food per person may be strained. Assistance with food production or other ways of earning income is essential. This may involve removing barriers that put poorer countries at a disadvantage in international trade.

Malthus believed that population growth will always strain food per person, because he assumed that technology cannot keep up with population growth. For him, technology was not constantly changing but was fixed for long periods of time, as shown in Figure 2-3.

Figure 2-3. The "Technology Schedule"



In Figure 2-3, the technology lines do not refer to birth control technology or medical technology. They refer only to technology that affects the ability of people to produce food/earn income.

Figure 2-3 shows that, because of technological limits, there is a trade-off between the population's size and food per person. The technical possibilities might suddenly improve, because of good weather or a new invention; this is shown by the New Technology line being above the Old Technology line. With the New Technology, the original population of size N can now enjoy a higher level of food per person, FPP'. That sounds great; however, that improvement in food per person will set off population growth, reducing food per person. The economy will move along the higher technology line from (FPP', N) to (FPP*, N'), ending up at the original level of food per person. Population growth falls back down to zero; however, the population is now higher than it was originally.

Malthus - conclusions

Malthus and others concluded from this model that it is pointless to help the poor. They reckoned that most people won't use late marriage, birth control, and other "preventive checks", so population will surge if people get more to eat. As population surges, resources will become scarce due to technological limits. "Positive" checks like disease, crime and warfare will hasten the return to the original level of food per person. Indeed, as we have already discussed, a growing population needs to have the means to support itself; if not, sad things can happen.

Before we become too discouraged, however, we should listen to our humanitarian values and take a more critical look at the model.

The first thing we can question is whether Malthus' two main assumptions hold. Clearly, they do not hold in modern times. The birth rate is no longer simplistically and positively correlated with the standard of living. The global birth rate is trending down. And food production has grown much faster than population. The world's population has grown and become better fed at the same time!

In some societies, for example where government is corrupt, markets rife with inefficiencies, international trade restricted, loans unavailable, and technology outdated, people may be very reliant on local resources and food systems. The Malthusian model would have some predictive power there. Most pre-industrial societies fit this description.

But even in those situations where a Malthusian equilibrium could be expected to exist, helping the poor is not, materially speaking, pointless. Giving a population size N a higher level of food per person than FPP* can accomplish important things for the economy.

First, the period of relative prosperity during which (FPP',N) transitions to (FPP*, N') in Figure 2-3 could accomplish several beneficial things. The population is catching a break. It is happier and feeling more secure with loved ones surviving. It plans and invests for a longer lifespan. It has greater health and strength and, possibly, motivation. It can use its (temporarily) extra income to invest in tools, infrastructure, and education. It has opportunities to trade, explore, and experiment. New technologies may be discovered that reinforce the increase in the standard of living. A positive feedback loop could develop as technology improves, food per person rises, and the new healthier population develops new technologies.

Second, the population grows larger, and a larger population is sometimes advantageous for reasons we will explore in Chapter 19.

Demographic history before 1700 AD

Archeology, oral and written history, and literature attest to the fact that, prior to the Industrial Revolution which began around 1750 AD, humanity experienced a much lower standard of living and a much lower rate of population growth than what we have seen since then.

Barter between old Nordic peoples (to the left) and Rus people (to the right). From Lars Henriksson's Clipart Collection (Public Domain). Retrieved from wikimedia commons.

As observed and predicted by Malthus, many societies experienced close to zero population growth as well as a stagnant standard of living which was close to a subsistence level of food per person.

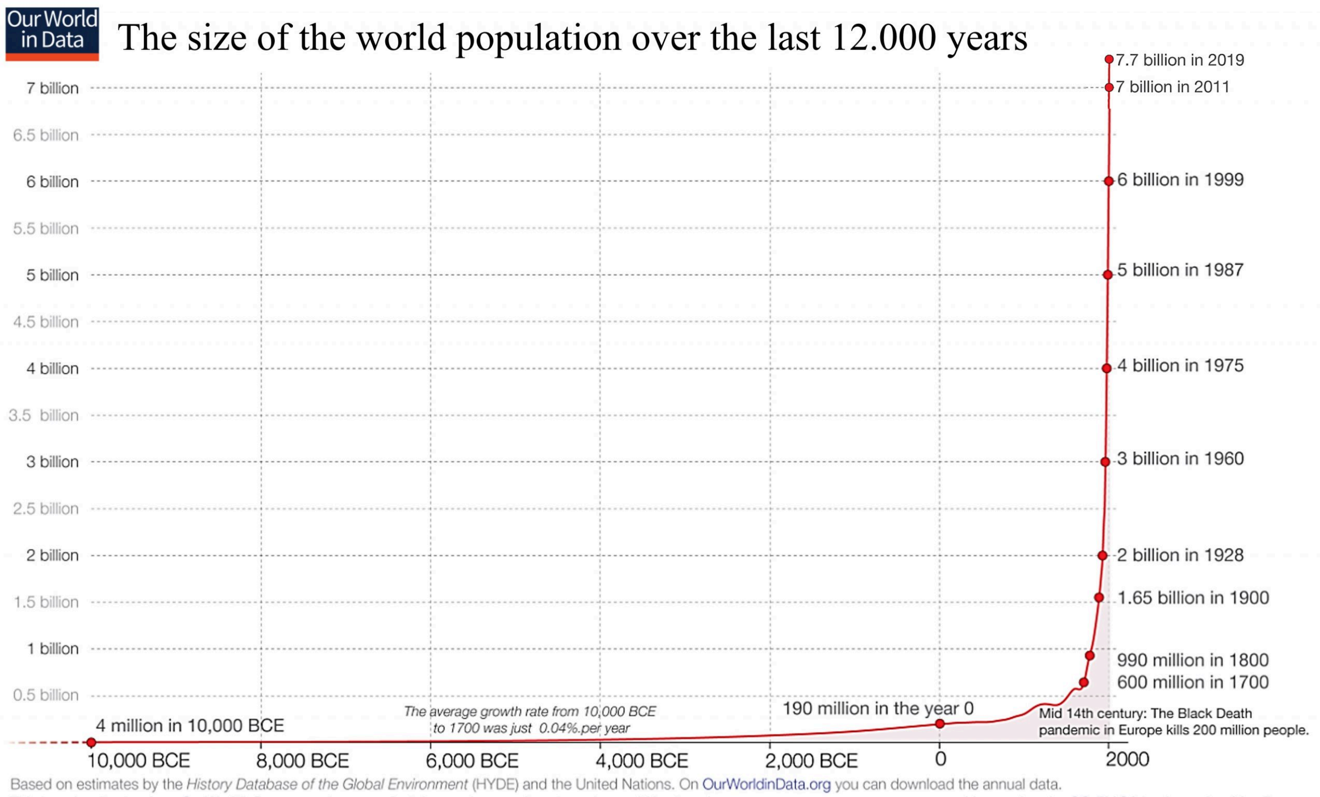
A traditional Chinese tale (Lily Toy Hong, 1995) explains that The Emperor of Heaven took pity on humanity's struggle to find enough to eat. He sent the Ox star from the sky down to earth with the message that hardworking people would be able to eat well every three days. But the Ox garbled the message, promising three square meals a day. To keep His word, the Emperor of Heaven conscripted the Ox to help humans. Without its help, three meals per day would have been impossible.

We know that there were times of prosperity for all; then again, there were terrible famines and the collapse of civilizations. The human population of our planet grew slowly until AD 0, with many reversals. The population growth that occurred was equivalent to that which would have occurred if the population had grown from 9000 BC at a constant exponential rate of 1/20th of one percent. Figure 2-4 shows the extremely gradual increase in population believed to have occurred in prehistoric times.

The Gleaners (1857). Painting by Jean-François Millet (Public Domain)

By AD 0, total population was probably about 300 million. After AD 0 the population continued to grow at the same modest pace, resulting in a population of about 790 million in 1750.

Figure 2-4. Population trend over human history



Source: OurWorldData.org. Credits to: Max Roser (CC By-NC-SA 2.0)

Before 1750, most people everywhere lived in poorly heated homes, experienced periods of famine, and died young. The slow rate of population growth prior to 1750 is attributed to:

- Low rates of technological change
- A standard of living so low that it left the population vulnerable to crises such as crop failure, pandemic disease, and war
- High chronic mortality rates which decreased when food per person increased
- Fertility rates significantly less than the maximum biologically possible
- Fertility rates which increased when food per person increased

We might also add, poking Malthus in the eye

- Income inequality and a lack of a safety net for the poor. With many people unable to participate fully in production, trade, travel, education etc., technological advancements were delayed or missed completely.

Malthusian-era Mortality Rates

The fact that mortality rates were high in pre-industrial times is no surprise. We all know how little technological and medical assistance was available to people back then. Their clothing, housing, and sanitation were crude. They gave birth without ultrasound, hand-washing, or sterilizing of equipment. They didn't know about the need to boil water given to infants; there was no infant formula and no pasteurization of cow's milk. They worked with crude tools and heavy livestock. Most people were employed in weather-dependent agriculture, hunting, fishing, trapping and gathering, without benefit of insurance. It is estimated that **life expectancy** at birth was between 20 and 40 years. (Life expectancy at birth includes the many infants that would have died shortly after birth in those days. So although life expectancy at birth was between 20 and 40 years, many people who made it to adulthood lived longer than 40 years.)

In pre-industrial times there was little sense that the government should work for peaceful international relations, provide for the poor, or stimulate the economy. There were more frequent violent conflicts between individuals, tribes, and nations.[1]

Malthusian-era fertility rates

Because we observe today that nations with lower incomes tend to have more children per woman, we might suppose that fertility was high in the pre-industrial era. It was indeed higher than it is today, but not as high as you might expect. Certainly fertility was NOT normally near 15 children per woman, which is the maximum biologically possible. For one thing, many women and men did not get married. Think back only 150 years in Canada, and you will recall from novels you may have read the many more "spinsters", "bachelors", priests and nuns. Poverty, social isolation of farming men, strict social norms around courtship and engagement, and high mortality rates for men in war and work meant that many potential couples did not unite.

Even within marriage, infertility, poor nutrition, length of time breastfeeding, women's deaths in childbirth, and early widowhood (death of husband or wife) conspired to keep fertility rates lower than the maximum possible.

Estimates of pre-industrial fertility differ. Clark (2007, Table 4-2) estimates that the average woman in England before 1790 gave birth to about 5 children, not all of whom survived. Meanwhile, in New France

1. For evidence that violence has declined, see S. Pinker's *The Better Angels of our Nature*. New York: Viking, 2011.

(now Quebec), where farmland was readily available to colonists, the average married man of European descent had 9 children, but only 4.36 of these children would survive to have children of their own[2].

Among Indigenous peoples on Turtle Island before contact with European colonizers, families were apparently not large[3]. Most tribes had nomadic lifestyles, which would not be possible with a large number of infants, toddlers, and young children needing to be carried long distances. Population growth had to be balanced with the capacity of the natural environment to provide enough food through hunting and gathering. There is some evidence of infanticide among the people of the Plains and among the Inuit. Breastfeeding on demand inhibited conception to some degree.

Later

Mortality and Fertility have changed a great deal since 1750, when the Malthusian era began to give way in the wake of the Industrial Revolution. In our coming chapters we'll take a look at

-how mortality and fertility changed

-how economic factors influence mortality, fertility, and migration

-how mortality, fertility, and migration translate into population growth, shrinkage, and aging

-how changes in population size, growth, and age composition affect the economy

-what models of population and economic change might replace the Malthusian model

But first we'll talk about how we measure birth and death rates, and where our demographic data comes from.

Exercises: Chapter 2

1. Consider Figure 2-1.
    a) When food-per-person surges above FPP*, what happens?
    b) When food-per-person drops below FPP*, what happens?
    c) When births drop at all levels of food-per-person, what happens?
    d) When deaths drop at all levels of food-per-person, what happens?
2. According to Malthus, the equilibrium level of population growth is
    a) unsustainable
    b) high because people do not use preventive checks
    c) low because, in the absence of preventive checks, positive checks cause death
    d) zero

2. Clark and Hamilton (2012)
3. Hageman and Galoustian (2021)

3. Briefly describe the following before 1750:
    a) technological innovation
    b) productivity
    c) population growth
    d) mortality
    e) fertility
    f) the standard of living

TOOLS OF THE TRADE

Chapter 3: Demographic Data

> The principal sources of demographic data are vital statistics registries and surveys.

Demographic data are data that describe the population – the number of people, the number of people being added to the population, the rate of population growth, the age and sex composition of the population, and the prevalence of various family structures. The make-up of the population could also be described in terms of race, sexual identity, type of residence, educational achievement, income, health status, and an infinite number of other descriptors.

Vital Statistics

Vital Statistics are those that relate to births and deaths, marriages and divorces. For much of human history, it was up to individual families to memorize or record these critical events. In the Middle Ages, European synagogues and churches recorded key life events; some of those records from the last few hundred years still survive. Today, many governments collect birth and death data, and also marriage and divorce data.

In some developing countries today, many people are born and live their lives without being officially registered. This interferes with their ability to vote, own land, and receive loans. It also impairs the ability of government to make informed and appropriate policy decisions.

In Canada, every citizen must report birth, marriage, divorce, and death information to the provincial government. Statistics Canada collects these vital statistics as well as vital statistics for Canadians living in some American states. Citizenship and Immigration Canada documents immigration and citizenship, but not emigration. Emigration data must be inferred from other data.

Until recently, Canada has not included racial information in its vital statistics, labour statistics, homelessness statistics, and other data, something for which it has been criticized by the United Nations.

Canada does ask about Aboriginal identity, country of origin, and ethnic origin in its (anonymous) census, and publishes that for each community surveyed.

Class Discussion

What are the pros and cons of collecting race-based data?

Surveys

A survey is a questionnaire or interview. The survey can be broad in scope or can target a particular group. The survey can follow the same group of people over time, or can be repeated over time with a randomly-selected group of people. A survey that follows the same group over time is called a **longitudinal survey**. Some fabulous surveys to study are available online, including the USA's Panel Study of Income Dynamics, which tracks individual households from 1968 on. Canada's Survey of Labour and Income Dynamics begins in 1993 and can be found at the Canadian Research Data Centre Network's website.

International agencies such as the World Health Organization conduct many informative surveys. Currently funded by USAID, the Demographic and Health Surveys Program collects demographic data in 205 developing countries. Demographic survey data is compiled on United Nations and World Bank websites.

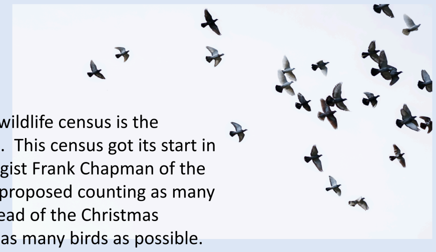
The opposite of a longitudinal survey is a cross-sectional survey which is a snapshot of a population at one particular point in time. The most famous cross-sectional survey is the Census.

Census

A census (latin root: censere, to assess) in its simplest form is a count of the entire population at one point in time. These go back to ancient times; the ancient censuses often focused on men of fighting age, or those able to pay a significant amount of taxes.

Regularly scheduled national surveys of the entire population became established in many countries in the early nineteenth century. Canada's first national census took place in 1871.

The Canadian Census is not just a count of the Canadian population, but an extensive survey of the population's characteristics. It is conducted by Statistics Canada every 5 years. Each household is mailed a form which must be filled out and mailed back. (Online responses are also accepted.) The form contains several questions having to do with the persons in the household: their names, ages, gender, first language, and how they are related. A longer form is sent to a smaller, random selection of addresses. The longer form version includes many more questions, including questions about country of origin, Aboriginal identity, occupation, income, who pays the rent, and the condition of the house.



Did you know?

The longest-running wildlife census is the Christmas Bird Count. This census got its start in 1900 when ornithologist Frank Chapman of the US Audubon Society proposed counting as many birds as possible instead of the Christmas tradition of shooting as many birds as possible. During the Christmas Bird Count of December 14, 2022- January 5, 2023, people at 2,543 locations reported a total of 40,068,865 birds.

First Day Cover for a 1971 Canadian postage stamp celebrating the Census. Photo by A. Hageman for the Public Domain.

In 2010, the Canadian government announced that the questions on the longer form were too intrusive and that filling in the longer form would not be mandatory. The following year, the longer form census was replaced by a voluntary "National Household Survey" which asked similar questions and was mailed to 4.5 million households. One of the questions it asked was whether respondents would waive their right to privacy after 92 years, in which case their responses will become part of the National Archives after 92 years.

The response rate for the (voluntary) National Household Survey was 68.6 percent, much lower than 93.8 percent for the previous (mandatory) long form census, and much lower than the 98.4% response rate for the re-introduced (mandatory) long form census of 2016. 2011 now represents an unfortunate blip in the series of Canadian census data, a blip of less complete and thus less reliable data.

Censuses suffer from overcoverage when they include people who should not be covered (for example, visitors to the country) or when they count the same persons twice. They also suffer from undercoverage – leaving out some people who should be included. These might be people to whom forms were not sent, or people who were unwilling or unable to fill in the form. In Canada, a few First Nations do not participate in the Census.

In 2016, the Canadian Census had an estimated undercoverage rate of 4.32%, while the overcoverage rate was 1.96%.[1]

Combining Census information with Vital Statistics

Birth and death statistics tells us who should be living in a nation; the census tells us who actually is living in that nation. The difference is migration. With immigration data, we can infer emigration.

The **fundamental equation of population growth** is simple:

> Population growth over some period of time = births – deaths + immigrants – emigrants

That is to say, Population growth = **natural increase** – **net migration**.

Canada typically includes permanent residents (who are not yet citizens) in its population count. It does not include temporary foreign workers or international students in its population count.

With birth and death information from Vital Statistics, and overall population numbers from the census and other sources, we can compute birth rates and death rates for the population. In its Quarterly Demographic Estimates, Statistics Canada publishes updated summary information on Canadian birth, death, and immigration rates.

National Identity Registers

To avoid the need to estimate or cobble together statistics, some countries maintain up-to-date population registers that list all individuals with their vital events, including change of residence. These are expensive, and raise concerns about privacy and personal freedom. Britain has a “National Identity Register”. Canada and the USA do not.

Historic Data

Much detective work and deduction must be applied to the limited historical record. For Canadian historical data up to the 1970s which cannot be found at Statistics Canada, the source below is a good place to search.

1. Statistics Canada (October 8, 2019)

UNIVERSITY OF TORONTO LIBRARIES

MAP AND DATA LIBRARY

Basic demographic calculations

Now let's calculate some important demographic statistics.

> Crude Birth Rate = 1,000 x number of births in the population in question/ midyear population

To find the **crude birth rate** for a population, calculate the number of live births (babies born alive) during the year, then divide by the mid-year population. The mid-year population can be approximated by averaging the population at the beginning and the end of the year. Multiply by 1000, and you have the birth rate per 1000 people. The reason we multiply by 1000 is so that we can avoid having to report tiny numbers such as 0.0086. "8.6 per 1000" is easier to say than "0.86 percent".

Since the population's overall size can be significantly different at the beginning of the year compared to the end of the year, we use the midyear population as a rough average population size for the year.

The **crude death rate** and the **net migration rate** are calculated the same way.

The population in the denominator of Canada's crude birth and crude death rates is defined as all the people whose usual residence is in Canada, including soldiers and diplomats abroad, as well as non-permanent residents of Canada. Other countries may do things differently.

We call these rates "**crude**" because they do not take into account the composition of the population in question. Naturally, a population having a larger proportion of women of child-bearing age will have a higher birth rate than a population with a lower proportion of women of child-bearing age. If we compare only the crude birth rates, we might conclude that the population with more women of child-bearing age has larger families. That might not be true.

Fertility rates give us more precise data about family size than do than birth rates. The **general fertility rate** is the number of live births divided by the midyear population of women of childbearing age. This at least adjusts for the number of women of childbearing age. One can also calculate **age-specific fertility rates**, which are fertility rates specific to a particular age group. For example, The fertility rate for 25 year-old women, $ASFR_{25}$,

= # live births to 25 year-old women/ midyear population of 25 year-old women, all multiplied by 1000

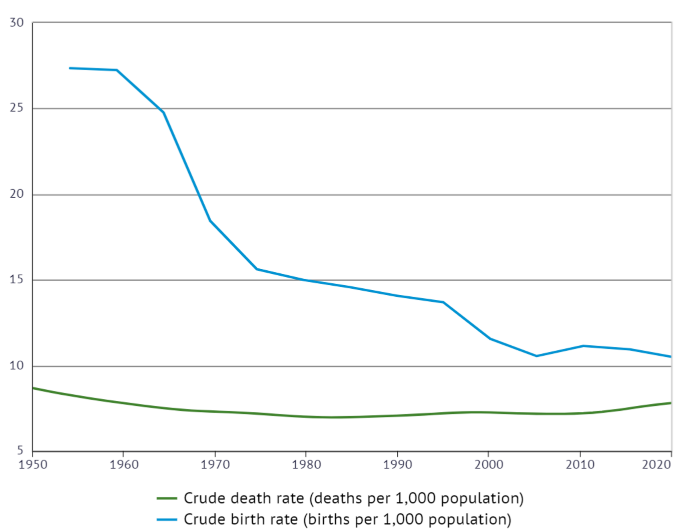
Letting n_x represent the number of women age x at mid-year, the weighted sum of the age-specific fertility rates, where the weights are the share of the female population belonging to each age group, is this expression:

$$\sum_x ASFR_x * n_x / \sum_x n_x$$

It should match the Crude Birth Rate. The Crude Birth Rate is not calculated this way, but representing it as a weighted sum of age-specific fertility rates shows us that the Crude Birth Rate depends not only on the fertility rates at different ages, but also on the age structure of the population.

Similarly, the crude death rate depends on **age-specific mortality rates** and on the the age structure of the population. So, looking at Figure 3-1 below, the death rate might be rising between 2000 and 2010 just because the population is getting older.

Figure 3-1. Crude Death Rate and Crude Birth Rate for Canada, 1950-2020



Source: Knoema.com (2019). Figure 3-1 Crude Death Rate and Crude Birth Rate 1950-2020. World Population Prospects.

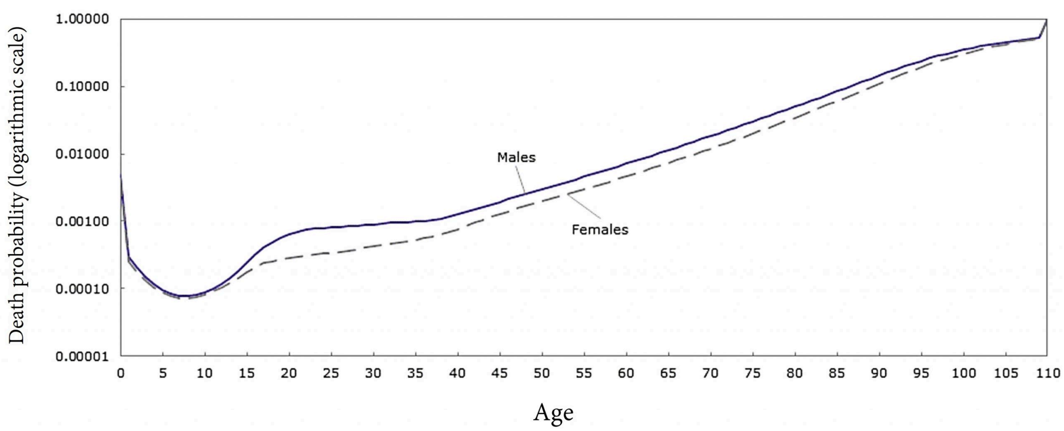
Discussion Idea

How might a high rate of immigration affect a nation's birth rate or death rate?

Mortality by age

Age-specific mortality rates are highest at birth and in one's senior years. The Figure below shows probabilities of dying using a logarithmic scale to measure risk of death because the probabilities of dying when very young/old are so very much greater than the probabilities of dying at other ages. The Figure below also shows us that in Canada today, male mortality rates are typically higher than female rates.

Figure 3-2. Death probabilities by age and sex, Canada, 2014/2016



Source: Statistics Canada. 2017. Life tables, Canada, provinces and territories, catalogue no. 84-537-X.

The Sex Ratio

The **sex ratio** is the ratio of males to females. Traditionally, male and female are the only two sex identities recorded. In our next chapter we will consider other sex identities. For now, consider "male", "female", "boy", or "girl" etc. in terms of biological sex.

By nature, more boys than girls are born: the sex ratio at birth is typically 105 or 106 males to 100 females.

The sex ratio appears to be naturally a bit higher in northern and Asian countries, and lower in southern climates. It is slightly negatively correlated with the age of the father, age of the mother, and birth order (whether the baby is the first, second, or higher order child).

The sex ratio changes with age. Because males typically have higher mortality rates than females, the sex ratio eventually falls below 100 males per 100 females.

The lower mortality of females has been attributed to several factors including

-a “spare” set of X chromosomes

-having less testosterone. Testosterone may impair immune function.

-a perception that girl children are more delicate leading to greater parental protection for girl children

-less risk-taking behaviour on the part of females

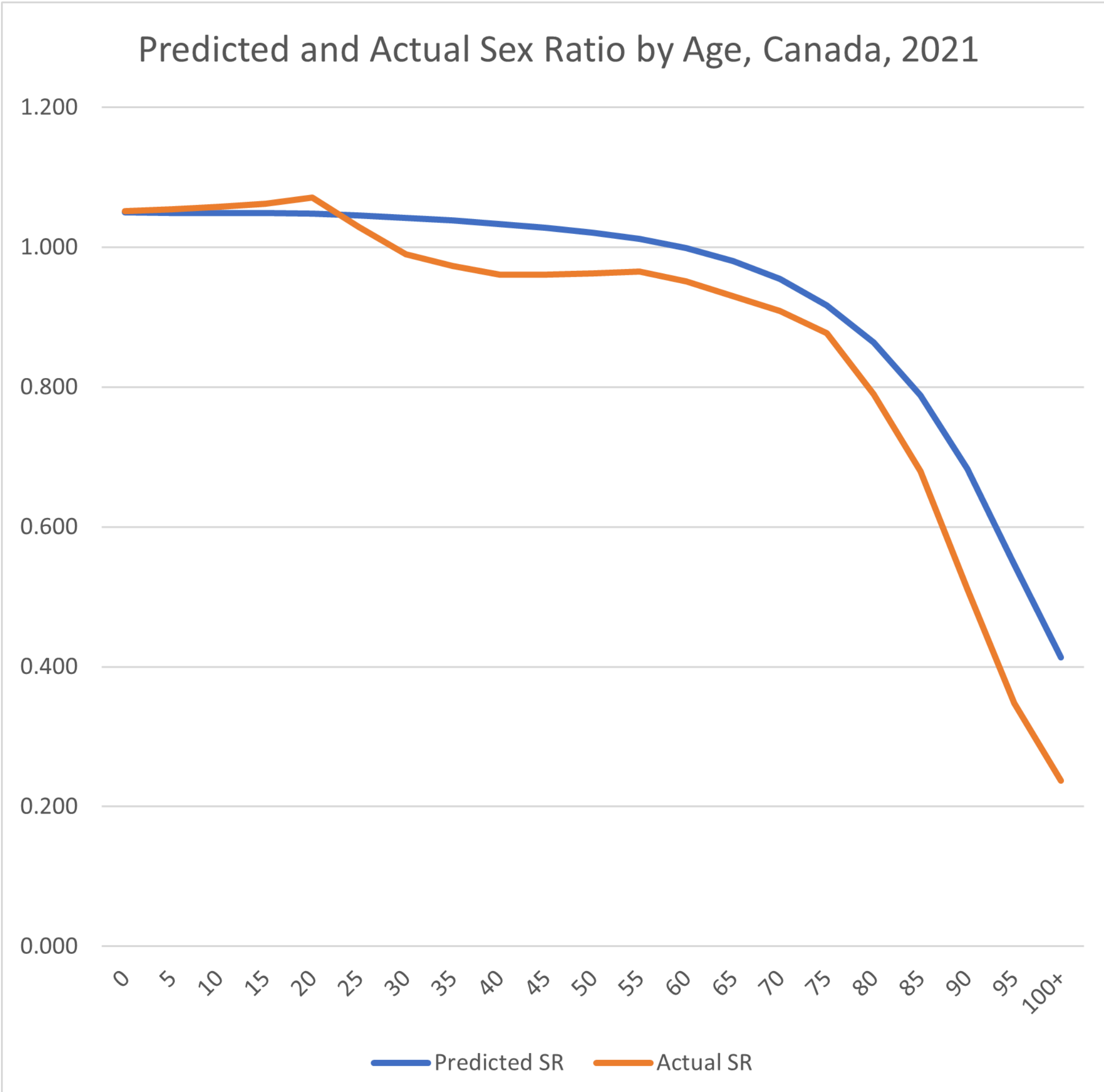
-lower participation of females in heavy manual labour, higher risk professions, and military combat

At the same time, girls and women are smaller and have less muscle mass; they also undergo unique stressors related to menstruation, pregnancy, childbirth, and breastfeeding.

Figure 3-3 shows future predicted and actual sex ratios for Canadians in 2021, with “0” on the horizontal axis meaning “ages 0-4”, “35” meaning “ages 35-39” and so on. Let’s start with the actual sex ratio, represented by the orange line. It shows that in 2021, the sex ratio increases with age for the children and teens residing in Canada in 2021. There is a big jump down between ages 20-24 and 25-29, and the sex ratio falls below 1 male per female for ages 30-34 and up. The sex ratio increases for 50 and 55 year olds, then declines again. A rapid decline occurs after age 75.

The blue line in Figure 3-3 shows what the sex ratio at any age 0,5,10,15 etc. will be if 105 boy babies are born for every 100 girls (the case in Canada in 2021) and if people go through life at the age and sex-specific mortality rates existing in 2021.

Figure 3-3. Sex Ratios for Canada, 2021



The predicted sex ratio for ages 0,5,10...100 is based on a sex ratio at birth of 105, and Statistics Canada's 2021 Life Tables for men and women recorded in their annual Table 13-10-0837-01. The actual sex ratio is based on population counts from the 2021 Census, in five year age groups from 0-4 to 95-99 with the final age group being 100+. Compiled by A. Hageman.

If the predicted line had been created using the mortality rates today's men and women actually faced growing up, then the discrepancy between predicted and actual sex ratios would indicate missing men.

All we can say now is that, comparing these two lines, there were not as many men per woman in Canada in 2021 as we would expect from a sex ratio at birth of 1.05 and 2021 age-specific mortality rates.

The sex ratio can be a consequence of demographic and economic changes, such as changes in mortality rates or the arrival or immigrants and international students. The sex ratio in turn can affect demography and the economy. We'll trace some of those impacts in this course.

The sex ratio differs significantly across countries. For example, in 2020 Latvia had a sex ratio of 85.5 men per 100 women, whereas Qatar had a sex ratio of 302. If we look at the sex ratio at birth, we see that Latvia (107) and Qatar (105) are not so far apart. The high sex ratio in Qatar is caused mostly by the number of male migrant workers. Migration has the potential to increase a community's sex ratio overnight.

In our next chapter we'll pause to consider the fact that not all people identify as male or female. How will this affect the collection of demographic statistics?

Exercises: Chapter 3

1. If the population at the beginning of the year is 100,000, and the population at the end of the year is 105,000, what is the population growth rate?

2. If the population at the beginning of the year is 105,000, and the population at the end of the year is 100,000, what is the population growth rate? The answer is NOT -5%.

3. If the population at the beginning of the year is 75,798, and the population at the end of the year is 80,352, what is the population growth rate?

4. If the population at the beginning of the year is 80,352, and the population at the end of the year is 75,798, what is the population growth rate?

5. The population of Canada on July 1, 2012 was 34,880,491. The population on June 30, 2013 was 35,284,483. What was

a) the increase in the population

b) the population growth rate

c) the midyear population

The number of births during this period was 383,822 and number of deaths during the period was 253,241.

d) what was the birth rate?

e) what was the death rate?

f) what was Natural Increase?

g) what was the rate of natural increase?

The number of immigrants during this period was 312,288.

h) what was the number of emigrants? (Use the fundamental equation of population change).

i) what was the net migration rate?

Chapter 4: Sex and Identity

> So much of Demography has been developed relying entirely on the binary distinction between male and female. In this chapter we acknowledge the complexity of gender and sexuality.

In our previous chapter we discussed the sex ratio. In Demography until recently, people have been identified only according to biological sex, and biological sex has been described only in binary terms – male or female. However, this understanding of sex is being challenged, and a rapidly growing number of identities are being recognized. It remains to be seen how these identities will be represented in demographic reporting and analysis. It will be the work of our generation to discover the consequences of gender diversity for fertility, mortality, migration, population change, and the economy.

The terminology to describe the various identities may change over time and could be different in different communities and countries. In North America in 2022, the term LGBTQ2S+ was widely used to refer to lesbian, gay, bisexual, transgender, queer, two-spirit, and other identities.

Identifications generally fall into four categories of identifiers that can both be stand alone and intersect with each other (Downie (2019)).

Table 4-1. Some Definitions

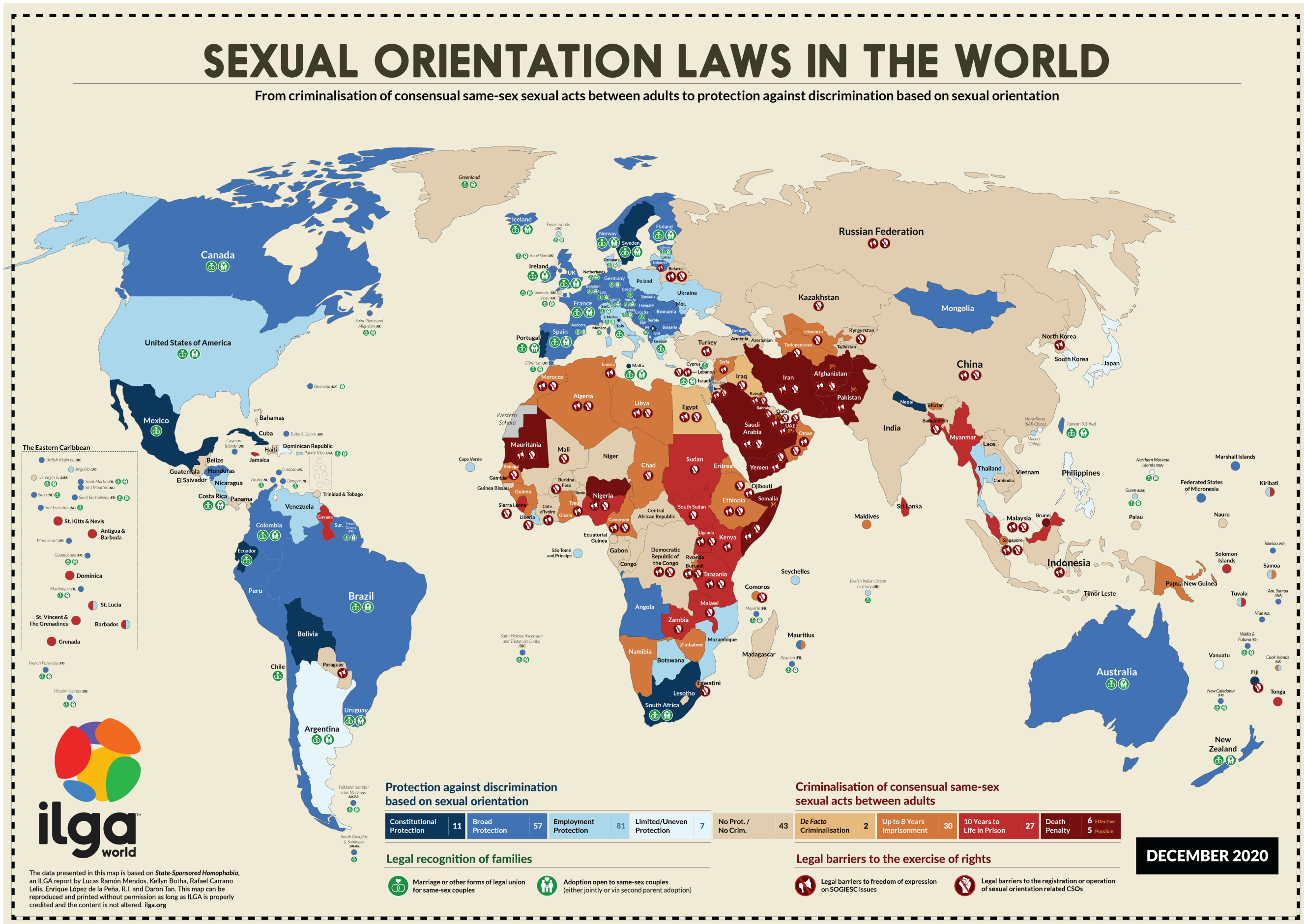
Category of Identity	Categorical Description	Terminology /Language
Sex	This is typically used to describe the biological organs, reproductive biology and categorization that a person is assigned at birth. This category of identifier is commonly included in official documents, census questionaries, medical records etc.	Male Female Intersex + Other
Sexual Orientation	This is a categorization that describes sexual and emotional attraction to other people. This category is distinct from gender identity and could be fluid, stable and may not even reflect behaviours associated with sexual attraction at all.	Asexual Bisexual Gay Heterosexual Homosexual
Gender/ Gender Identity	This is category describing the non-visible aspect of a person's own identity and how they feel about themselves. This category can exist both regardless of or in conjunction with sex assigned at birth or sex after gender reassignment.	Agender Gender fluid Non- Binary Transexual
Gender Expression	This is the external expression of the person's identity that is visible to the public eye and can include the way a person looks, dresses, acts, their choice of name and the pronouns that they utilize.	Cisgender Agender Transgender Intersex

Data deficiencies

There is generally a lack of data concerning LGBTQ2S+ people due to the relatively recent recognition of some identities, the illegal status of LGBTQ2S+ people in some countries, and the challenges of collecting this very personal information. The transgender, intersex, and non-binary communities are especially underrepresented in the data.

The map below show the legal status of LGBTQ2S+ persons across the world, ranging from constitutional protection (dark blue) to death penalties (dark red).

Figure 4-1

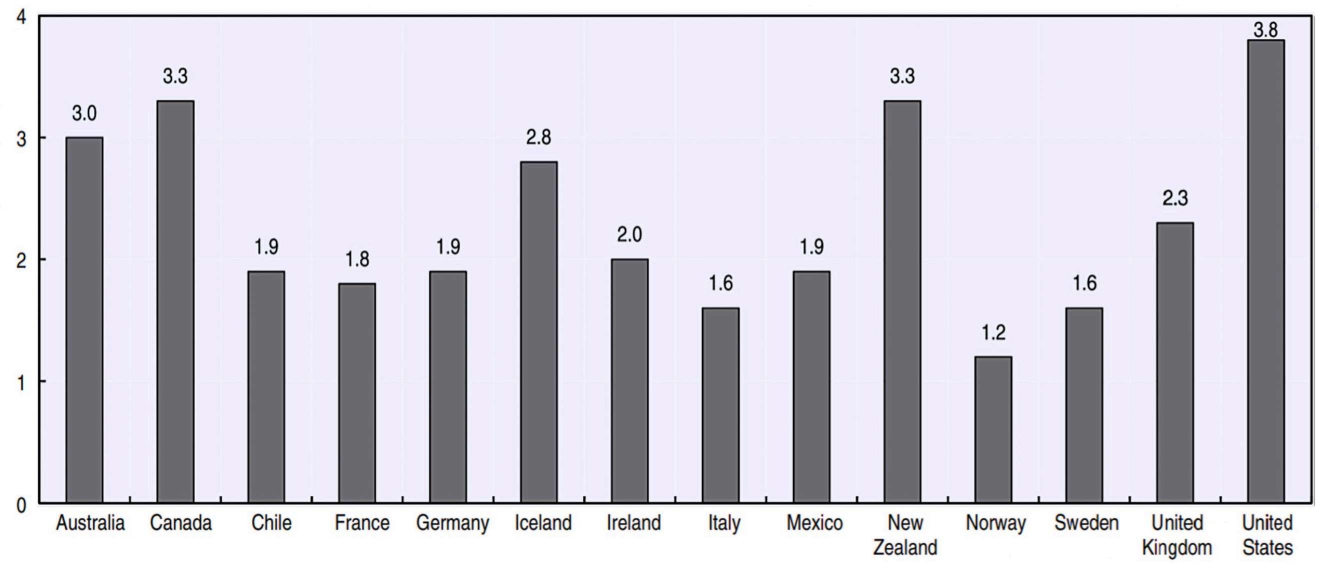


Credits to ILGA World (2019). Map of Sexual Orientation Laws in the World. The International Lesbian, Gay, Bisexual, Trans and Intersex Association.

Some statistics

According an OECD report based on survey data in fourteen mostly western countries, the lesbian, gay, and bisexual community comprised 2.7% of the surveyed population on average. This is shown in Figure 4-1 below. Keep in mind that data collection methods in the different countries may vary with respect to survey participation, methods of administering the survey, the degree of anonymity, and other factors (OECD 2019).

Figure 4-1. Fraction of population self-identifying as lesbian, gay or bisexual, 2009-2019.



Source: Figure 1-1 of OECD (2019). Note: Countries are not ordered given that estimates of the LGB population rely on survey methods that differ across countries.

Canada and the United States currently provide the most elaborate set of available statistics to date. They have the largest LGBTQ2S+ populations by estimated and recorded numbers.

Statistics Canada (June 2021) estimated that, based on several different surveys, there were over one million people in Canada who identify with the LGBTQ2S+ community, about 4% of the Canadian population.

In the USA, 2021 polling by Gallup found that the LGBTQ2S+ population is 5.6% of the US population, which amounts to 18.65 million people.[1]

Transgender, intersex, non-binary and gender-expansive people

Goodman et. al. (2019), looking at 17 countries over fifty years, estimate that between 0.1% to 2% of each country's population may be trans +. In 2011 it was reported by the Williamson Institute that the trans, intersex and non-binary+ community constituted 0.3% of the US population (See Gates (2011)). This doubled in 2021 to account for 0.6%. Statistics for Europe are difficult to compare as each country chooses its

1. Deeper US statistics Gallup Poll: https://news.gallup.com/poll/329708/lgbt-identification-rises-latest-estimate.aspx

own data collection policy. The UK claimed a trans + population between 200-800 thousand people in 2018.[2].

Canada is the only country that by 2021 had implemented several new categories of gender and sexual identity into its Census. The 2021 census found that 59,460 Canadians aged 15 or older self-identified as transgender, and 41,355 identified as non-binary, accounting for 0.33% of the population in this age group.[3]. They were principally urban: more than ninety percent lived in a city with over 100,000 people. Nova Scotia, British Columbia, and the Yukon had proportionately higher numbers of transgender and non-binary people.

The same census noted that transgender people on average had lower incomes than the average Canadian. More than twenty percent of non-binary people lived in poverty, compared to about eight percent of Canadians.[4]

Implications for Demography

How will the increasing recognition of diverse forms of sex and identity affect the collection and analysis of demographic data? And what changes from sex and gender diversity can we expect for fertility, mortality, and migration, the three drivers of population change?

Data sets that include detailed sex and identity information instead of the binary M (male) or female (F) designations offer more information for researchers to study, and may result in greater insights into human behaviour and health; however, statistics generated will not be perfectly comparable to those generated from earlier surveys.

Class Discussion

How has the rigid understanding of sex and identity possibly skewed research in the past when it comes to population change?

Unless individuals are tracked by a national identity register, a nation's census may report a decline in the number of men that is not related to death or migration but to the fact that there are more men transitioning to women than vice versa. If individuals do not report that they have transitioned, their data may confuse studies which track health and other outcomes related to biological sex.

Gender non-conforming people have faced hostility from parents, messages of shame from religious teachings and society more generally, discrimination in the workplace and in healthcare, and violent attacks

2. Government Equities Office (2018)
3. Statistics Canada (April 2022)
4. Statistics Canada, Nov. 9 2022.

motivated by hate. Common sense suggests their mortality rates, including suicide rates, have been higher than average. Increased acceptance of gender diversity will bring these mortality rates down. At the same time, some activities – such as hormone replacement and gender affirming surgeries, and some lifestyles – such as having multiple partners – may add risk.

Gender non-conforming people have faced difficulty finding partners with whom they can live openly, and have been barred from adopting children. With increasing freedom to form partnerships and adopt children, and with modern reproductive technologies and surrogacy arrangements available, the fertility rate could rise. Again, some activities – such as hormone replacement and surgeries – may reduce the fertility rate.

People of diverse orientations have traditionally migrated to larger cities. In larger cities there is more tolerance of diversity, a greater chance of finding someone similar to oneself, and a greater variety of occupations available. One reason cities are economically more productive than other regions is the creativity of gender-diverse and other non-conforming people. This is particularly observable in the Arts, Design, Entertainment, and Fashion sectors.

Migration of gender diverse people across provinces, states, and nations will occur in response to differing national policies and prevailing attitudes relating to LGBTQ2S+ rights, which affect economic opportunities for LGBTQ2S+ people.

Discussion Idea

What new statistics would be useful to demographers?

Chapter 5: Standardizing Rates and Inferring rates of Growth

> Birth, death, and migration rates allow us to calculate population growth rates, which we explore in this chapter. First, however, we will learn how to standardize rates so that countries with very different age distributions or sex ratios can be fairly compared.

In Chapter 3 we learned how to calculate the crude death rate. We divide the number of deaths by the midyear population, then multiply by 1000 for convenience. Because the crude death rate has population in its denominator, it automatically adjusts for the fact that larger populations will have more people dying. **There is no reason that a large country must have a higher death rate than a smaller country.**

Population size does not directly affect the death rate, but having a lot of older people in your population does.

Japan has an older population than Afghanistan, so old that Japan's 2019 crude death rate, 11 per 1000, was higher than Afghanistan's crude death rate, 6 per 1000. This makes Japan look like a less healthy and more dangerous place to live than Afghanistan. Is it?

No. At every age of life, the 2019 age-specific mortality rates were lower in Japan than they were in Afghanistan. A twenty-year old in Afghanistan had a higher chance of dying that year than a twenty-year old in Japan. However, a twenty-year old in Afghanistan did not have a higher chance of dying that year than a fifty-year old in Japan. And Japan had a higher fraction of its population age 50 or older than Afghanistan did. That's why Japan's crude death rate was higher than Afghanistan's, and why the crude death rate can be misleading when comparing countries.

Let's learn how to transform a crude death rate into a **standardized death rate**. We'll use the Table below.

Table 5-1. Deaths from COVID-19 (Japan and Taiwan) January 1 2020- September 30 2020

	TAIWANESE COVID DEATHS (by age)	DIVIDED BY TAIWAN'S POPULATION (by age)	TAIWAN'S COVID MORTALITY RATES	JAPANESE COVID DEATHS (by age)	DIVIDED BY JAPAN'S POPULATION (by age)	JAPAN'S COVID MORTALITY RATES	HYPOTHETICAL JAPANESE DEATHS BY AGE = Japan's COVID mortality rates age multiplied by Taiwan's population (by age)
0-24	0	5,638,872	0	2	27,140,000	7.4 E-05	0 (actually 0.42)
25-49	2	8,863,376	2.3 E-04	39	38,540,000	1.0 E-03	9
50-74	4	7,628,528	5.2 E-04	429	41,483,000	1.0 E-02	79
75+	1	1,431,547	7.0 E-04	1105	18,720,000	5.9 E-02	85
Total	**7**	**23,562,323**		**1575**	**125,883,000**		**173**

	TAIWAN	JAPAN	JAPAN IF IT HAD TAIWAN'S POPULATION:
Death Rate	**3 per 10 million people**	**125 per 10 million people**	**73 per 10 million people**

Compiled and calculated by Pauline Galoustian. Data Sources: Coronavirus Country Profiles, Our World In Data; Taiwan population counts from Monthly Bulletin of Interior Statistics; Japan population counts from e-Stat, Site of Official Statistics of Japan.

Table 5-1 shows us the actual number of deaths from COVID-19 in Taiwan and Japan as of September 30, 2020. By that date, Taiwan had experienced a total of 7 deaths, 2 from 25-49 year-olds, 4 from the 50-74 age category, and 1 person age 75+. If you divide those 7 deaths by Taiwan's population of 23,562,323 people, then multiply by 1000, you get a crude death rate for Taiwan of 0.0003 deaths per 1000 people, or 3 deaths for every ten million people. Clearly, Taiwan was doing very well.

Japan wasn't doing too badly either, with a crude death rate of 125 per ten million people, but its crude death rate was about 40 times as high as Taiwan's.

Now let's standardize the death rates. To do so, we are going pretend that each country has the same, standard age distribution. What is this standard age distribution? Often, the United States population is used as the standard. Or we could use the World Health Organization's "World Standard Population", which is an estimate of the age distribution of the entire world.

In this example, we are going to choose Taiwan's age distribution as the standard. Taiwan will be our "reference country".

Since Taiwan already has Taiwan's age distribution, we don't have to do anything to its data. Taiwan's death rate, standardized to itself, will simply be its original crude death rate of 3 per million.

However, Japan's standardized death rate will be different from its crude death rate.

Step 1 of finding Japan's standardized death rate is to find the number of people of each age who would have died in Japan if Japan had had Taiwan's population. For each age group, we take the Japanese mortality rates (second-last column) and multiply by the number of people that age in Taiwan (3rd column). This gives us the last column in the table. We see that, if Japan had had the population of Taiwan, nine 25-49 year-olds would have died, seventy-nine 50-74 year-olds would have died, and eighty-five people age 75+ would have died.

Step 2 of finding Japan's standardized death rate is to add up all the deaths in that last column and use it to find the overall death rate. The nine 25-49 year-olds plus the seventy-nine 50-74 year-olds plus the eighty-five people age 75+ who died add up to 173 deaths. We then divide those deaths by the total population (using Taiwan's population) and multiply by 1000. This gives us the standardized death rate of Japan, standardized relative to Taiwan's population.

Japan's new, standardized death rate is 73 per million, less than its crude death rate of 125 per million. If Japan had had Taiwan's younger population, fewer people would have died. Japan's crude death rate was misleadingly high. It made Japan look like it was dealing with COVID-19 less well than it actually was. The large fraction of elderly in Japan was biasing the crude death rate.

To repeat, standardizing to Taiwan's population, Japan's death rate falls from 125 per million to 73 per million. Its death rate is still higher than Taiwan's but the difference is not as great as before, showing that part of the reason Japan's crude death rate was higher than Taiwan's is that Japan had a higher proportion of older adults.

A possible paradox

A student once reported that Japan's COVID-19 death rate, if standardized to Taiwan's population, would fall, while Taiwan's COVID-19 death rate, if standardized to Japan's population, would also fall. In other words, standardization made both countries look better relative to each other.

The reason the student got this result is that they had collected the wrong data. They reported that, in Japan, most people who died of COVID-19 were older adults (TRUE), but in Taiwan, most people who died of COVID-19 were young adults (FALSE). If both statements had actually been true, then giving Japan Taiwan's younger population would indeed make Japan's COVID-19 death rate fall, and giving Taiwan Japan's older population would indeed make Taiwan's COVID-19 death rate fall too.

Photo by Olga Berrios, flickr.com, CC BY 2.0 DEED

Though most people who died of COVID-19 in both Japan and Taiwan were older adults, it's possible that a disease could impact different age groups differently in different countries. Simply standardizing by the age distribution of one of the countries' populations would not be meaningful in that case. We would have to form a reference population more creatively, as the following example shows.

Sudharsanan et al. (2020) age-standardized the COVID-19 Case Fatality Rate in different countries, studying deaths from COVID-19 in nine countries up until April 19, 2020. (The Case Fatality Rate, or CFR, is the percentage of people who die *once infected*.)

To begin, Italy had the worst crude Case Fatality Rate (CFR), at 9.2%. That means 9.2% of people who caught COVID-19 died. By contrast, Germany's crude CFR was only 0.7%. Once the case fatality rates were standardized to a reference population, however, the gap between Italy and Germany shrank: Italy had a standardized CFR of 3.9% compared to 1.3% for Germany. Italy's and Germany's CFRs weren't as far apart once the authors adjusted for the average age distribution of the people who were infected. In Italy, the people who got infected tended to be significantly older than the people who got infected in Germany.

The authors didn't use any one country's age distribution as the reference population. The authors used the nine countries' average age distribution of *people who actually got infected* as the reference population.

They found that 66% of the difference in countries' crude case fatality rates arose from the countries having different age distributions of people infected.

After standardizing this way, Italy was still in last place but not by as much. Switzerland, the Netherlands, and France improved their rankings while Germany, the US, South Korea, China and Spain slipped.

Inferring rates of population growth

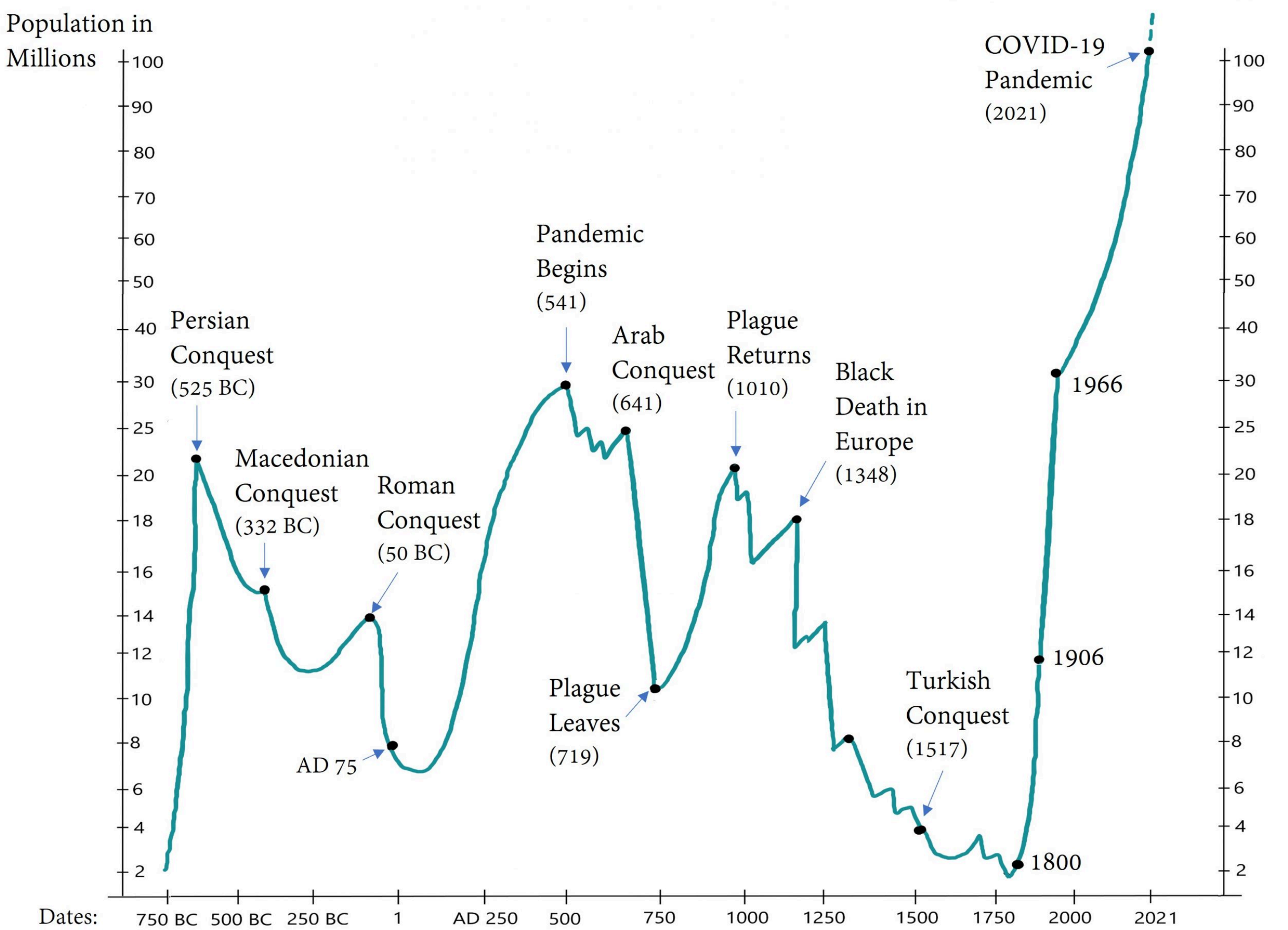
If you add the crude birth rate (per 1000) and subtract the crude death rate (per 1000), and add on the net migration rate (per 1000), you will have the rate of population growth (per 1000); however, this rate of population growth is relative to the midyear population. That's because the crude birth rate, the crude death rate, and the net migration rate are all evaluated per 1000 people at mid-year.

The way population growth is usually described is *as a percent increase or decrease from the initial, beginning-of-year level.*

$$\text{Population growth in percent} = 100\left(\frac{\text{population end of year} - \text{population start of year}}{\text{population start of year}}\right)$$

The population growth rate can fluctuate as a consequence of changes in fertility, mortality, and migration. Fertility, mortality, and migration can change for many reasons, such as war and famine. See Figure 5.1 to see how the population of Egypt, and the rate of growth of the population of Egypt, fluctuated over time.

Figure 5-1. The population of Egypt (664 BC to 2021)



Adapted by Pauline Galoustian from Hollingsworth (1969) and Cox (1970).

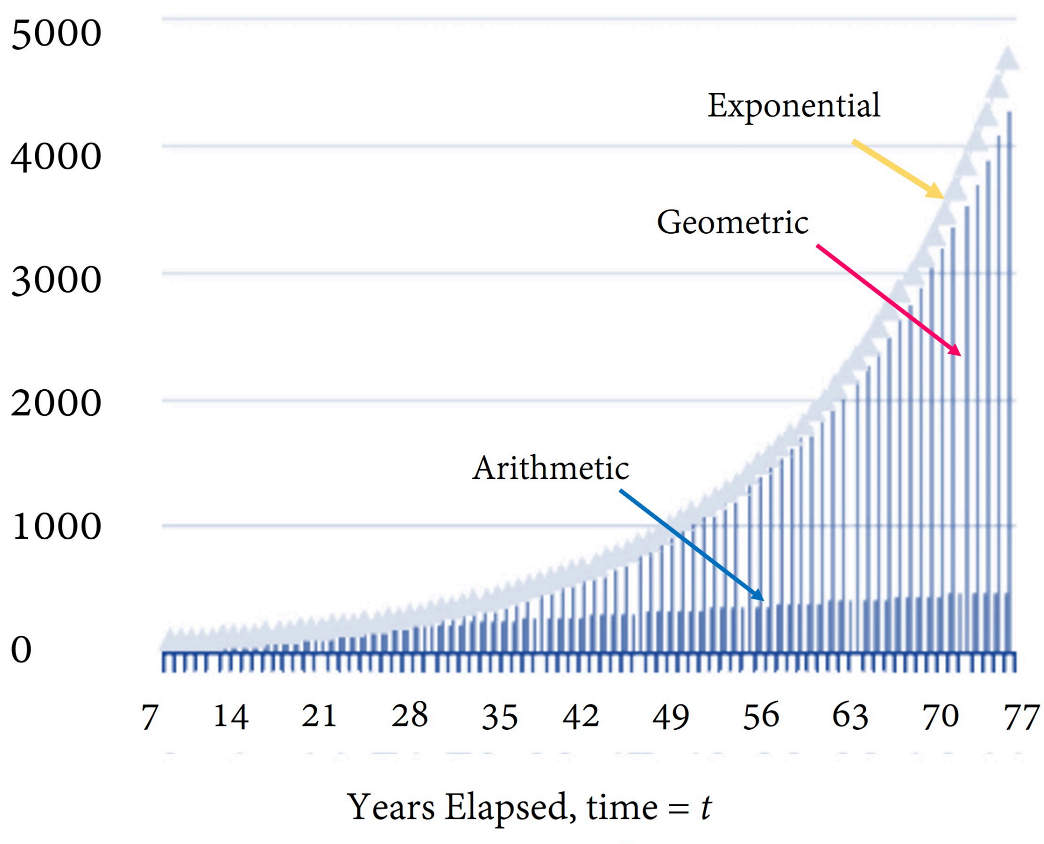
Donald Rowland writes in his 2003 text,

> *"In the twentieth century, dire warnings and apocalyptic forecasts for the planet followed from the assumption that a particular pattern of increase...would persist in the future. The twentieth century also brought forth national population decline, or at least a fear of it, as a recurring theme in some more developed [sic] countries... Assumptions about constant rates leading to extinction, however, will be as untenable as those about constant rates creating ever burgeoning numbers."*

Although population growth has at times accelerated and at other time decelerated or declined, demographers often use the assumption of constant growth to describe what happened in the past or to make simple forecasts.

The three kinds of constant growth in math are arithmetic, geometric, and exponential growth. They are shown in the Figure below.

Figure 5-2. Population of 100 growing 3 different ways



Arithmetic growth is steady. The increase in numbers is constant each year. Graphed over time, population grows with a constant slope.

Geographic and exponential growth are not steady over time. The larger the population becomes, the greater the increase in the population.

Arithmetic growth

In the context of height, arithmetic growth means growing a set number of inches per year regardless of how tall you already are. It is like earning a fixed amount of interest each year: the interest does not compound, but is paid only against the initial amount deposited.

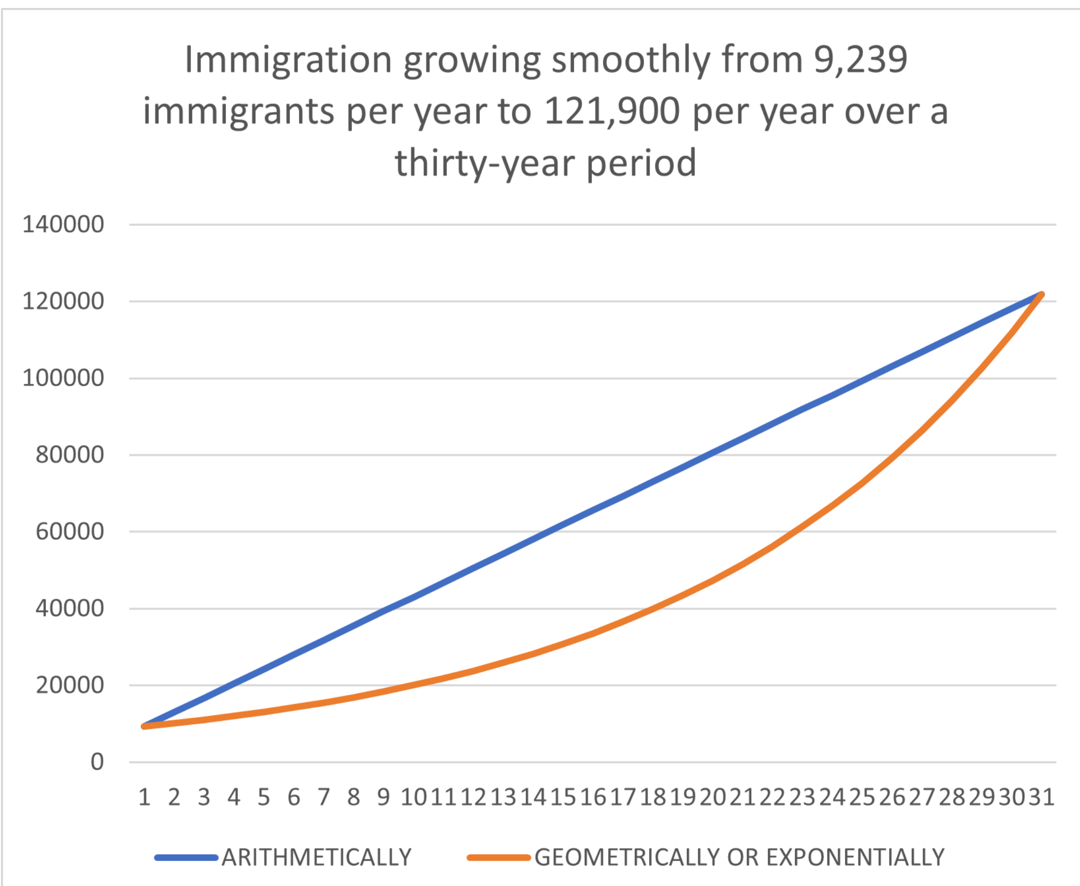
Malthus assumed erroneously that agricultural output could only grow arithmetically, for example by people clearing a fixed number of additional acres of land each year.

Malthus knew that population does not grow arithmetically, but in proportion to the base population. Nevertheless, we sometimes use the assumption of arithmetic population growth, especially for short time periods.

For example, to find the mid-year population, we simply assume that population was growing arithmetically during the year: we sum the population at the beginning of the year with the population at the end of the year, and divide by two.

Demographers often use the assumption of steady growth when estimating what happened between two historical periods of time for which they have data. For example, if all we knew was that in 1941, 9,239 people immigrated to Canada and that in 1971, 121,900 people immigrated to Canada, we might assume, in the absence of other information, that immigration grew steadily during that time. We might assume it grew steadily in an arithmetic way, a geometric way, or an exponential way. Over such a short period of time, there would not be much difference between the geometric and the exponential growth path, as shown in the Figure below. The geometric path would be a series of step functions, flat during a year, then rising at the beginning of the following year, while the exponential path would be completely smooth.

Figure 5-3. Possible immigration growth paths



The arithmetic growth path can be found by subtracting the 9,239 immigrants in 1941 from the 121,900 immigrants in 1971 and dividing the difference by 30 to get 3,755.4 extra immigrants every year. 9,239 immigrants in 1941, 9,239+3,755.4 new immigrants in 1942, that number plus 3,755.4 in 1943, etc.

In year 1941+t, the number of newly arriving immigrants would be y = 9,239 + 3,755.4*t

The arithmetic growth path is just a straight line with intercept 9,239 and slope 3,755.4.

To estimate the total number of immigrants that arrived during the period 1941-1971, we would find the area under that straight line, which is simply the rectangle 9,239 x 30 plus the triangle (121,900-9,239) x 30 x 0.5 for a total of 1,689,915.

What if we had assumed geometric growth or exponential growth? We see that the area under those curves is less than the area under the line representing arithmetic growth. (See Figure 5-3 above). Geometric or Exponential growth assumptions will give us a lower estimated number of total immigrants for the period. That's because geometric growth and exponential growth take a while to get going.

Geometric and exponential growth

Geometric growth is like growing a fixed percentage of your initial height each year. It is like the growth of your bank account when you are paid interest once a year, and the interest compounds over the years.

r, the rate of growth over the period, is defined as { {P(1)-P(0)}/P(0) }

Equivalently,

$P(1) = P(0)\ (1+r)$, where r is the rate of growth over the period.

$$P(2) = P(0)\ (1+r)\ (1+r) = P(0)\ (1+r)^2$$

Generally,

$P(n) = P(0)\ (1+r)^{n}$, where n is the number of periods that have gone by.

If we shorten the time between intervals when the growth is reckoned, we have continuous compounding i.e. exponential growth. "r" is still the official, annual rate of growth, but a fraction of it is implemented every second.

$$P(1) = P(0)\ e^{r} \text{ and generally, } P(n) = P(0)\ e^{rn}$$

Exponential growth occurs when the interval at which growth or interest is compounded shrinks down to almost zero. It is like growing a tiny percentage of your height, every second, with your height being constantly updated. Exponential growth is smooth and continuous, which seems more realistic than geometric growth. However, real-life growth tends to come in spurts and fits, and there is certainly a turnaround time before a new baby can reproduce him or herself. So constant exponential population growth is not all that realistic an assumption.

Incidentally, Rowland (2003) points out that "The world's population growth rate has never exceeded 2.1 per cent [per year] (doubling time 33 years), and the growth rate has been falling since the mid-1960s."

A rate such as 2.1 per cent raises the question, 2.1 per cent of what? and lets you know that we are talking either about geometric or exponential growth. Usually demographers talk about exponential growth.

Doubling Time

To find **doubling time**, simply divide the number 70 by the average growth rate per period. For example, if the growth rate is 2.1% per year, then the approximate time it will take for the population to double is 70/2.1 = 33.3 years. This is the "Rule of 70" which comes from the mathematics of exponential growth below:

Photo by MNEM, flickr.com. CC BY 2.0

$$\mathrm{P(n)} = \mathrm{P(0)}\, e^{rn} \quad \text{or} \quad \frac{P(n)}{P(0)} = e^{rn}$$

We want to solve for n, the number of years that go by before P(0) is doubled. We know what "r" is, and what P(0) is, and we know that P(0) will double after n years, meaning that:

$$P(n) = 2\,P(0)$$
$$P(n)/P(0) = 2$$
$$P(0)e^{rn}\ /\ P(0) = 2$$
$$e^{rn} = 2$$
$$rn = \ln(2)$$
$$n = \ln(2)/r$$

Thus n, the number of periods required for doubling = ln(2)/ r ≈ 0.70/ r, where r is expressed as a decimal. (If using 70 instead of 0.70, r is not expressed as a decimal, but as a percent as in 70/2.1 percent = 33.3 years).

Getting back to our immigration example, if we assume that immigration grew geometrically from 9,239 people in 1941 to 121,900 people in 1971, we can solve for the annual rate of growth this way:

$$121{,}900 = 9{,}239\ (1+r)^{30}$$
$$13.19 = (1+r)^{30}$$
$$(13.19)^{1/30} = 1+r$$
$$1.09 = 1+r$$
$$r = 0.09 \text{ or } 9\%.$$

How many people immigrated during the period? That would be:

$$9{,}239 + 9{,}239(1.09) + 9{,}239(1.09)^2 + 9.239\ (1.09)^3 + \ldots =$$
$$\sum_{t=0}^{30} 9{,}239\ (1.09)^t = \mathbf{1{,}381{,}925\ people}$$

This is not very convenient to compute. It is easier to compute assuming exponential growth.

If we assume that immigration grew exponentially, we can solve for the rate of growth this way:

$$121{,}900 = 9{,}239\ e^{30r}$$
$$13.19 = e^{30r}$$
$$\ln(13.19) = 30\ r$$
$$2.58 = 30\ r$$
$$r = 0.086 \text{ or } 8.6\ \%.$$

How many people immigrated during the period? That would be:

$$\int_0^{30} 9{,}239\ e^{.086(t-0)}\ dt$$

Which is easy to solve using the formula:

$$\int_a^b z\ e^{rt}\ dt\ =\ (z/r)\ (e^{rb}\ -\ e^{ra}\ )$$

In this case, the total number of immigrants arriving between 1941 and 1971 is:

$(1/.086)\ (9{,}239)\ (e^{.086(30)} - e^{.086(0)}) =$ **1,310,341.4 people**

In real life, the number of immigrants who came to Canada between 1941 and 1971 was 3,597,689. In real life, the immigration rate was not smooth in any way, neither exponentially, geometrically, or arithmetically.

Does it seem funny that our exponential growth assumption resulted in the smallest estimate of total immigrants? Recall that really big gains from exponential growth are not evident for a while. Exponential growth takes a while to get going. That is true of geometric growth as well.

Exponential math has been used to estimate the number of people who have ever lived.

Box 5-1. The number of people who have ever lived

Keyfitz and Caswell (2005) explain how to compute the number of people who have ever lived on earth. The calculation is very similar to finding the total number of immigrants over a period. Think of babies as immigrants from heaven.

1. First, you need estimates of annual births at various time periods. Cook (1962) estimated that there was 1 birth at 600,000 BC, 250,000 annual births by 6,000 BC, 25 million births annual in 1650 AD, and 110 million births annually by 1962 AD.
2. Next, find the implied growth rate in births between each period. For example, annual births grew from 25 million in 1650 to 110 million by 1962. If r is the constant exponential growth rate in births, then we find r by solving 110 million = 25 million e^{312r}, where 312 is the number of years between 1650 and 1962.

This equation gives us an assumed constant exponential growth rate of 0.475 percent.

3. Now that we know the *growth rate* in annual births during the period, we can calculate the *number* of births during the period using integration.

$$\int_{1650}^{1962} 25{,}000{,}000 e^{0.00475(t-1650)}\,dt$$

$$= \{25{,}000{,}000\ e^{312(0.00475)} - 25{,}000{,}000 e^{0(0.00475)}\}/0.00475$$

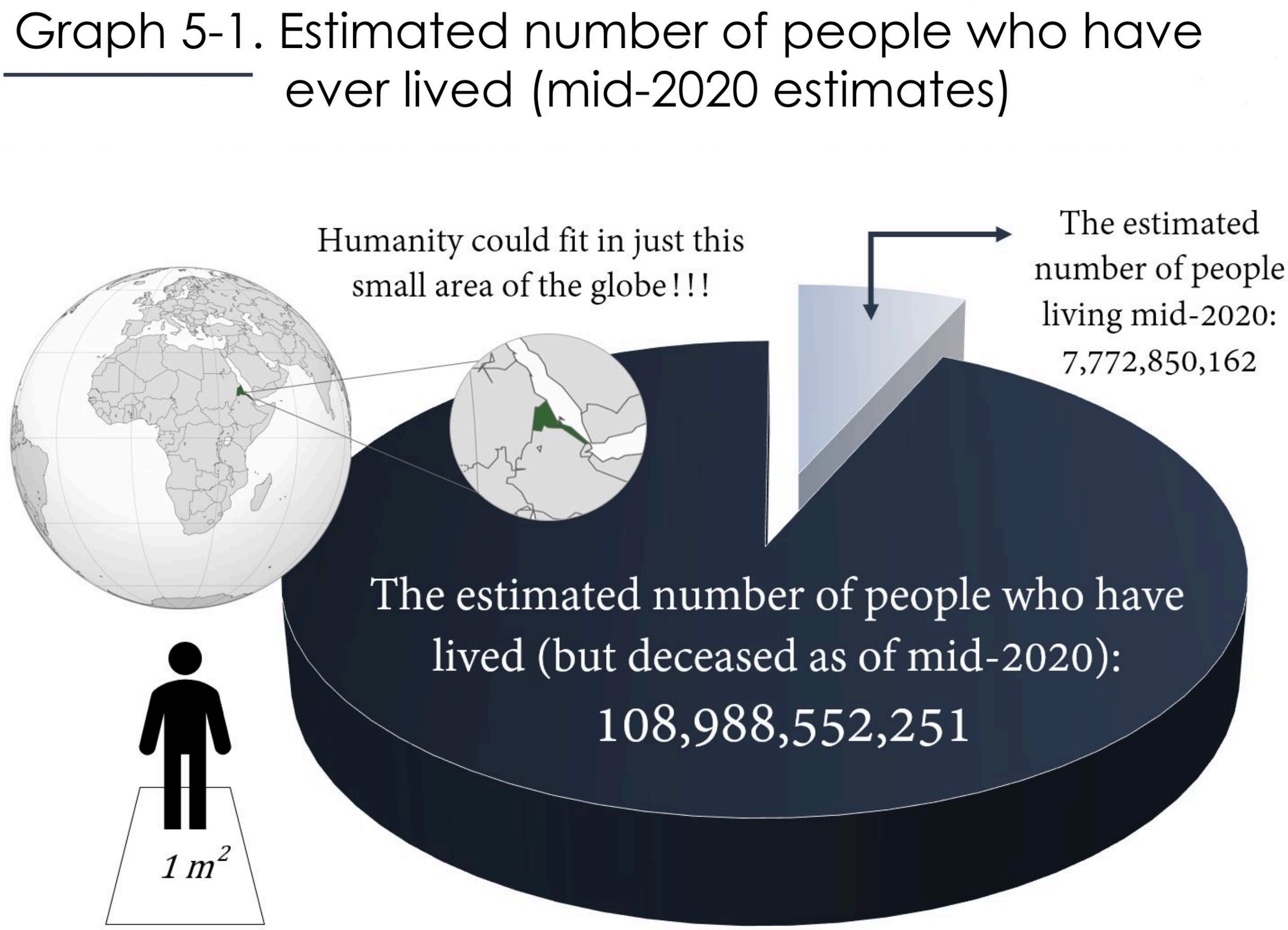
because the integral of e^{ax} is $(1/a)\ e^{ax} + c$

= 17.9 **billion** people born between 1650 and 1962.

4. Performing the same calculation for the other time periods 600,000 BC - 6,000 BC, and 6000BC – 1650 AD, approximately 70.9 billion people in total were born prior to 1962, so today's population of 7.3 to 7.9 billion does not even come close to matching the number of people who have lived previously.

The Population Reference Bureau (https://www.prb.org) provides an up-to-date estimate of the number of people who have ever lived, and in mid-2020 it reckoned that the number of people alive represented 6.7% of the people who have ever lived.

If all of the people who have ever lived stood side by side, with a space of one square meter allocated per person, the entire human race would occupy an area approximately the size of modern-day Eritrea (117,600 sq. km)[1].



Combined pie chart of world historic population and orthographic map of Africa (highlighting the nation of Eritrea). Data Source: Population Reference Bureau, 2021. By Pauline Galoustian following Sémhur/ Rei-artur/Martin23230 (CC BY-SA 2.0), found on wikimedia commons.

In the next Chapter we will explore the concept of the life table and its importance for population economics.

1. https://mapfight.xyz/map/hn/#er

Exercises: Chapter 5

1. Based on the following table, complete the questions:

Age	Midyear Population, K.U.	Annual deaths, K.U.	Age-specific mortality rate, K.U.	Midyear Population, Waitku	Annual deaths, Waitku	Age-specific mortality rate, W.
Under 30	5,000	5	1 per 1000	2,000	40	
30+	55,000	220		4,000	20	

a) Fill in the blanks in the above table.

b) Using the information in the table, compute each country's crude death rate, and also each country's standardized death rate using K.U. as the standard/base country.

c) How does your impression of Waitku change once you perform the standardization?

2. If the sex ratio of 20-24 year-olds is currently equal to 1, and if the flu season results in many more 20-24 male deaths than female deaths, what will happen to the sex ratio in that age group?

3. Ignoring medical and other advances, what happens to a nation's crude death rate as its population gets older? How could we adjust for this effect?

4. If the population of gerbils is 53,460 today, and the population has been growing exponentially at a rate of 2% per year, what was the population of gerbils 10 years ago?

5. How long will it take for this population to double?

6. At the time of creating this question, the world's population was expected to grow from 7 to 8 billion in 13 years. What rate of exponential growth would that imply?

7. Consider a nation which had 100 people in 1900. By 1980 they had 500 people. At what geometric rate did this population grow? At what exponential rate did this population grow? At what arithmetic rate did this population grow?

8. If the number of births in 1900 was 1, and the birth rate grew at a 4% exponential rate, write an expression for the number of people born during 1900-1980. Solve for the number of people born during 1900-1980.

Chapter 6: Calculating Life Expectancy

The Life Table - formerly called the Mortality Table - is a statistical construct that has been used for hundreds of years to predict life expectancy.

While the math can be a bit tricky, the data requirements for a Life Table are minimal. All you need to construct a life table are age-specific mortality rates. The Life Table does not show how the population grows, shrinks or changes. It merely shows how quickly a cohort - a group of people born during the same time period - decreases in size as the members die.

Life Tables

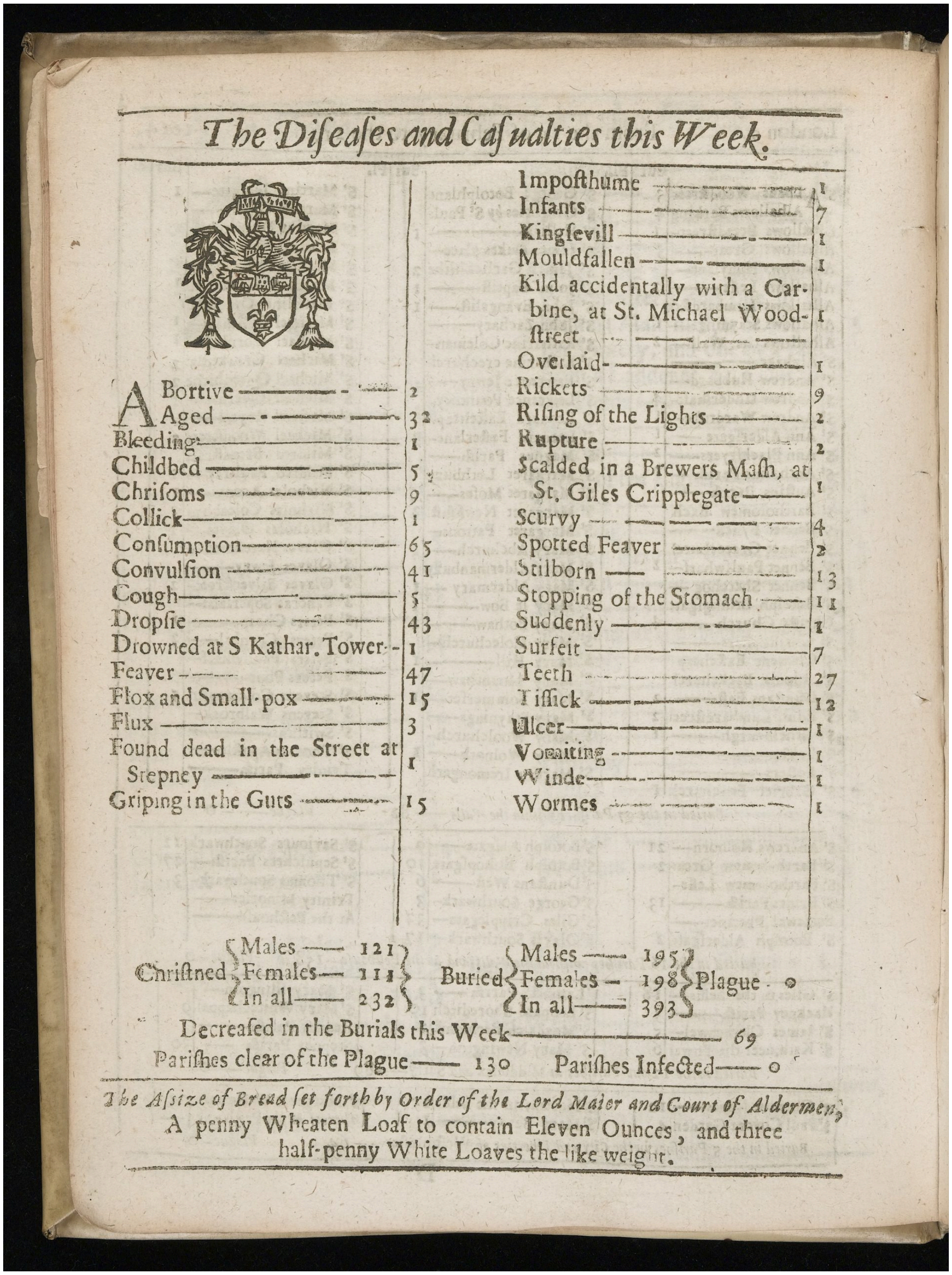
The **Life Table** is a fascinating tool that provides us with an estimate of life expectancy. It computes, for every age group, how many years of life are left to the average person in that age group.

The Life Table should really be called the Death Table, because it begins with an arbitrary number of births in a given year and calculates how quickly the newborns die off.

The first person to perform such calculations was John Graunt (1662), a hat maker living in London in the seventeenth century. He took a keen interest in the weekly death bulletins issued by the various parishes[1]. He estimated that, out of 100 people conceived in London in his day, only 64 percent would survive to age 6, only 40 to age 16, and so forth. Three of every one hundred newborns would make it to age 66, and only one to

1. A parish is a neighbourhood served by a Christian church of some denomination, in this case, the Church of England.

age 76. Graunt was not able to say, however, how long the average newborn could be expected to live. The complete method for estimating life expectancy would be delineated later by the astronomer Edmond Halley.[2]



The Diseases and Casualties this Week.

Abortive	2	Impostume	1
Aged	32	Infants	7
Bleeding	1	Kingsevill	1
Childbed	5	Mouldfallen	1
Chrisoms	9	Kild accidentally with a Carbine, at St. Michael Woodstreet	1
Collick	1	Overlaid	1
Consumption	65	Rickets	9
Convulsion	41	Rising of the Lights	2
Cough	5	Rupture	2
Dropsie	43	Scalded in a Brewers Mash, at St. Giles Cripplegate	1
Drowned at S Kathar. Tower	1	Scurvy	4
Feaver	47	Spotted Feaver	2
Flox and Small-pox	15	Stilborn	13
Flux	3	Stopping of the Stomach	11
Found dead in the Street at Stepney	1	Suddenly	1
Griping in the Guts	15	Surfeit	7
		Teeth	27
		Tissick	12
		Ulcer	1
		Vomiting	1
		Winde	1
		Wormes	1

Christned: Males 121, Females 111, In all 232
Buried: Males 195, Females 198, In all 393 — Plague 0
Decreased in the Burials this Week 69
Parishes clear of the Plague 130 — Parishes Infected 0

The Assize of Bread set forth by Order of the Lord Maior and Court of Aldermen, A penny Wheaten Loaf to contain Eleven Ounces, and three half-penny White Loaves the like weight.

Bill of Mortality from February 21 -28, 1664. A plague-free week. Credits to: Wellcome Library (2014) . CC BY 4.0

2. Halley, Edmond, "An Estimate of the Degrees of Mortality of Mankind, Drawn from the Curious Tables of the Births and Funerals at the City of Breslaw, with an Attempt to Ascertain the Price of Annuities upon Lives," Philosophical Transactions, Volume 17, 1693, pp. 596-610.

To compute life expectancy at birth, as well as life years remaining at any particular age, age-specific mortality rates are manipulated in a series of calculations that are best organized in the rows and columns of a table or spreadsheet. Life Tables are constructed for men, women, or both. When data suffice, a Life Table could be constructed for other sex identities. Life Tables are constructed for particular occupational categories, ethnicities etc. by interested parties such as life insurance companies.

The entire Life Table depends on the age-specific mortality rates that are inputted. We use the latest data available. But the Life Table will soon be out of date, because mortality rates are constantly changing. As a matter of fact, Queen's University in Kingston, Ontario was found in the 2010s to have under-invested in its professors' pensions. Actuaries[3] advising the University had failed to realize that Queens professors' mortality rates were declining faster than the mortality rates of other groups.

Typically, each life table begins with 100,000 hypothetic newborns. The actual number doesn't matter, since we're only concerned with the proportion that dies in any age group. We like to begin with a nice big number so that, when we multiply by mortality rates, we won't get tiny fractions. We like a number divisible by ten so we can easily calculate percentages. In the Life Table below, the one hundred thousand newborns are Canadian females born in 2019. You'll find them in first row of numbers, fifth column, the column labeled "*l*" (lowercase "L").

Table 6-1. Life Tables for Canadian females, 2019

3. An actuary is a professional specializing in risk measurement and management.

Age Range	n	M	q	l	d	L	T	e
<1	1	0.0038429	0.0038297	100,000	382.97116	99655.32595	8405355.395	84.05
1-4	4	0.0001323	0.0005291	99617.028	52.716850	398341.5949	8305700.069	83.37
5-9	5	6.51E-05	0.0003256	99564.311	32.422845	497740.5028	7907358.474	79.42
10-14	5	9.75E-05	0.0004875	99531.889	48.528266	497538.125	7409617.971	74.44
15-19	5	0.0002203	0.0011010	99483.360	109.53344	497142.9708	6912079.846	69.48
20-24	5	0.0003042	0.0015200	99373.827	151.05235	496491.5063	6414936.875	64.55
25-29	5	0.0003964	0.0019801	99222.775	196.47112	495622.6976	5918445.369	59.65
30-34	5	0.0004919	0.0024569	99026.303	243.30170	494523.2655	5422822.671	54.76
35-39	5	0.0006064	0.0030278	98783.002	299.09747	493167.2675	4928299.406	49.9
40-44	5	0.0008946	0.0044630	98483.904	439.53867	491320.6772	4435132.138	45.03
45-49	5	0.0013797	0.0068748	98044.366	674.03828	488536.7347	3943811.461	40.22
50-54	5	0.0022447	0.0111611	97370.327	1086.7671	484134.7211	3455274.727	35.5
55-59	5	0.0036508	0.0180892	96283.560	1741.6983	477063.5574	2971140.005	30.86
60-64	5	0.0055660	0.0274484	94541.862	2595.0319	466221.7317	2494076.448	26.38
65-69	5	0.0083519	0.0409055	91946.830	3761.1391	450331.3039	2027854.716	22.05
70-74	5	0.0136365	0.0659348	88185.691	5814.5134	426392.1722	1577523.412	17.89
74-79	5	0.0227102	0.1074505	82371.177	8850.8311	389728.8105	1151131.24	13.97
80-84	5	0.0412032	0.1867768	73520.346	13731.896	333271.9905	761402.4297	10.34
85+		0.1146295	1	59788.449	51788.449	428130.4391	428130.4391	7.16

Source: World Health Organization (2019)

Have a look at those 100,000 newborns highlighted in Table 6-1. In the cell to the left of the highlighted cell, you see the number q=0.0038297. This is the probability that a newborn will die before it reaches the age of 1. The number to the left of that is the mortality rate expressed as a decimal, M. M=.0038429.

Why is M, the mortality rate, not the same as q, the probability of dying? Recall that M is always defined over the midyear population. But the probability of dying is defined from the beginning of the year, or birth. We'll talk more about that later.

Multiplying q by the 100,000 newborns, we can figure that 382.97 of them will die before reaching the age of 1. That's the number you see in the cell to the right of the 100,000, the column labeled d for deaths.

Since 382.97 newborns are estimated to die, that leaves 100,000-383 = 99,617 babies making it to age 1. That's why, in the next row, under the 100,000, you have 99,617 individuals.

We track a **cohort** of babies over time, not just one baby. That's because we don't know if an individual is going to die or not. We do know that, for every 100,000 newborns, 383 die.

Each successive row is an older age group, all the way down to the last row. In each successive row we have fewer and fewer people in the *l* column, the column that shows us the number of people entering the age group.

In each row, moving left to right, we have the age group, the length of that age group, the mortality rate, the probability of dying, the number of individuals entering the age group, the number of individuals dying, then big L, big T, and "e". "e" is the expected number of life years remaining for the average person in the age group.

In Table 6-1, we see that our 100,000 newborns each have 84.05 life years remaining. As a group, they have 84.05 x 100,000 life years remaining, as shown in big T.

Unlike big T, which shows all the life years remaining for the group of babies, the first row of big L shows just how many years of life they will spend being babies; due to **infant mortality**, this is some number less than 100,000 babies x 1 year of life. The rest of the Big L column shows how many life years the group (constantly diminishing in number) will enjoy during each successive phase of life.

Photo by Nathan Le Clair, 2007, flickr.com. CC BY-NC-ND 2.0

Before we learn more about these calculations, let's observe some basic features of the Life Table.

1) Typically, the older the age group, the lower the expected life years remaining.

2) The number of people entering age group x, divided by the number of newborns, gives you the probability that a newborn will survive to age x.

Ready for more?

As you know, the first column shows the age group. Newborns have an age group all their own, because they are unique. Not only do they have a very high mortality rate, but it is also true that their deaths are concentrated in the first months of life rather than being spread out randomly over the year. The newborn phase of life lasts 1 year minus one second.

The next age group is ages 1-4. That's a four-year phase of life: being one, being two, being three, and being four, all the way from age 1 to one second before you turn 5 years old.

The rest of the age groups, except for the last, are five years long.

The highest age group is defined without an upper age limit, for example 85+, 90+, 100+, whatever seems most appropriate for the population being studied. We're not sure how long that last phase of life will last. That's why the second column corresponding to that final age group is blank.

The second column gives us the number of years of life covered by that age group. For the newborns, it's one year of life, and for the age group 1-4, it's four years of life: being a 1 year-old, being a 2 year-old, being a 3-year old, and being a 4-year old. All other age groupings are typically five years long, because people tend to round their age to the nearest five years.

Because the highest age group has no upper age limit, we don't know how many years of life this age group covers, so the last entry in the second column is a question mark.

The third column of the Life Table, M, is the mortality rate expressed as a decimal. We do not use the mortality rate to calculate deaths because the mortality rate is a yearly calculation which assumes that people die randomly throughout the year and employs the mid-year population as its base. But in the Life Table

- newborn deaths cluster near the beginning of the year
- initial population sizes, not mid-year population sizes, are used
- age categories may cover more than a single year

Consequently, we manipulate the mortality rate so that we get q in column four. q is the probability of dying before the end of the age category. q is the probability of not making it to the next age category.

Translating mortality rates expressed as a decimal into probabilities of dying q works as follows[4]:

$$q = \frac{nM}{(1 + fnM)}$$

n is the number of years in the age group, and f is the fraction of n lost by the average person who dies during those n years.

For most age groups, f = 0.5, meaning that the average person in that age group dies halfway through the period of time covered by that age group. But for newborns (age 0-1), f = 0.9, because most newborns who die, die soon after birth and miss out on 90% of their year.

Multiplying q by the 100,000 newborns we see that about 383 newborns die, leaving 99,617 to graduate into the second age group, as you can see in column 5, labelled l. l_x is the number of people entering age x.

The next age group is 1-4 year-olds. People who survive this age group have spent a full 4 years in it. The probability of dying before reaching the age of 5 is 0.0005291. Pretty low!

4. derivation shown at end of chapter if you are interested

What is q for the highest age group? Once a person reaches the highest age group, they have a 100% chance of dying in that age group, since there is no higher age group. q is therefore equal to one.

We now understand the meaning of the first six columns!

Columns 7, 8, and 9 are even more interesting.

- Column 7, labelled "L", represents the total years lived in that age group by all those who made it to that age.
- Column 8, labelled "T", represents the total years lived by that age group from that age onward. The age group will shrink over time, but life will go on for at least some of them.

Column 9, labelled "e", gives you the life years remaining for the average person in that row's age group. We saw that "e" for our newborns, life expectancy at birth for Canadian females born in 2019, is 84.09.
Does that mean that today, the average Canadian girl born in 2019 can expect to die when she is 84? Only if mortality rates have not changed since this Life Table was calculated.

Let's look at what's going on when Canadian females born in 2019 turn 40. According to the mortality rates in this Life Table, for every 100,000 newborns, there will only be 98,484 women left. Big T, total life years remaining for the whole group, is 4,435,132.138 years. That doesn't include the years they spent as newborns to age 39. Those years are gone. We only look forward. 40-44 year olds as a group can expect to live 4,435,132.138 more years: 491,320 years as 40-44 year-olds; 488,536 years as 45-49 year-olds; 484,135 years as 50-54 year-olds, and so on as listed in column L.

To get the expected life years remaining for these 40-44 year-olds, we divide the 4,435,132.138 years of life left to this group by the 98,483.9 people who entered this age group. This gives us an average of 45.034 years of life left to live for each person who entered the 40-44 year old age category. These people are truly middle-aged, as their expectation of life is roughly the same as their current age. They are half-way through.

We haven't yet discussed how to find L, the number of years lived by an age group in a particular age category. This is the hardest part, but it's not so bad.

If everyone who entered age group x survived age group x, we could just multiply the number of people entering the age group by the number of years in that age bracket to get L_x. L_x would be equal to l_x multiplied by n_x. This is like multiplying the number of people who go to a party by the number of hours the party lasted, in order to find out how many party hours were enjoyed by people. However, what if some people leave the party early?

Photo by George Groutas, 2009, flickr.com. CC BY 2.0

Because some people die before graduating from the age group, and don't get to experience the entire age interval for that age group,

> $L = nl - nfd$, where l is the number of people entering the age group, and f is the fraction of time the average non-survivor is deceased.

f is the fraction of time in the age interval that the person lived. f is like the fraction of a party that a person attended before leaving the party. Multiplying f by n gives you the average number of years the deceased person has missed. d is the number of deaths in the age group.

For the last age group, where we don't have an "n", the calculation is slightly different [5]:

> $L = l/M$, where M is the mortality rate expressed as a decimal.

5. To understand why this is, think of deaths = M multiplied by L, so L = deaths/M and also deaths = l, since no one survives the last age group by definition.

Now that we have gone through all the calculations, we know some other important points about Life Expectancy:

3) The expected number of years of life you have remaining depends on your mortality at *every* future stage of your life.

4) If the mortality rate for an age group older than you changes, your expected life years remaining will be affected.

5) If the mortality rate for an age group younger than you changes, your expected life years remaining will not be affected.

6) If any mortality rate changes, life expectancy at birth will change.

We have now gone through all the calculations needed to produce life years remaining – at birth or at any other age. All we need is age-specific mortality data, and we are good to go. Try it yourself using the practice questions at the end of the chapter.

Health-Adjusted Life Expectancy (HALE)

Now that we know how many life years remaining the average person of any particular age has left, we can go a step further by scoring each remaining year of life between 0 and 1 depending on health quality. This will give us **Health-Adjusted Life Expectancy**, indicating what those remaining years of life add up to in terms of years of perfect health.

To assign a health score between 0 and 1 to a year of disability or illness, researchers interview people and ask them how many months of perfect health they would like to trade for a full year with a particular disability or illness. For example, interviews show that many people would accept just 0.973 of a year with perfect sight in exchange for an entire year spent wearing glasses. This means that a year with glasses will be counted as only 97.3% of a year of life in perfect health, according to people's own stated preferences.

A Health Utilities Index has been developed by Feeny, Furlong and Torrance (2002) to assign an overall health score to a person based on that person's utility scores in eight categories: vision, hearing, speech, mobility, dexterity, emotion, cognition, and pain. The overall score can range from 1 (perfect health) through 0 (death) to -0.36 (worse than death).

Using data on health from the National Population Health Survey and the Canadian Community Health Survey, and using the Health Utilities Index values, Bushnik, Tjepkema and Martel (2018) found that, for men born in 1974-75, life years remaining at age 20 was 55.9 years, 47.3 years adjusted for health. For men born in 1995, life years remaining at age 20 was 60.5 years, 51.1 years if adjusting for health. For both cohorts of women age 20, life years remaining and health-adjusted life years remaining were higher than for men, but the gap between female and male life years remaining narrowed between 1994-5 and 2015. Life expectancy and Health-Adjusted Life Expectancy for women each rose 2.8 years between 1994-5 and 2015, a smaller increase in expected life years remaining than men experienced.

Figure 6-1. Living Longer

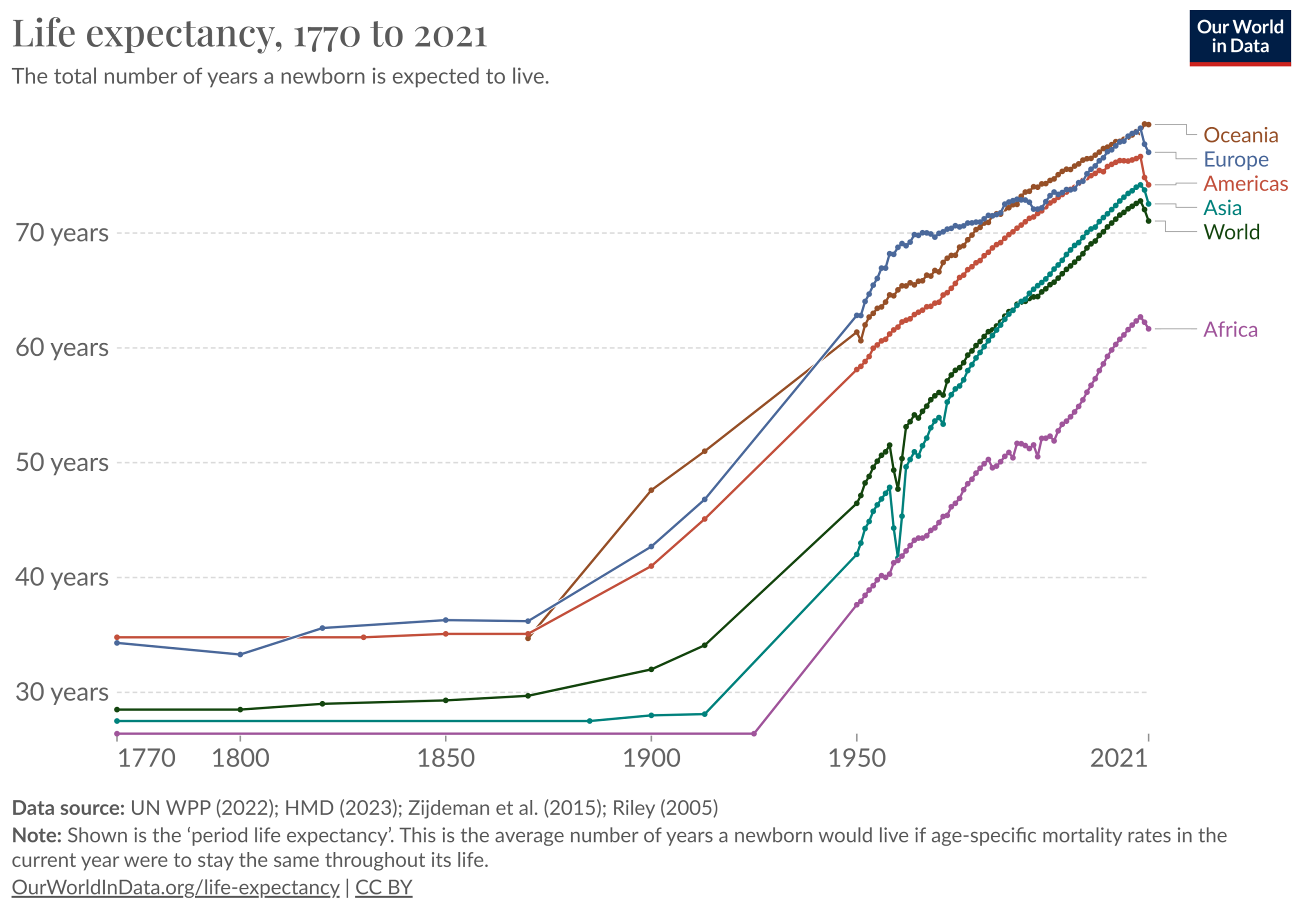


Figure 6-1 shows the substantial increases in Life Expectancy at Birth recently enjoyed by all the regions of the world. The data for this graph begins at 1770, a time of great inequality, colonization, and slavery. The transition to higher life expectancies will be explored in Chapters 8 and 9. Before we get there, we will explore the Life Table a little more.

Appendix: Chapter 6

Converting mortality rates into probabilities of dying

The probability of dying is not the same thing as the mortality rate. The mortality rate is expressed in terms of the underlying number of people in the age group, which changes over time. To get the probability of dying, one needs to adjust the mortality rate for the number of time periods involved and the average amount of time lost by a person who dies.

Define l_x as the probability of surviving up to age x. If there were 100 people, l_x would be the number of people who live up to age x. ($l_x - l_{x+n}$) is the probability that you die between age x and age x + n.

Let *f* be the fraction of time lived during an age interval, by the people who end up dying during that age interval.

Out of 100 people, ($l_x - l_{x+n}$) people are living *nf* years each. These are the people who die between time x and time x + n. l_{x+n} people are living the full *n* years.

Add this up and you get that *n*/2 multiplied by ($l_x + l_{x+n}$) is the number of life years enjoyed in this age interval, or the average number of people alive each year multiplied by *n* years.

Expressed as a fraction of 1, the mortality rate for that age interval is equal to the number of people in that age group who die during the interval, divided by the number of people who are in that age group over the *n* years.

So the mortality rate is:

$$M = \frac{(l_x - l_{x+n})}{nf\,(l_x + l_{x+n})}$$

If you multiply both the numerator and the denominator by l_x, and then rearrange, you will get this, let's call it **Equation A**:

$$\frac{l_{x+n}}{l_x} = \frac{(1 - nfM)}{(1 + nfM)}$$

We can use this relationship to express the probability of dying in terms of M.

The probability of dying while age x to x + n is equal to 1 minus the probability of surviving the age period. The probability of surviving the age period is simply l_{x+n}/l_x. So the probability of dying, *q*, is equal to 1 – (l_{x+n}/l_x). Using **Equation A**, we can write:

$$\boldsymbol{q = \frac{nM}{(1 + nfM)}}$$

Exercises: Chapter 6

1. a) Using Table 6-1 in Chapter 6 of our text, what is the life years remaining for the average Canadian woman born in 2019 expected to be once she reaches 50 years of age?

b) In 2069, what will be the life years remaining for women born in 2019?

2. Based on the chart below:

Age Group	n	q	l	d	L	T	e
<1	1.00	0.30	100,000		85,000	290,730	2.91
1	1.00	0.10	70,000	7,000.00			2.94
2	1.00	0.05	63,000	3,150.00	61,425	139,230	
3	1.00	0.20			53,865	77,805	
+4		1.00	47,880	47,880	23,940		0.5

Fill in the blanks, assuming that gerbils die at a constant arithmetic rate during each age interval.

b) What changes if the average newborn dies 10% of the way through the first year?

Chapter 7: Interpretation and Use of the Life Table

> The Life Table gives us information to predict the number of men and women who should be alive based on how many were born.
> This gives us a way to predict the population's age structure and sex ratio, and a way to look for missing people.

We've learned that, by using today's age-specific mortality rates, we can compute expected life years remaining for people of any age alive today. This is only a projection based on the assumption that mortality rates will not change in the future.

We also saw that survival probabilities from birth to any age x can be read off the Life Table. Similarly, survival probabilities from any age x to any other age x+t can be derived by dividing the number of people entering age x+t by the number of people who entered age x.

Let's squeeze a little more juice out of the Life Table and see what it can tell us about the age distribution of the population.

Photo by You As a Machine, 2012, flickr.com. CC BY-NC-ND 2.0

If the same number of newborns are born each year, and if mortality rates do not change – that is, if the population is what we call "stationary" – then the "l" column of the Life Table will give us the population's breakdown by age, scaled up or down depending on whether the number of newborns used in the Life Table is higher or lower than the actual number of newborns. If there literally are 100,000 newborns every year, and 99% make it to age 1, and 98% make it to age 5, then every year there will be 100,000 newborns, 99,000 one-year olds, 98,000 five year olds etc.

If the population were not stationary, but **stable**, with the number of newborns growing or shrinking at some constant rate r each year, then again we could determine the population by age by looking at the "l" column of the Life Table, but we would have to perform a small adjustment. If the population were growing in a stable way, so that each successive cohort of newborns was r percent larger than the previous cohort, and letting x be actual ages, not age groups, we would have to multiply each l_x by e^{-x} to show that the older groups come from smaller generations of newborns. If the population were stably shrinking, we would multiply each l_x by e^x to show that the older groups come from larger generations of newborns. Once we had performed this adjustment, the age distribution of the Life Table would be the same as the age distribution of the population.

Paradox of the Life Table

As we get older, we normally have fewer life years remaining. But when mortality is very high in a particular age group, those who survive to the next age group may have a higher expected number of life years remaining than before! For example, in 2009, the expectation of life years remaining for newborns (both sexes together) in Afghanistan was 48.3, but the expectation of life years remaining for 1 year-olds was 54.7, and for 5 year-olds, 55.[1] Because of high infant mortality, a **Paradox of the Life Table** can be expected in places of great poverty.

What is going on? Recall that expected life years remaining at age x is equal to:

$e_x = T_x$ divided by l_x.

As we get older, we run out of life and T falls, so the numerator falls and our life years remaining fall.

However, the denominator is also getting smaller as we get older. The number of people our age, our birth cohort, is shrinking. If, because of a pandemic, for example, the number of people our age is shrinking faster than the life years our group can expect to enjoy is shrinking, expected life years remaining for the average person in our age group could be higher after the pandemic.

The survivors of the pandemic would have more life years left to live than what the average person in our age group had before the pandemic began. This concept will be relevant to understanding the **Black-White Crossover Effect** to be described in Chapter 9.

Suggested Activity:

→ Observe Table 7-1 for Afghan Females for 2019.

→ What are some differences can you identify in comparison to Table 6-1 from Chapter 6 for Canadian Females for the same year?

→ Are there any differences in the represented variables that surprise you?

1. World Heath Organization (WHO) (2022), Global Health Observatory Data Repository, apps.who.int/ghodata/?vid=720

Table 7-1. Life Tables for Afghan females, 2019

Age Range	n	M	q	l	d	L	T	e
<1	1	0.0441042	0.04278338	100,000	4278.3387	97005.16285	6315551.10	63.15
1-4	4	0.0035459	0.01406413	95721.6612	1346.2426	379655.6626	6218545.94	64.96
5-9	5	0.0004533	0.00226439	94375.4186	213.70283	471342.836	5838890.28	61.87
10-14	5	0.0003519	0.00175809	94161.7157	165.54478	470394.7169	5367547.44	57.0
15-19	5	0.0011805	0.00588544	93996.1709	553.20941	468597.8314	4897152.73	52.1
20-24	5	0.0017914	0.00891710	93442.9615	833.24061	465131.7063	4428554.89	47.39
25-29	5	0.0024181	0.01201819	92609.7209	1113.0020	460266.0996	3963423.19	42.8
30-34	5	0.0031525	0.01563927	91496.7188	1430.9424	453906.2383	3503157.09	38.3
35-39	5	0.0046858	0.02315811	90065.7764	2085.7531	445114.4993	3049250.85	33.86
40-44	5	0.0069143	0.03398444	87980.0232	2989.9526	432425.2348	2604136.35	29.6
45-49	5	0.0101058	0.04928421	84990.0706	4188.6686	414478.6815	2171711.12	25.55
50-54	5	0.0148466	0.07157659	80801.4019	5783.4891	389548.2868	1757232.43	21.75
55-59	5	0.0219444	0.10401571	75017.9127	7803.0421	355581.9585	1367684.15	18.23
60-64	5	0.0313030	0.14515573	67214.8706	9756.6242	311682.7926	1012102.19	15.06
65-69	5	0.0441851	0.19894908	57458.2464	11431.265	258713.068	700419.401	12.2
70-74	5	0.0660051	0.28328069	46026.9807	13038.555	197538.5159	441706.333	9.6
74-79	5	0.0982628	0.39442183	32988.4255	13011.355	132413.7399	244167.817	7.4
80-84	5	0.1446710	0.53122347	19977.0704	10612.288	73354.63001	111754.077	5.6
85+		0.2368968	1	9364.7816	9364.7816	38399.44733	38399.4473	4.1

Data Source: World Health Organization (2019)

"Model" Life Tables

If you do more reading in demography, you will soon come across so-called **model Life Tables**. Model Life Tables are stylized Life Tables, each of which attempts to generalize the mortality data of a group of similar nations. "Similar" nations experience similar climate, have similar lifestyles, are at a similar stage of economic development, and have access to similar medical care.

Model Life Tables are constructed by using the data from a related group of countries to correlate the probability of dying in one age group to the probability of dying in the next age group and thus generate a set of typical age-specific mortality rates.

Using model Life Tables, a nation can compare its mortality data with those of similar nations.

Also, if you don't have all the age-specific mortality rates to make a Life Table for your nation, you could use one of these model Life Tables to fill in the gaps in this way:

1) Choose which model Life Table to use based on your population's level of economic development, and how its fertility and mortality rates compare. There are different model Life Tables for different kinds of countries.

2) Compare some representative datum from your nation e.g. life expectancy at birth, age-specific mortality rate for 20-25 year old males etc. to the corresponding datum in the model Life Table.

3) Scale the model Life Table up or down until the two data points match.

4) Read the data you are interested in off the scaled model Life Table.

Instead of working with existing model Life Tables (which rapidly become outdated), today's scholar equipped with statistical training and computers would be likely be forming their own estimates of any missing data. They would correlate any age-specific mortality rate data that they do have to past values, to the values of other age groups' mortality rates, and to socioeconomic indicators and come up with a way to guess the missing numbers.

In our next chapter we will see that scholars used this kind of statistical work to predict what Puerto Rico's mortality rates would have been had Hurricane Maria not occurred.

For more information on model Life Tables, see C.J.L. Murray *et al*. in the References.

Looking for people who are missing because of extraordinary mortality

We noticed previously that male mortality rates tend to be higher than female mortality rates. There are "extra" male deaths in that sense. But that doesn't mean there is any foul play. To check whether there is anything suspicious going on, we should compare male mortality relative to female mortality in our nation to the male mortality relative to female mortality in similar nations, i.e. using model Life Tables.

Looking at Table 7-2, we see that male mortality rates during 2010-2013 were very different for the average Canadian compared to First Nations people with Indian Status. Neither set of mortality rates can be used as a model for the other. Something seems wrong.

We also observe that male mortality for Status men was not as much higher compared to Status women as the mortality of Canadian men compared to Canadian women. This was not because of an advantage that Status men had; sadly, it was because Status women's mortality was significantly higher than the mortality of the average Canadian woman.

Table 7-2. Mortality rates per 100,000 and relative mortality rates (2010-2013)

Age Group	Status Men	Status Women	Status Ratio	Cdn Ratio	Diff	Cdn Men	Cdn Women	Age Group
5-9	13.51	12.83	1.0530008	1.15736041	0.90983	9.12	7.88	5-9
10-14	23.85	35.62	0.6695677	1.11142061	0.602443	11.97	10.77	10-14
15-19	123.22	92.85	1.3270867	1.89724919	0.699479	46.9	24.72	15-19
20-24	172.05	113.25	1.5192053	2.40565417	0.631514	73.18	30.42	20-24
25-29	204.53	112.84	1.8125665	2.29559939	0.789583	75.64	32.95	25-29
30-34	217.34	165.46	1.3135501	1.86723424	0.703474	81.15	43.46	30-34
35-39	241.24	191.98	1.2565892	1.71815718	0.731359	101.44	59.04	35-39
40-44	358.6	257.43	1.393	1.59790621	0.871766	149.58	93.61	40-44
45-49	459.84	324.95	1.41511	1.49870968	0.944219	232.3	155	45-49
50-54	593.2	408.75	1.4512538	1.50266172	0.965789	372.6	247.96	50-54
55-59	926.5	493.62	1.8769499	1.55422535	1.207643	595.89	383.4	55-59
60-64	1288.04	883.98	1.4570918	1.60748993	0.906439	926.3	576.24	60-64

Data Source: Akee and Feir (2018)

Akee and Feir (2016, 2018) found that, between 2010 and 2013, women with Indian Status ages 5-64 had mortality rates 3-5 times higher than those of the average Canadian woman ages 5-64. Status men had mortality rates 2-4 times higher than Canadian men. These are very distressing facts, but keep in mind that mortality rates for Canadian men and women are very very low to begin with.

Akee and Feir (2016) write, "*Our estimate of excess mortality for Status women and girls is almost three times the number of all missing and murdered Indigenous women and girls reported by the RCMP.*" They noted that most of the extra deaths were due to non-violent causes. **Chronic living conditions**, especially poverty, were important in explaining the higher mortality.

Banner with names of missing and murdered Indigenous women. 25th Annual Women's Memorial March, Vancouver. Credits to: Jen Castro (CC BY-NC 2.0)

Figuring out how many extra deaths were experienced by Status women is not as easy as it looks. You might think that we could just apply the "normal" mortality rates for Canadian females to the number of Status women of any age to get the expected number of deaths under normal circumstances, and then compute how many more deaths were actually experienced by Status women. But the number of Status women of any age is too small already compared to what it should be, because of high mortality. We need to know what happened to the cohort of women from the time they were born. Unfortunately, birth information for Status persons is not well organized.

In Canada and elsewhere, much work remains to be done in order to understand, honour and enhance Indigenous peoples' lived experience.

"Teachings of the Past, Present and Future" by Erica Potvin for Camosun College, 2021, flickr.com, CC BY-NC-ND 2.0 DEED

Jiang, Feldman, and Jin (2005)[2] also wanted to find the number of missing women, in their case women living in China, and they had similar data problems. They didn't know how many women should have been born, or how many should have been entering each age group. They mistrusted the government's records as to how many girls had been born. They even mistrusted the female mortality data. But they had one advantage: they had accurate and unsuspicious birth records for males.

The team began by assuming a sex ratio at birth of 1.06 due to China being in a more northerly climate (the sex ratio is slightly lower in southern climates); for each generation of children born in the same year, i.e. each cohort, they began with 106 infant boys in the numerator and 100 infant girls in the denominator as the expected sex ratio at birth.

To get the sex ratio at any age x, they first multiplied the numerator (the 106 infant boys) by the survival probability from birth to age x. They used a Chinese Life Table to find the survival probability. This gave them the expected number of boys age x. They then multiplied the denominator (the 100 infant girls) by a model Life Table's survival probability for girls from birth to age x. This gave them the expected number of girls age x.

Dividing the numerator by the denominator, they obtained the expected sex ratio for age x.

$$(1)\quad SR_x^e = SR_0^e \frac{\frac{l_x^m}{l_0^m}}{\frac{l_x^f}{l_o^f}}$$

$$e = expected$$

$$SR_x{}^e = expected\ sex\ ratio\ at\ age\ x$$

$$m = male$$

$$f = female$$

The $\frac{l_x^m}{l_0^m}$ is the probability of men surviving from birth (age 0) to age x, as read off the Life Table.

The $\frac{l_x^f}{l_0^f}$ is the probability of women surviving from birth to age x, as read off the model Life Table.

Next, Li et. al went looking for census and other estimates of what the **actual** number of boys age x had been x years after the cohort in question was born. They divided the actual number of boys by the expected sex ratio to find what the number of girls age x *should have been*.

2. later Jiang, Li, Feldman, and Sanchez-Bárricarte (2012)

$$(2)\ expected\ number\ of\ females\ age\ x = actual\ number\ of\ males\ divided\ by\ SR_x^e$$

They compared this expected number of girls age x to the **actual** number of girls age x recorded in the census or other estimates for that year.

$$(3)\ number\ of\ missing\ female\ age\ x = expected\ number\ of\ females\ age\ x - actual\ number\ of\ females\ age\ x$$

As a result of their calculations, the team estimated that 35 million Chinese females were lost over the course of the twentieth century. That would be about 4.65 percent of all females who were otherwise expected to be born and survive.

What possibly happened to these girls and women? Think of the three drivers of population change.

- ***Fertility:*** the actual sex ratio at birth was higher than 1.06 due to infanticide at the time of birth and the birth not being reported as a live birth, or, in the last part of the twentieth century, sex-specific abortion.
- ***Mortality:*** the actual mortality rates were higher than the model Life Table mortality rates: a greater fraction of girls and women died or were killed in China than in comparable countries.
- ***Migration:*** some women emigrated (at a higher rate than men their age) (unlikely) or were forcibly removed to another country (also unlikely).

The twentieth century was a very difficult century for China. It included a political revolution, a cultural revolution, three episodes of civil war, a famine, an invasion by the Japanese, and a period of strict birth control measures enforced by the government.

Despite these pressures, most girls and women were loved and cherished.

Discrimination against female children will be discussed more in Chapter 24. For now, we will talk more about mortality.

Exercises: Chapter 7

1. Consider Table 7-1. What is the probability that an Afghan female born in 2019 will become at least 20 years old?
2. According to the same Table, what is the probability that an Afghan female born in 2019, having just turned 1 year old, will become at least 20 years old?
3. Compare your answers in 1. and 2. Is this a paradox? Where/ where else can you see the Paradox of the Life Table in Table 7-1?
4. The natural sex ratio at birth for the nation of Alametra is 1.05. From 100,000 hypothetical new-born females, 98,500 are alive at age 25 in Alametra and similar countries in the region. In similar countries, from 100,000 hypothetical newborn males, 97,000 are alive at age 25. In Alametra today, there are 1.5 million women and 1.2 million men. How many men appear to be missing from Alametra? Why might these men be missing?
5. In Country X, there are 28,275 females age 15 and 30,000 males age 15. Migration of children under 15 has been negligible. In a life table that uses mortality rates typical for countries at a similar state of economic and demographic transition, females have a 95 % chance of surviving until age 15, and males have a 94 % chance of surviving until age 15. The sex ratio at birth should be 1.05. For Country X, what is the number of missing females among those born 15 years ago?

LIFE AND DEATH

Chapter 8: Measuring Mortality

What kills people? In this chapter we distinguish between usual and unusual causes of death. Which has been more deadly?

The COVID-19 pandemic which began in 2020 was a crisis. The virus was new to us; we did not know exactly how it spread, how easily it spread, or how sick it could make us. This crisis caused deaths directly and indirectly. There were deaths from COVID infections, and there were deaths from other conditions in people weakened by COVID-19. There were deaths because of delays in medical treatment or fear of going to hospital. There were deaths from substance abuse and suicide related to the isolation of lockdowns, economic hardship, and uncertainty caused by the pandemic. There have been and will be deaths due to the long-term effects of having been infected.

Disease Categorization

Endemic disease = a disease that occurs regularly in a population, like the common cold, common types of influenza, and diabetes

Epidemic = a sudden outbreak of a new disease or new variant of an endemic disease that spreads rapidly

Pandemic = an epidemic involving multiple nations

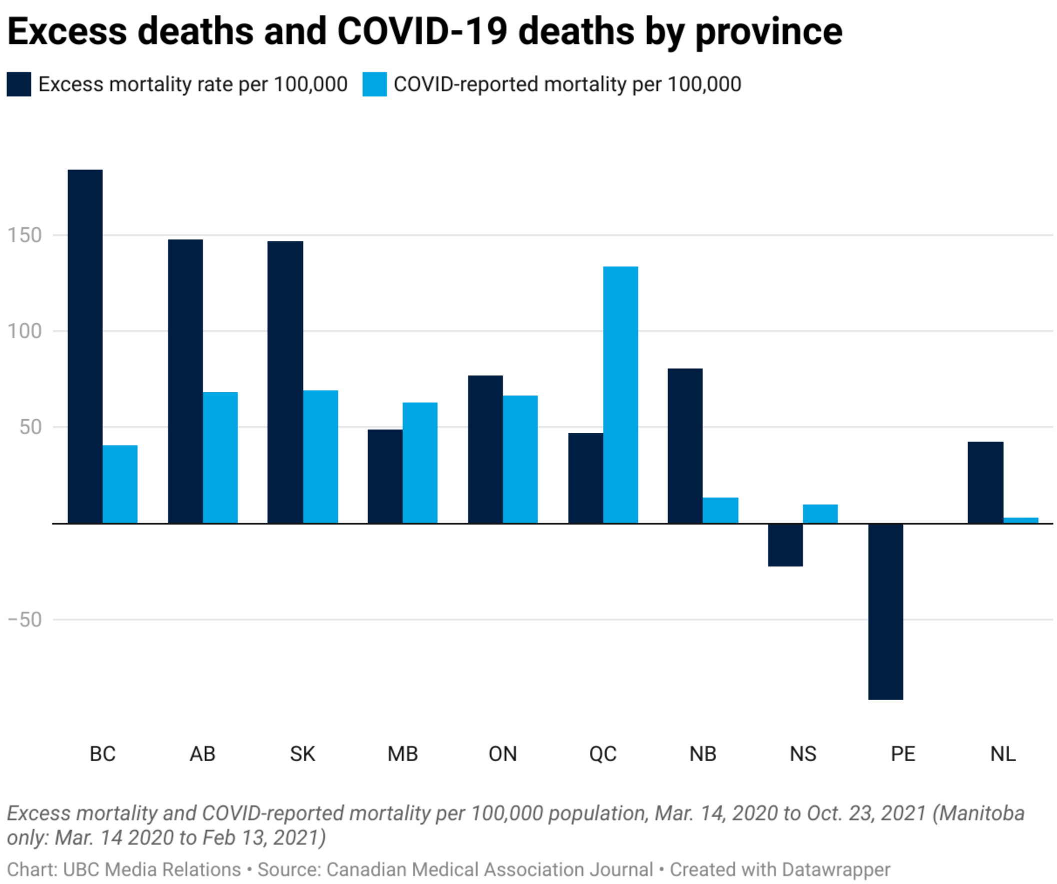
Crisis deaths are deaths which are caused by exceptional situations -epidemics or pandemics, natural disasters, war, and severe economic downturns. By contrast, **chronic deaths** are deaths we expect due to the prevailing standard of living – the prevailing level of income, nutrition, medical care, sanitation, and safety – and due to the endemic diseases that exist in the population.

Photo by Isaac Quesada, 2020. CC BY 2.0/Unsplash License

Usually, the presence of a crisis and the resulting crisis deaths means that the population will have more deaths than it would have otherwise. There will be **excess deaths**, that is to say, more deaths than what would have been expected under normal conditions. However, crises could conceivably result in fewer people dying than usual. COVID-19, which typically did result in excess deaths, nonetheless reduced the number of chronic deaths from ordinary forms of influenza as people washed their hands more frequently, wore masks, and socially distanced themselves. As people quarantined, air quality improved, and the number of workplace and traffic accidents fell.

Figure 8-0 shows us that, in the first 17 months of the pandemic, Nova Scotia and Prince Edward Island experienced fewer deaths than usual: excess deaths were negative. In contrast, British Columbia had more than 150 excess deaths per 100,000 people at midyear, or 1.5 per 1000.

Figure 8-0.



Source: Figure 2 of McGrail (2022).

To calculate whether a nation experienced excess deaths due to a disaster or pandemic, we need to know the number of deaths that would have occurred without the disaster. How do we do that?

Nowadays we use statistical regression analysis to predict the number of deaths that will occur in any year. Regression analysis sifts through mounds and mounds of data to tease out the relationship between the the number of deaths in a particular age/sex group and a number of factors, factors like the size of the age/sex group, the number of deaths in that age/sex group in the previous year, GDP, average daily temperature, average daily sugar consumption, etc. Then, to find what deaths for each age/sex group would have been in 2020 without the COVID-19 pandemic, the researcher makes an inference based on what the 2020 values of all the relevant factors would have been without the pandemic.

Case of Hurricane Maria

Hurricane Maria was a Category 5 storm that battered the northeastern Caribbean in September, 2017. In 2018, the Milken Institute School of Public Health at George Washington University published a study of excess deaths in Puerto Rico due to Hurricane Maria. To come up with their calculations, they first collected age and gender-specific mortality rates and socioeconomic data for many years prior to the disaster, then used this data to predict what mortality rates would have been in the period September 2017 – March 2018 without the hurricane. They then compared these predicted deaths to the actual deaths during September 2017 – March 2018.

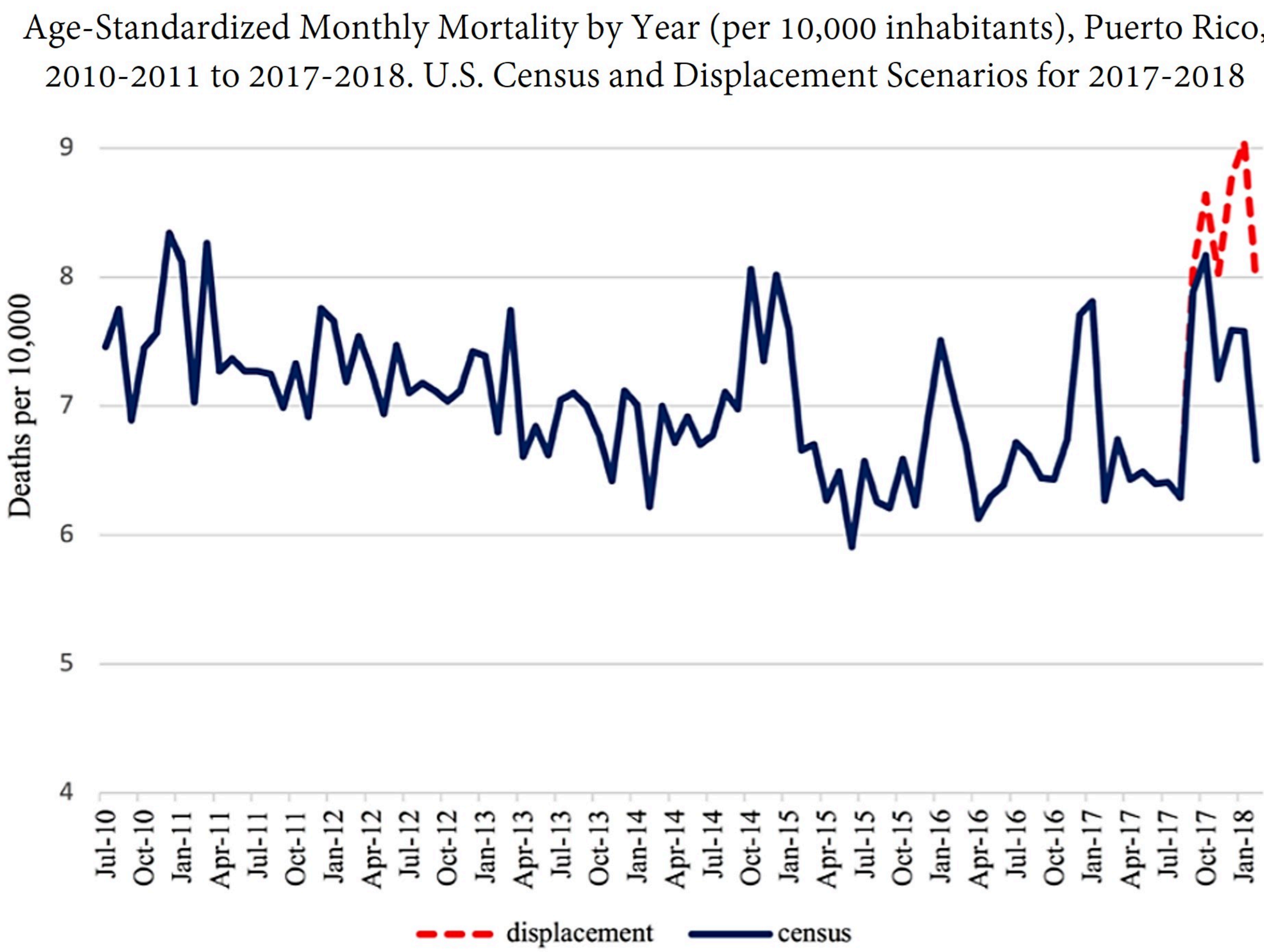
The scholars found that, during the six months after Hurricane Maria, Puerto Rico experienced 2,975 more deaths than would have been experienced without the hurricane. These excess deaths made up about 20% of the total deaths during the six-month period. As a comparison, excess deaths due to COVID-19 in 2020 were about 5% of total deaths in Canada and 11% of total deaths in the USA.[1].

Morning after Hurricane Maria, 2017. Photo by R. Skerrit, 2017. Public Domain

Figure 8-1 below shows the spike in the monthly death rate in Puerto Rico in 2017. The dotted red line shows that the death rate would be even higher if you removed from the denominator all the people who left Puerto Rico during that 6-month period. The denominator in these monthly death rates is the mid-month population.

1. Statistics Canada's *The Daily*, April 16, 2021

Figure 8-1. Mortality rate by year, Puerto Rico

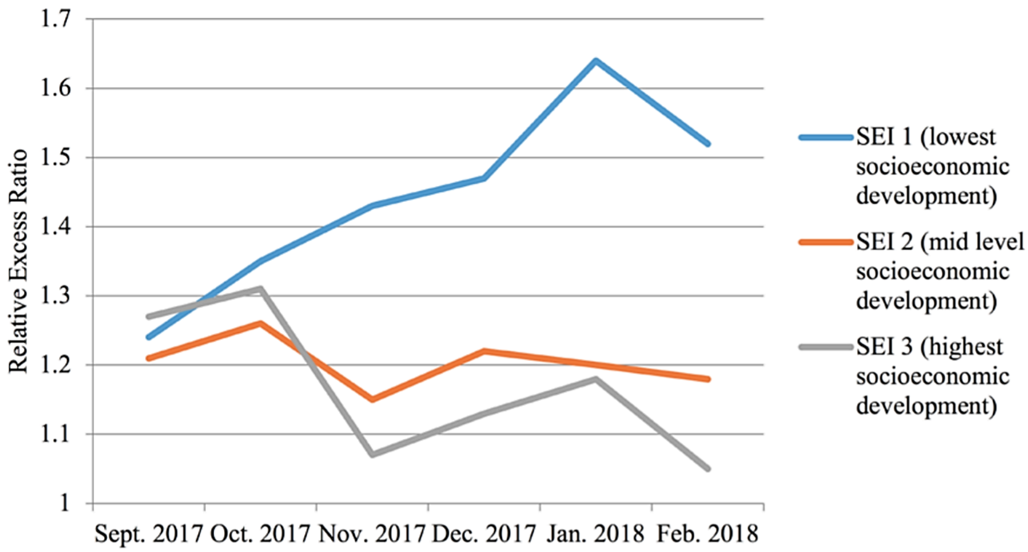


Source: Milken Institute School of Public Health (2018)

Figure 8-2 shows that less-privileged people suffered more excess deaths, and that their experience continued to deteriorate for four months, both in an absolute sense and relative to more privileged people.

Figure 8-2. Relative excess mortality, Hurricane Maria, by socioeconomic group

Source: Milken Institute School of Public Health (2018)

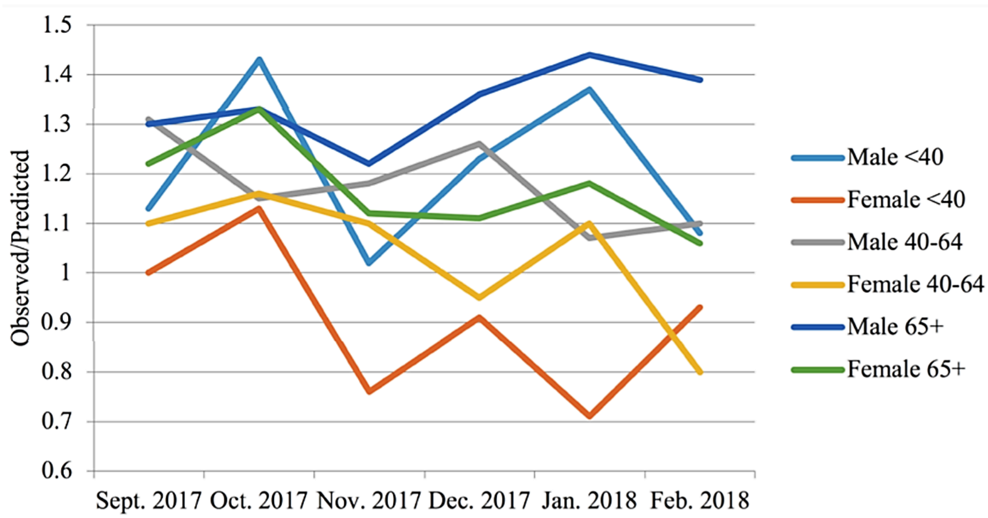


To understand Figure 8-2, note that the vertical axis shows the ratio of actual deaths to usual deaths. A level of "1" means no excess deaths. A level of "1.2" means that there are twenty per cent more deaths because of the hurricane.

Figure 8-3 shows that it is not necessarily true that women suffer more during crises. The oldest people of both sexes, and middle-aged male Puerto Ricans, were hardest hit in the month following Hurricane Maria, possibly because of actions they were taking to protect others. All groups recovered to some degree in October. Later, young and middle-aged women began to experience *less* mortality than usual, while men, especially the older men, continued to suffer excess deaths.

Figure 8-3. Relative excess mortality, Hurricane Maria, by sex & age group)

Source: Milken Institute School of Public Health (2018)



In another study of excess deaths in Puerto Rica due to Hurricane Maria, Cruz-Cano and Mead (2019) determined that out of 1205 excess deaths in September and October 2017:

> *"Most excess deaths occurred from heart disease (253 deaths), "other" causes (204 deaths), diabetes (195 deaths), Alzheimer's disease (122 deaths), and septicemia (81 deaths)."*[2]

The crisis led to a deterioration of living conditions and lack of medical care. In this way crisis deaths included deaths from endemic diseases such as diabetes.

Which has been more historically important – crisis or chronic mortality?

Historically, have more people been killed by pandemics, war, famine and other disasters, or by the daily grind of malnutrition, heavy labour, exposure to the elements, domestic violence, crime, endemic diseases and so forth?

Robert Fogel (1992) tackled this question and concluded that chronic living conditions were the main determinant of death rates in the past. He presented two pieces of evidence to support this claim.

2. https://www.nature.com/articles/d41586-019-00442-0

First, Fogel examined Wrigley and Schofield's excess death calculations for England for the period 1541-1871[3]. Fogel found that the excess deaths during the three hundred and thirty year period were a small fraction, less than 5%, of total deaths.

La Miseria by Cristóbal Rojas (1886). Rojas was suffering from tuberculosis when he painted this. In this painting we see nineteenth century living conditions that would have influenced disease outcomes. Public Domain.

The second thing Fogel did was collect data on height – which is a measure of the net intake of nutrition from conception through adolescence – and weight – which is a measure of current net nutrition. Based on how height and weight affect mortality rates today, Fogel found that the height and weight of English, French, and Swedish soldiers prior to 1875 implied mortality rates very similar to the mortality rates they actually experienced. Fogel concluded that most of the mortality 1775-1875, and half the mortality 1875-1975, could be explained by nutrition, at least for the adult age groups he considered.

French retreat from Russia in 1812 resulting in mass starvation and deaths of French soldiers. Artist: Illarion Pryanishnikov, 1874. Public Domain.

Kannisto and his team (1999) found that during famine (1866-1869) and wars (1789, 1808-9), most deaths in Finland were caused by infectious disease spread by armies, veterans, and refugees. People's base level of health, nutrition, housing, and sanitation – their chronic living conditions – were key to survival.

Ordinary living conditions matter. We saw during the COVID-19 pandemic that the people whose health suffered most from COVID-19 were people with pre-existing health conditions, people eating poor diets, and people whose jobs required them to take public transit and to serve in public places. By the same token, some of the most powerful remedies against infection were simple: distancing, masking, and washing of hands. How many of these new habits will become part of our everyday lives? How many of our pre-COVID social norms and traditions developed in response to crises long ago?

3. Wrigley and Schofield did not use modern methods to compute excess deaths, so this stream of research should be updated.

Exercises: Chapter 8

Consider two nations. In one, most of the population lives in poverty and without access to hospitals. In the other, most of the population enjoys a good diet, clean water, and access to sophisticated medical care. A newly-evolved flu virus attacks both nations.

1. Which nation is likely to experience a greater number of crisis deaths per 1000? Why?
2. Which nation is more likely to have a higher ratio of crisis to chronic deaths? Why?

Chapter 9: Determinants of Mortality

Mortality, like so much in life, depends on nature, nurture, choices, and the inexplicable divine grace or, secularly speaking, lucky breaks we encounter. How does mortality change in response to economic factors?

The influence of economic factors may be different whether we are talking about personal income, national income, income inequality, or the stage of the business cycle.

While non-economic factors such as relationships, self-esteem, and risk tolerance affect mortality, income plays a significant role.

How mortality varies with income

Purchasing power or individual income

It makes common sense that the richer you are, the better able you are to afford good nutrition, shelter, and medical care. You are more likely to be literate and educated, which helps you make better informed choices concerning your health. Indeed, life expectancy is higher for individuals with greater income.

Chetty et al. (2016) tracked 1.4 million Americans between 1999 and 2014 and found that expected life years remaining – specific to a particular year, age, sex, race, and location – increased with income. For men age forty and older, there was a 14.6 year gap in life years remaining between those in the bottom 1% of income earners and those in the top 1% of income earners. For women age forty and older the gap was 10.1 years. The gap was unfortunately increasing over the time period studied.

In the United States in 2017, Black men had a life expectancy at birth 4.6 years below non-Hispanic White men[1]. Economic disadvantage would be a major reason why. For Black women the gap was 2.9 years. However, Hispanic (Latino) women had a higher life expectancy than White women, by 3.3 years, indicating that income is not the whole story. Similarly, Hispanic men had a 3-year advantage over White men. This phenomenon of a higher life expectancy for the lower-earning racial group is known as the **Hispanic Paradox**.

Another apparent paradox is the fact that, since 1900, African Americans age 75 and older have more life years remaining than White Americans age 75 and older. That is to say, once age 75 has been reached, Blacks are more likely than Whites to live longer. This Black-White Crossover Effect could be an instance of the Paradox of the Life Table. If the Paradox of the Life Table is indeed the primary explanation, it speaks volumes about the hardships experienced by Black Americans before the age of 75: those who make it to age 75 are stronger than the typical White American person age 75.

Canada has a similar story to tell. Although Canada did not collect death statistics by race up until the early 2020s, estimates of life expectancy by Indigenous identity had been computed a few times. Those estimates presented cause for concern.

Table 9-1. Life years remaining, both sexes combined, First Nations, Métis, and Inuit, as of 2011, selected ages.

Life Years Remaining	Non-Indigenous	Métis	First Nations	Inuit
At age 1	84.3	79.5	75.2	73
At age 20	65.5	60.9	56.8	55.5

[26] Source: Table A of Tjepkema et al. (2019).

Life expectancies at birth could not be computed because of the lack of birth data by race. As discussed in Chapter 7, Akee and Feir (2016, 2018) delved into the mortality data for people who were listed on the federal government's Status Indian Register. They found that the gap in mortality rates between Status persons and the average Canadian was greater than the gap between Black and White Americans.

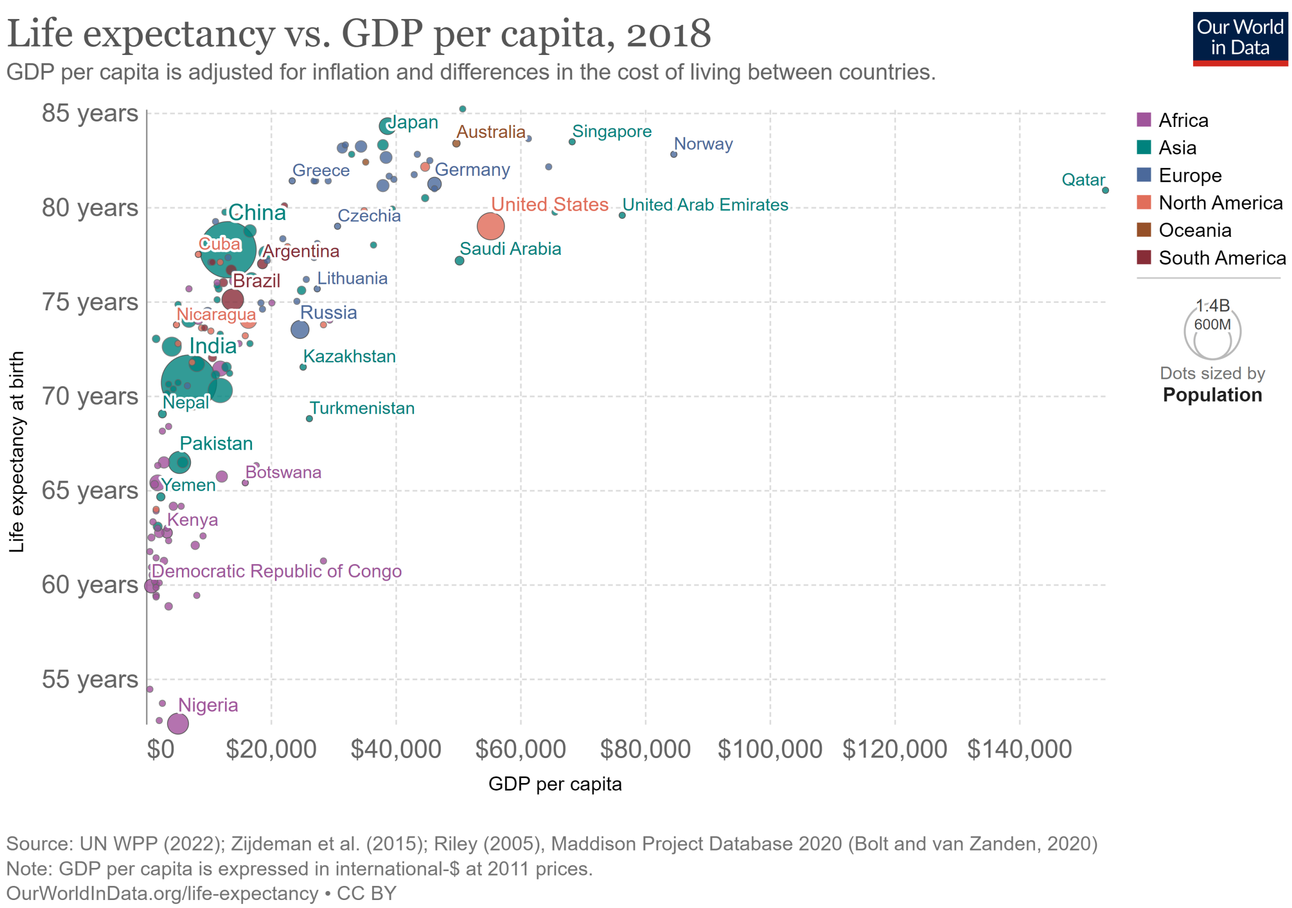
National Income

Life expectancy is higher in countries with higher standards of living, but the marginal improvement to life

1. National Vital Statistics Reports, 68(7), June 24, 2019

expectancy from higher national income diminishes as countries become richer. A few studies, including those summarized by Euromonitor International (2014), found a U-shaped relationship between national income and life expectancy, meaning that increases in national income were correlated with lower life expectancy for the highest-income countries, but this result has not been established. Figure 9-0 below is suggestive.

Figure 9-0.



Income Inequality

Ward and Viner (2017) provide citations for the general result that income inequality within a nation is associated with increased infant mortality, increased obesity, higher levels of violent crime, poorer self-reported health, and reduced life expectancy. They then proceed to demonstrate that, in 2012, across 103 low and middle income countries, both GDP and household income inequality were strong predictors of child and youth mortality, especially of mortality from contagious disease. GDP was associated with decreased mortality, especially for children, while income inequality was associated with increased mortality.
A high degree of income inequality indicates that there are communities or classes within the overall

population which experience substantially less economic opportunity and access to health care. Without significant government intervention, these communities will experience mortality rates higher than would be expected based on that country's GDP, and may host pathogens which have been eradicated elsewhere in the country. In Canada, Tuberculosis (TB) is a disease which affects Indigenous peoples, especially, Inuit, disproportionately. In 2021 the incidence of TB was 135.1 per 1000 among the Inuit compared to 13.4 per 1000 (10 times less) among foreign-born Canadians and 0.2 per 1000 (675 times less) among the non-Indigenous Canadian-born[2].Income inequality may also contribute to feelings of economic insecurity, low self-esteem, and political tensions, which can have health impacts.

The Business Cycle

Stephen Bezruchka (2009) confirmed a pattern first observed in Ogburn and Thomas (1922): for richer nations, mortality follows the business cycle, rising during booms, and falling during recessions. Though suicide rates increase during recessions, and degenerative diseases such as cancer seem unaffected by the business cycle, mortality rates for infants and mortality rates from accident, infection, and other diseases actually fall during recessions.

Taking a look at Canadian data between 1960-2020[3], we find a correlation coefficient of -0.52 between the unemployment rate and the infant mortality rate, indicating that infant deaths tended to decline when unemployment increased (1 means perfect positive correlation, -1 means perfect negative correlation, and zero means no correlation). It is almost the same at -0.51 when 2020, the first year of the pandemic, is excluded. When we compare infant mortality to the previous year's unemployment rate, the negative correlation is almost identical at -0.51, with the effect a slightly stronger (-0.53) if 2020 is excluded.

Dehejia and Lleras-Muney (2004) studied pregnancies and births in the United States between 1975 and 1999. They found that, although fewer babies were conceived in times of high unemployment, they were born healthier. Women pregnant during recessions were more likely to be between 25 and 35 years old and to attend prenatal care appointments. Black women pregnant during recessions were better-educated and more employable than Black women pregnant at other times, and were smoking and drinking less, though White women pregnant during recessions were less educated and lower income and tended to increase their smoking and drinking.

The following table brings other relevant issues to light.

2. Government of Canada (2023), "Tuberculosis in Canada: Infographic. Tuberculosis in Canada: Infographic (2021) - Canada.ca
3. OECD data from https://stats.oecdorg

Table 9-2. Income- related determinants of mortality

Low Income	Needs	High Income
-precarious	Safety and Freedom	-more secure
-homelessness, crowding possible	Adequate Shelter	-can afford
-difficult in urban slum, ghetto, or underfunded reserve	Clean Air and Water	-more likely
-malnutrition possible -possibly more locally-grown, fresh food	Nutrition	-can afford a more nutritious and varied diet
-not enough time to rest? -deeper rest from manual labour	Rest	-more stimulation and night lighting?
-more exercise due to labour requirements, lack of transportation	Exercise	-must be scheduled
-basic -manual labour results in more accidents	Healthcare	-best practices -some elective procedures may be harmful
-necessary for survival -may be disrupted by premature death, necessity of migration in search of work, poverty	Relationships	-may be diminished by greater distance between homes, private commuting in cars, competing activities, and the “I-deserve-more” attitude promoted by advertisers -emphasis on personal consumption and personal satisfaction
-greater material hardships to worry about -temptation to idolize material success -busier?	Inner Peace	-higher expectations of “success” -fewer excuses for “failure” -survivor guilt -more faith in material, temporal things -busier?

A higher income pays the bills and offers opportunities for enjoyment, but it can also be associated with overindulgence, overwork, and boredom. Let us now turn to the historical record to see how mortality rates have changed over time.

The stages of mortality transition

The idea that income promotes survival, until you have too much of it, is reflected in the three stages of mortality suggested by Abdel Omran (1971):

1. *the Age of Pestilence and Famine*
2. *the Age of Receding Pandemics*
3. *the Age of Man-made and Degenerative Disease*

The names basically speak for themselves, with the first Age being one of high mortality, the second being one where mortality falls, and the third being an Age where mortality rates creep back up due to poor lifestyle choices and old age.

Omran's predicted Age of Man-made and Degenerative Disease has not (yet) definitely arrived; however, later in this chapter we will discuss some recent downward trends in life expectancy.

It might be better to describe the three stages of mortality transition as:

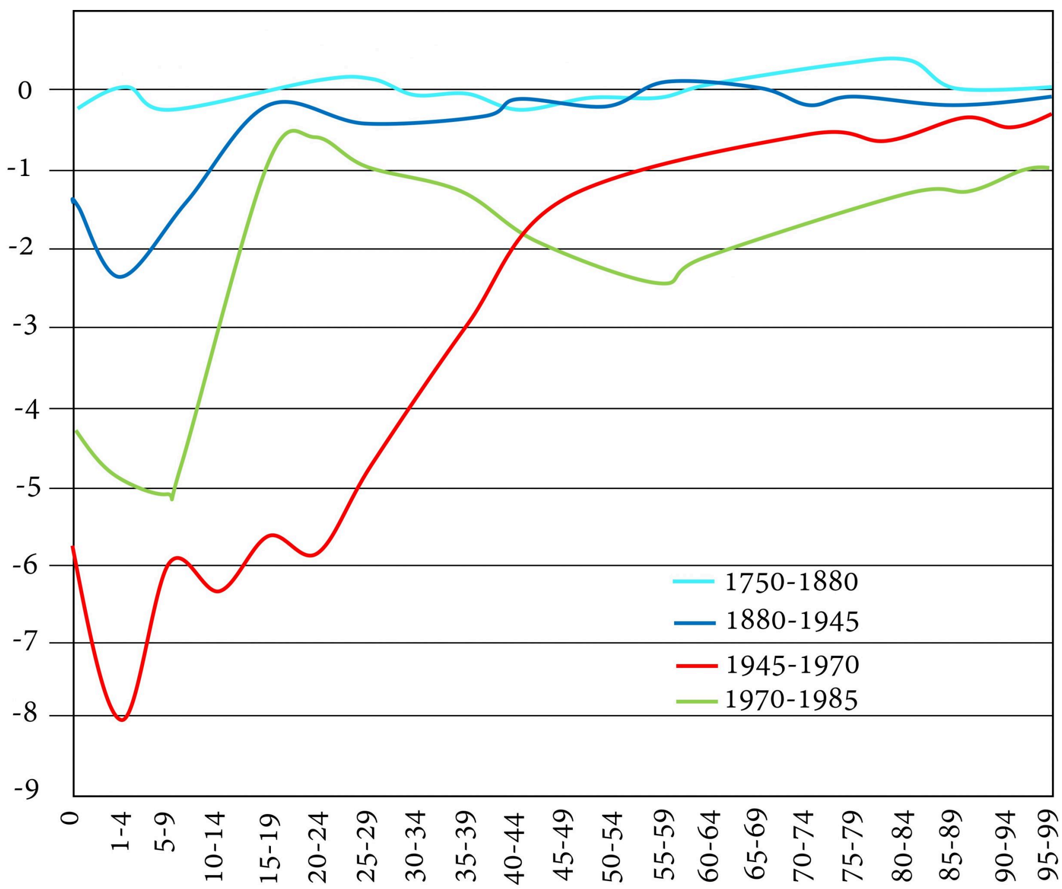
1. *Pre-transition mortality*
2. *Falling Mortality*
3. *Delayed Aging*

Most of the world's nations are in this Delayed Aging stage.

In the graph below, we see data collected by Kannisto et al. (1999) for Finland. The figure shows percentage decreases in mortality for different age groups along the horizontal axis. Each coloured line represents a different time period.

The top light blue line refers to a time period when mortality rates are not changing much, hence, a pre-transition stage. In Finland this did not end until about 1880. The dark blue and red lines refer to a time of major decreases in mortality, first for children only, then for children and younger adults. Finally, the greenish line shows that, during the period 1970-1985, middle-aged and older people's mortality fell significantly – the period of delayed aging.

Figure 9-1. Annual percent change in mortality by age and sex, by stage, males



Source: Figure 3 of Kannisto et al. (1999)

Pre-transition mortality

Generally, in pre-industrial times, age-specific mortality rates were particularly high for infants and children. Since so few survived to become adults, the ratio of children to adults was high. The average life expectancy was between 20 and 40 years. Females had higher mortality rates than males during their reproductive years, because of the riskiness of childbearing.

Omran (1971) writes grimly:

> *The scanty evidence available indicates that frequent and violent fluctuations characterized the mortality patterns of pre-modern societies and that the mortality level was extremely high even in the so-called good years.*

> *Caught between the towering peaks of mortality from epidemics and other disasters and the high plateaus of mortality dictated by chronic malnutrition and endemic diseases, life expectancy was short and human misery was assured. More than any other single factor, fluctuating but always high mortality offers the most likely explanation of the slow rate of world population growth until 1650 A.D.*

Cippolla (1994) writes,

> *Mortality was very high indeed in medieval and early modern Europe. A woman who managed to reach the end of her fertile life, let us say at age 45, had normally witnessed the deaths of both her parents, the majority of her brothers and sisters, more than half of their children, and often she was a widow. Death was a familiar theme. And it was a grim business. With no alleviation of pain, the bitterness of death was very real. To make things worse there was the cruelty of people, who had become hardened to the horror of natural death: apart from the give and take of warfare, there was the ferocity of justice, the homicidal intolerance of orthodox religion, and the lack of clemency for the weak and captive.*

During this era, crisis deaths, though fewer in number than chronic deaths, formed a greater fraction of deaths than they would later, because poverty and ignorance kept people vulnerable to crises such as weather, war, and epidemics.

Falling mortality

Kannisto et al. describe the years 1880-1945 as the Age of Bacteriology, and the years 1945-1970, the Age of Antibiotics. The changes Finland experienced during those years are typical of the stage of Falling Mortality. Medical advances and a rising standard of living reduce deaths from chronic disease such as diarrhea and tuberculosis. Infants, children, and young adults are the big winners. The Paradox of the Life Table is eliminated. Fewer women die in childbirth, and the female mortality rate drops below the male mortality rate for virtually all ages. Life expectancy at birth rises to 50 for men and women.

Omran attributes this declining mortality to a reduction in pandemic disease; but as we have discussed, the more significant breakthroughs have been against endemic, not pandemic, diseases. Learning how to fight bacteria and viruses has turned the tide against cholera, typhus, diptheria, tuberculosis, measles, and so many other formerly common threats. Anti-bacterial and anti-viral work was supported by developments in engineering, manufacturing, transportation, and farming, which improved materials, manufacturing, refrigeration, transport, the standard of living, the reach of commerce, and the capacity of governments to tax and spend.

Malthus had believed that an improving standard of living would lead to explosive population growth and terrible competition for scarce resources. There were indeed wars, pandemics, and famines during the eighteenth and nineteenth centuries. However, in Britain and western Europe, living standards more than kept pace with the growing population. As the improvements in technology and achievements in science spiraled ever higher, and – it should also be noted – as new lands, resources, and peoples were colonized in America, Africa, and Australia, the West sprung free of the Malthusian trap. Most of the rest of the world would soon follow.

Delayed aging

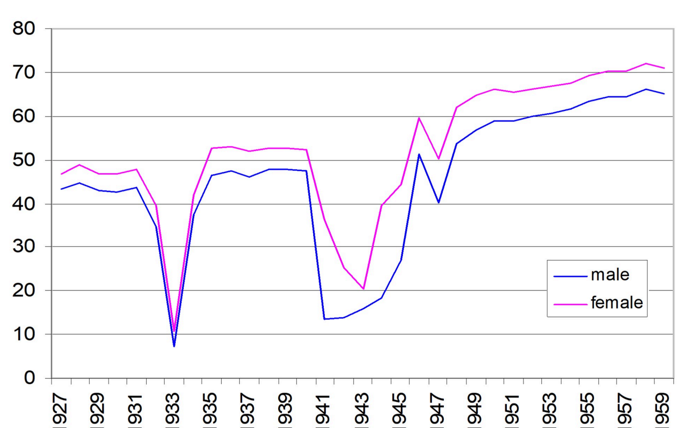
In this stage, people have more than enough resources to meet their basic needs. The standard of living is high and innovation, whether technical or medical, is ongoing. Formerly chronic diseases melt away. Crisis deaths become a tiny fraction of deaths. Life expectancy at birth exceeds 70.

During this stage, most people die of diseases which are degenerative or man-made. Degenerative diseases are those that are a natural result of aging, given the current level of medical knowledge. They include cancer, heart disease, stroke, and Alzheimer's. Man-made diseases are those that are caused by risky behaviour. They include diseases related to smoking, drinking, over-eating, a fat-rich diet, and lack of exercise.

Deviations from trend

In reality, mortality will not transition as smoothly as we have described above. For example, as shown in Figure 9-2, life expectancy in the Ukraine gyrated wildly in the first half of the twentieth century due to famine (1932-3, 1946-7) and Nazi aggression (1941-1945). The invasion by Russia in 2022 will depress life expectancy in Ukraine once again.

Figure 9-2. Life expectancy at birth, Ukraine 1927-1959



Recent increases in mortality in the US

Several years before the COVID-19 pandemic, economists Case and Deaton (2015) published a shocking paper showing that, between 1998 and 2013, life expectancy at birth actually fell for middle-aged American Whites, especially those without a college education. The higher mortality rates for this group ("USW" in Figure 1), compared to middle-aged Hispanic Americans ("USH" in Figure 1), is shown below. Middle-aged Hispanic Americans (light green line) and Black Americans (not shown; mortality rates too high) did not experience rising mortality rates.

The mortality was manifest in higher rates of poisoning (drug overdoses), suicide, and (alcohol-related) liver failure, as shown in Case and Deaton's Figure 2, below. There was also an increase in self-reported pain, and a decrease in self-reported mental health, physical health, and ability to work.

Figure 1: All-cause mortality by country

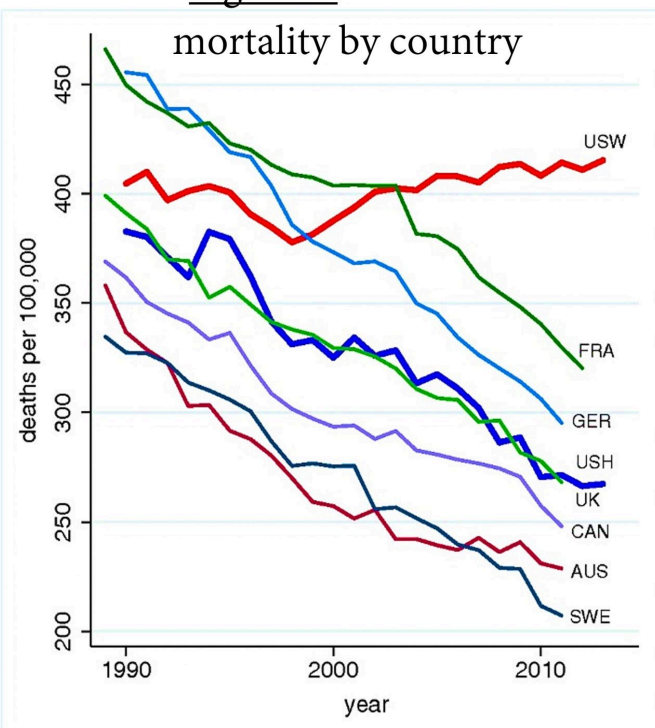
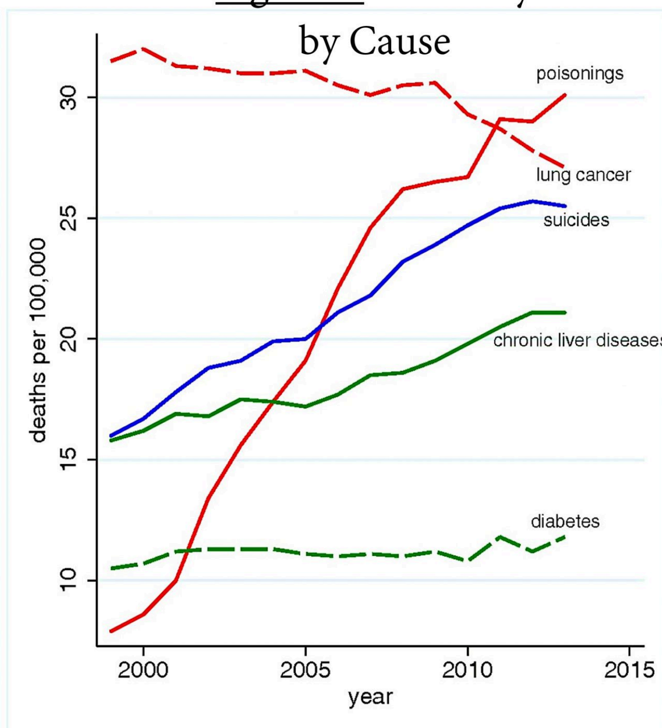


Figure 2: Mortality by Cause



In Figure 1, USW means American Whites. USH means American Hispanics. The mortality rates are for people ages 45-54. In Figure 2, the mortality rates are for American Whites ages 45-54. *Source: Anne Case and Angus Deaton (2015)*

Canada has also experienced rising opioid-related mortality, particularly among men ages 25-45. British Columbia initially reported a decrease in life expectancy of 0.38 years between 2014 and 2015 for its overall population, with drug overdose deaths accounting for about one third the increase (Ye et al. (2018)). It now reports a much smaller decrease for that year; however, life expectancy did fall for three straight years between

2014 and 2017 for a total loss of more than half a year[4]. It also fell by about half a year the first year of the pandemic.[5] In the entire country, life expectancy fell slightly between 2016 and 2017, and because of the pandemic, between 2019 and 2020.[6]. The Canadian and BC life expectancies did not distinguish people by race.

Scholars are still at work analyzing the increased mortality for middle-aged White Americans to determine its underlying causes. As neatly summarized by Ross Douthat (2015), left-wing thinkers tend to blame economic problems like rising income inequality, the gig economy[7], stagnating wages, and the cost of housing, which are problems that government can address. Right-wing thinkers tend to blame the behaviour of individuals and the disintegration of cultural institutions, citing the rising divorce rate and falling church attendance. Putting these factors together, less-educated White Americans are facing economic stresses at such time as their social supports are less strong than they used to be. And compared to Black and Hispanic Americans, White Americans may have fewer coping mechanisms for new challenges. They may be more undone by disappointment.

Stephanie Kelton (2020) writes, "A well-known fact in social science is that social capital – a technical term for communal bonds like membership in clubs, attending church, being married, interacting with one's neighbours – also increases noticeably with wealth and income."

Another perspective worth noting:

> *The culture and educational systems of the contemporary West are based almost exclusively upon the training of the reasoning brain and, to a lesser extent, of the aesthetic emotions. Most of us have forgotten that we are not only brain and will, sense and feelings; we are also spirit. Modern man has for the most part lost touch with the truest and highest aspect of himself; and the result of this inward alienation can be seen all too plainly in his restlessness, his lack of identity and his loss of hope.*[8]

That being said, the issues just described are found outside North America too, yet it is in North America that they appear to be so toxic.

4. Statistics Canada (August 2023)
5. Ibid.
6. Ibid.
7. The gig economy refers the the prevalence of insecure, part-time jobs without pensions or benefits.
8. Ware(1995)

Class Discussion

How do you interpret the increases in adult mortality first described by Coase and Deaton (2015)?

Suicides more generally

Suicide has been called a permanent reaction to a temporary problem. If you ever have thoughts of suicide, please reach out and tell people whom you trust. Help is at hand.

As reported by the World Health Organization (WHO 2021), only one percent of global deaths result from suicide. The suicide rate declined significantly between 2000 and 2019, except in the United States, where it is increasing, as discussed above.

In some countries, women are more likely to die by suicide, but globally, men are twice as likely to die by suicide. In Canada, men are three times as likely. More attention should be paid to this differential.

We usually associate suicide with young people because suicide is a leading cause of death of young people. But it is only a leading cause of death of young people because young people are, in general, very healthy and strong. The rate of suicide is actually higher in older age groups. The highest suicide rates in Canada are for those ages 40 to 59 years of age. The "mid-life crisis" is no joke and may be related to financial reversals, divorce, and other stresses.

After accounting for the actual year of the suicide (since each year brings its own distinctive stress factors), and the year of birth (since each cohort experiences unique stresses), Lise Thibodeau (2015) found that, between 1926 and 2008, suicide rates for Canadians were highest at age 50 for men and age 45 for women.

Deaths related to COVID-19

The decrease in life expectancy for US Whites, which Case and Deaton noted, was made worse by the ravages of COVID-19. In 2020 the US experienced 529,000 excess deaths and life expectancy at birth fell a whopping 1.5 years, the largest single-year decline since 1942-43 (during World War 2)[9].

9. National Center for Health Statistics (July 2021)

At the time of writing this book, Canada's life expectancy was recorded as having fallen about half a year between 2019 and 2020[10].

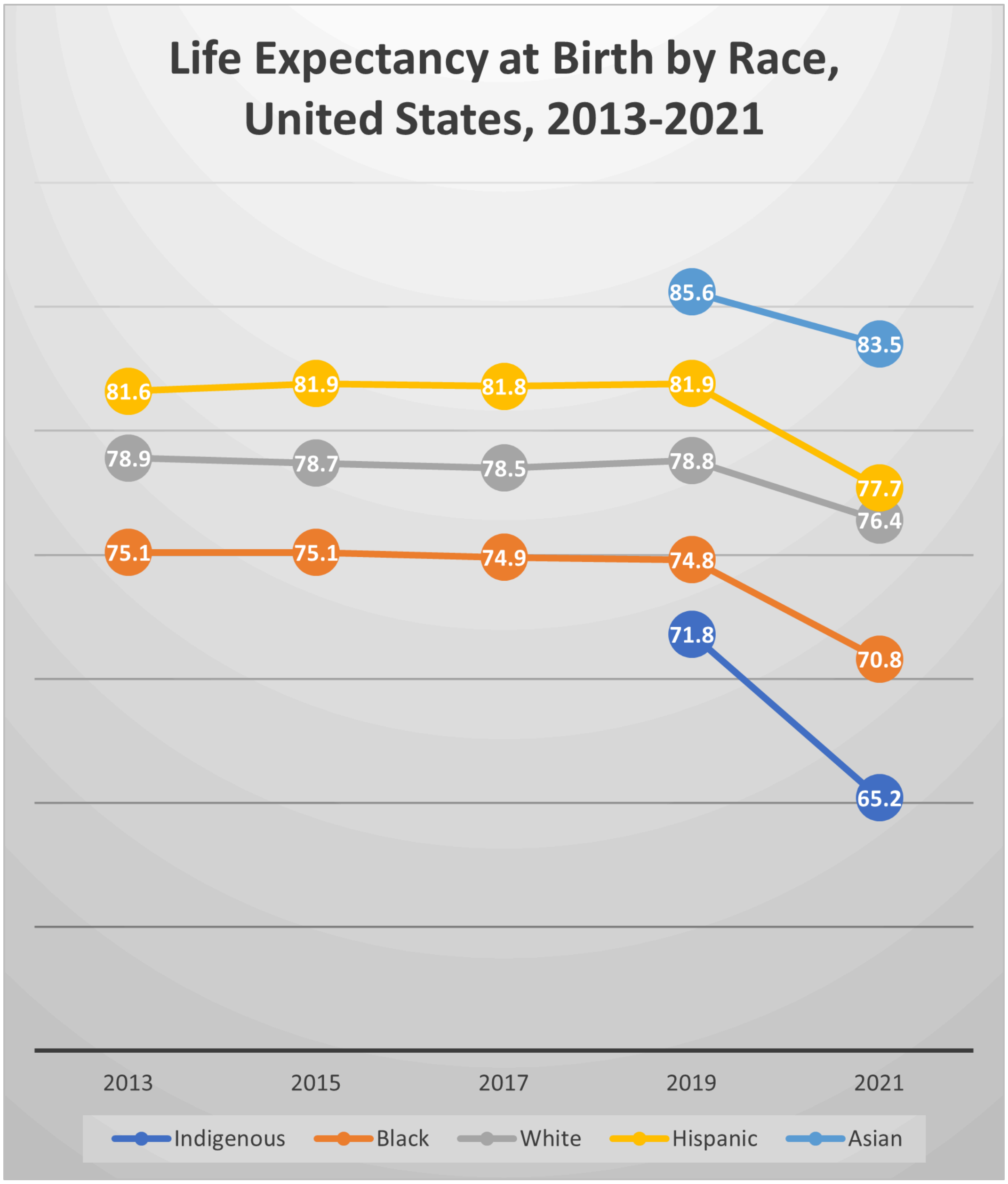
Figure 9-3 summarizes seven years of changes in life expectancy at birth for the United States, by racial group. Life expectancy at birth fell more for Hispanic Americans (3 years) and Black Americans (2.9 years) than White Americans (1.2 years) between 2013 and 2021, therebyreducing the Hispanic Paradox and unfortunately eroding some of the previous gains in relative life expectancy for Black Americans[11].

As reported in Elizabeth Arias et al. (2021), 74% of the 2020 increase in US death rates was due to COVID-19; 3.1% from homicide, about the same percentage from drug overdoses, 2.5% from diabetes, and 2.3% from chronic liver disease. The suicide mortality rate, however, decreased, as did rates of death from cancer, chronic lower respiratory disease, heart disease, and childbirth. These patterns held for Black, White, and Hispanic Americans.

In our next chapter we'll study how to design good policies to alleviate mortality.

10. The Globe and Mail, Dec. 23, 2021
11. National Center for Health Statistics (July 2021)

Figure 9-3



Compiled by A. Hageman from the following data sources: National Center for Health Statistics Data Brief No. 244 (April 2016), National Vital Statistics Reports Vol. 68 No. 4 (May 7, 2019) and No. 7 (June 24, 2019), National Vital Statistics Rapid Release No. 23 (August 2022) and National Center for Health Statistics Data Brief No. 244 (April 2016)

Exercises: Chapter 9

1. Dehejia and Lleras-Muney (2004) found that children conceived in times of high unemployment were healthier.

a) Suggest an explanation for this finding.

b) One explanation given by Dehejia and Lleras-Muney is that the people who give birth during recessions are different from the people who give birth during good times. What do you think they mean?

2. What can you say about mortality in the Age of Pestilence and Famine?

3. What turning points mark the end of this Age?

4. Why are medical innovations not enough to bring a society to the point where life expectancy moves up to 70 or 80?

5. Relying only on what is stated in the text, compare Elizabeth Arias' findings to Case and Deaton's findings.

Chapter 10: Policy Choice and Mortality Reduction

> Having spent a few chapters considering human mortality, we are ready to hear about programs and policies that might extend our life expectancy. This Chapter doesn't present those policies, but it teaches us how to gauge whether a policy is likely to be effective, or not.

Governments usually exert some intentional influence on mortality, as well as on the two other drivers of population change, fertility and migration. If effective, these policies may impact the every day lives of individuals and families profoundly. The policies will also have an impact on the growth rate of the population, the eventual size of the population, and the age and ethnic composition of the population. The motivation of government may be economic or it may be based on values ranging from compassion to hatred.

Five Principles of Policy Design

What are the best practices around policy design?[1]

Let's begin with

1. No discrimination or coercion. Can we agree that our government should work for the welfare of all ethnic and social classes, and all age groups? And can we agree that our government should not control our behaviour too closely?

Regarding coercion and control, it may not be easy to agree on exactly where the government crosses the line. For example, during the COVID-19 pandemic, a significant minority of people felt that the government had no right to mandate vaccination against COVID-19, and that employers, universities, airlines, and other entities had no right to require vaccination.

1. Believed to be the author's own assemblage; please contact author if previous source is found.

Regarding discrimination, during the COVID-19 pandemic in Canada and the United States, there were not enough vaccines, at first, to treat all who wanted to be vaccinated. There were not enough hospital beds to treat all who were sick. In terms of vaccine delivery, older adults, people with pre-existing conditions, and other vulnerable groups were prioritized. But in terms of admission to hospital and care of the sick, it was the other way around. In Canada, residents of long-term care facilities were often not taken to hospital. The early, panic-stricken days of the pandemic saw many long-term care residents all but abandoned by staff. In the United States, patients from long-term care were discharged from hospital back into long-term care facilities while still infectious and unwell. Laura Appleman (2021) reports on this and also the inappropriate use of trial vaccines, even quack medications in long-term care facilities, as well as the neglect of psychiatric patients and people with developmental disabilities living in institutions.

Once we determine that a policy does not violate Human Rights, we examine the policy for its likely effectiveness, using the following guidelines:

2. Target the ultimate goal as closely as you can. Identify the ultimate goal or the root cause of the problem you are trying to address. Is the proposed policy the most direct way to achieve your ultimate goal? For example, perhaps the ultimate goal of the policy is to reduce deaths from COVID-19 virus, but the policy focuses on the sanitization of surfaces. Since surfaces are not a major conduit of COVID-19 transmission, this policy will not be very effective at reducing deaths from COVID-19.

3. Target the binding constraint. A successful policy addresses the most critical bottleneck, the most pressing barrier to achieving the goal or reducing the problem at hand. For example, if the policy is intended to encourage vaccination, you need to know what is really holding people back from deciding to be vaccinated. It will be no use offering free transportation to the vaccination clinic if people don't want to go because they are afraid of the vaccine.

Photo by Hans Splinter, 2007, flickr.com. CC BY-ND 2.0

4. Target the appropriate margin. In microeconomics we learn that people evaluate things at the margin. They decide whether or not to study one more hour, not just whether or not to study at all. They decide whether and when to get the first shot of the vaccine, but then they also decide whether and when to get booster shots. Each margin needs to be considered.

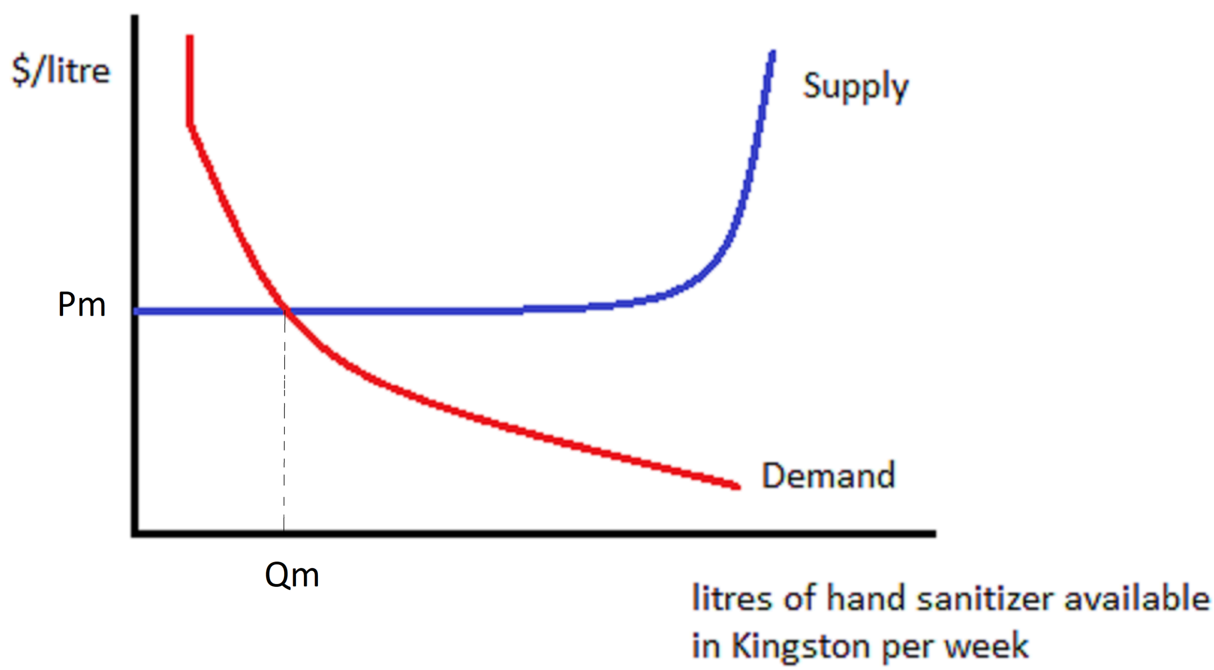
5. Understand who pays the financial cost. Most people think that, if you tax consumers, consumers will end up paying more, and that if you tax firms, firms might be able to pass some of the cost onto consumers. This is partly correct. If you tax firms, they may or not be able to pass some of the cost onto consumers. Also, if you tax consumers, they may or may not be able to pass some of the cost onto firms. Therefore you cannot predict who will bear most of the tax unless you know the relative elasticities of Demand and Supply.

If Demand is very inelastic, and consumers are desperate for the product, they will pay the tax. But if they are not desperate, and can switch to other goods and services, they will refuse to pay more. Suppliers will end up reducing the price in order to keep their customers. Suppliers will end up receiving less than before, which means they have been taxed. **The least price-elastic party pays more of the tax.**

In the case of a subsidy, we use the same logic. If a subsidy is applied to a product, people will want to buy more of it. If Supply is very flexible, people will be able to go out and get as much of the product as they want, and they will enjoy the benefit of the subsidy. However, if Supply is limited, the increased Demand due to the subsidy drives up the price of the product. Consumers may not save much when they use their subsidy; instead, suppliers enjoy a higher price. That means suppliers are benefiting from the subsidy. T**he least price-elastic party gains most of the subsidy.**

Let's look at an example.

Figure 10-1. Pre-pandemic Market for Hand Sanitizer in Kingston each Week (ignores sales tax)

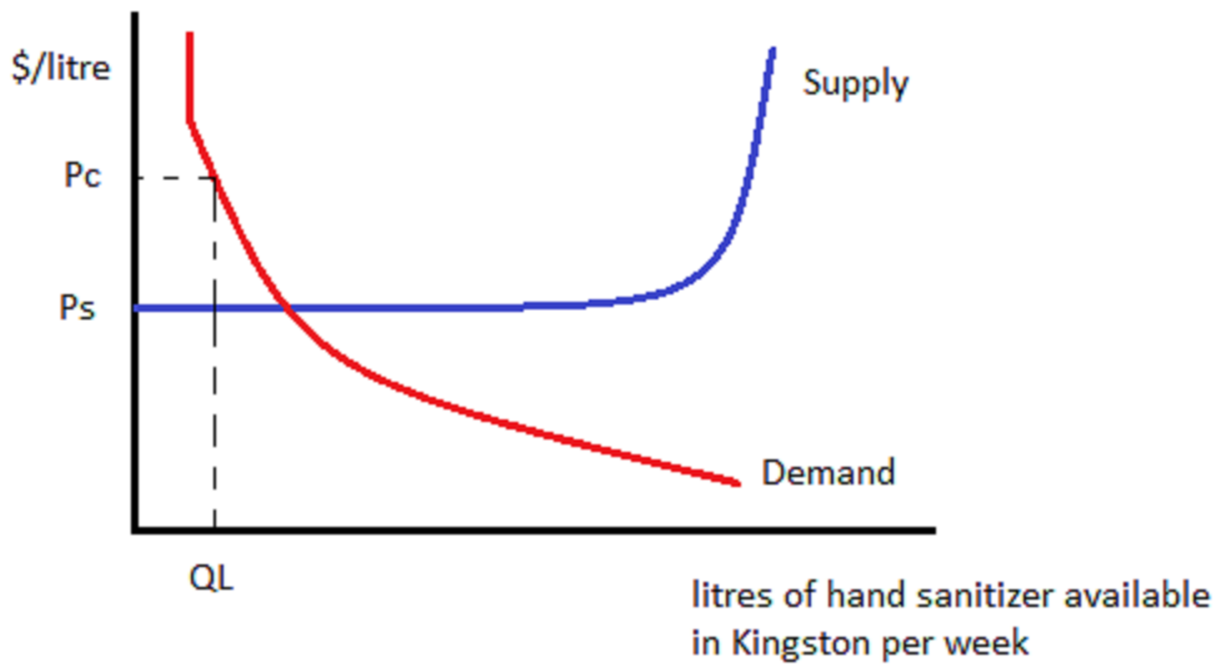


This graphic is a stylized depiction of the market for hand sanitizer in Kingston each week before the pandemic. Because of Kingston's hospitals, there is a very inelastic portion of the Demand curve, but after hospital demand has been satisfied, the rest of the Demand curve is not that steep. Meanwhile, there is enough hand sanitizer available to satisfy all of Kingston's demand without affecting the going price of hand sanitizer.

Let's label the market-clearing quantity of hand sanitizer in Kingston "Qm" litres per week. Let's label the initial price "Pm". Kingston is a small player in the hand sanitizer market and accepts the going price set by suppliers.

Now, what happens if, for some strange reason, the government were to impose enough of a tax on hand sanitizer to drive the quantity sold each week down to QL?

Figure 10-2. Pre-pandemic Market with High Tax per Litre of Hand Sanitizer



To get the Kingston market down to QL, the government imposes a tax per litre which is equivalent to the vertical distance between the two curves at QL, i.e Pc-Ps. We could draw the Demand curve shifting left until it intersects Supply at QL, or we could draw the Supply curve shifting left/moving higher until it intersects Demand at QL – *it doesn't matter*. It doesn't matter who is taxed – buyers or sellers!

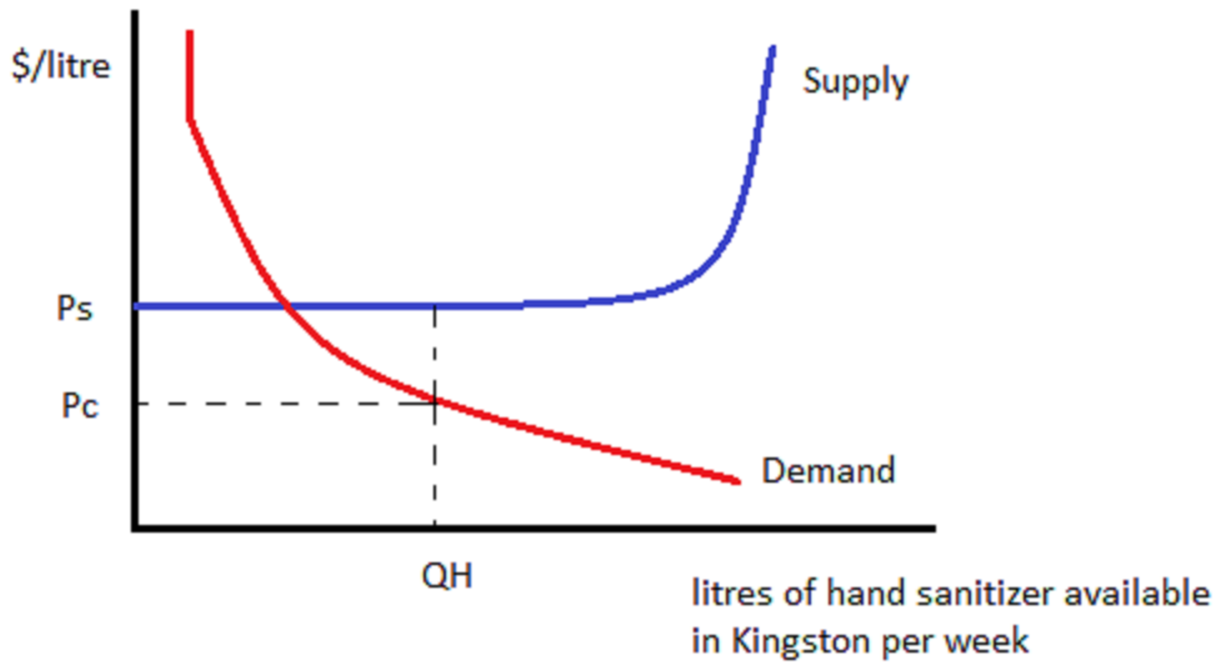
In real life there may be some complications, but I'm going to keep things oversimplified to make the broader point – it often doesn't matter who is taxed – buyers or sellers!

Whenever we draw a per-unit tax, we just have to move from Qm to the left until the distance between the initial Demand and initial Supply curves equals the tax, or until we get to the target quantity QL.

In this case, because the Supply curve is completely elastic, completely flexible, suppliers will not pay any of the tax. Instead, consumers will pay Ps + the tax = Pc. If you drew the Demand curve shifting left, you will see that consumer's willingness to pay drops to Ps at QL, because they know they have to pay the tax on top of that. The total amount paid is Pc, since the tax is equal to Pc-Ps.

The least price-sensitive party (Consumers) pay more (in this case, all) of the tax. Now let's see that the least price-sensitive party (Consumers) get more of the subsidy.

Figure 10-3. Pre-pandemic Market with High Subsidy per Litre of Hand Sanitizer



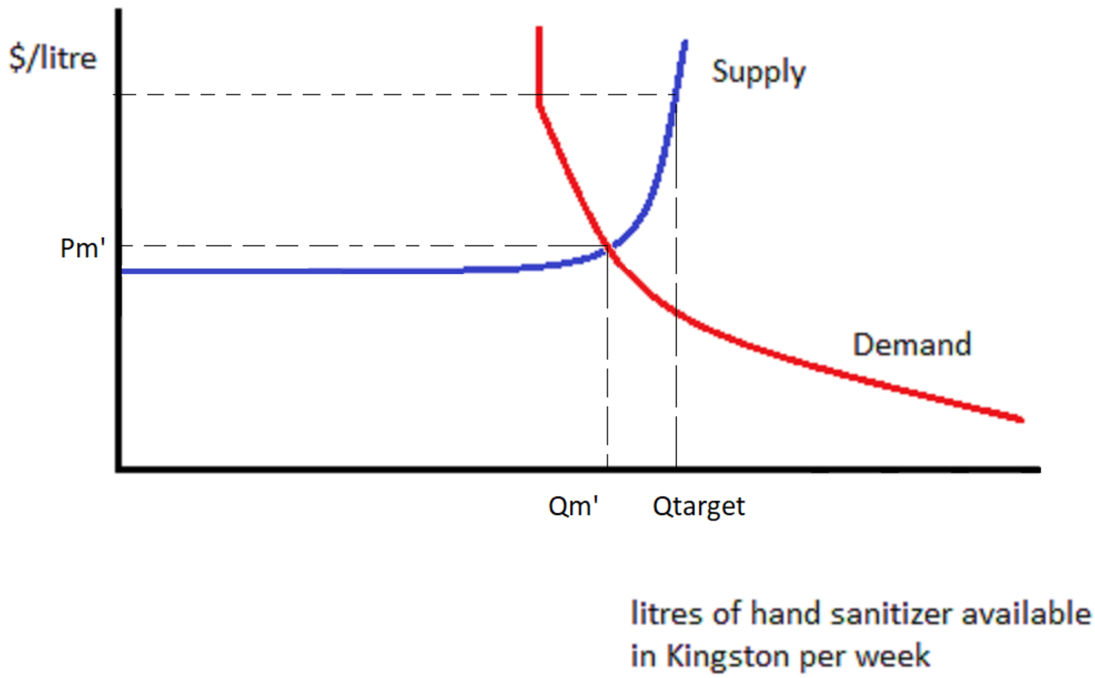
As we see in Figure 10-3, to draw a per-unit subsidy we don't need to draw the Supply curve shifting to the right/down or the Demand curve shifting to the right. Either one would work, but it doesn't actually matter which party is awarded the subsidy.

We move to the right of Qm until we get the targeted QH, which will occur when the vertical distance between the original Supply curve and the original Demand curve is equal to the amount of the subsidy.

Here we see that suppliers are receiving Ps as usual, but consumers are paying Pc which is below Ps by the full amount of the subsidy. If hand sanitizer subsidies were given to consumers, they would go out and buy more, but that would not affect the price of hand sanitizer, so consumers receive the entire benefit.

What if we were at the beginning of a pandemic, and Demand had shifted to the right a great deal, such that suppliers could not provide enough hand sanitizer without facing higher costs? Let's look at Figure 10-4.

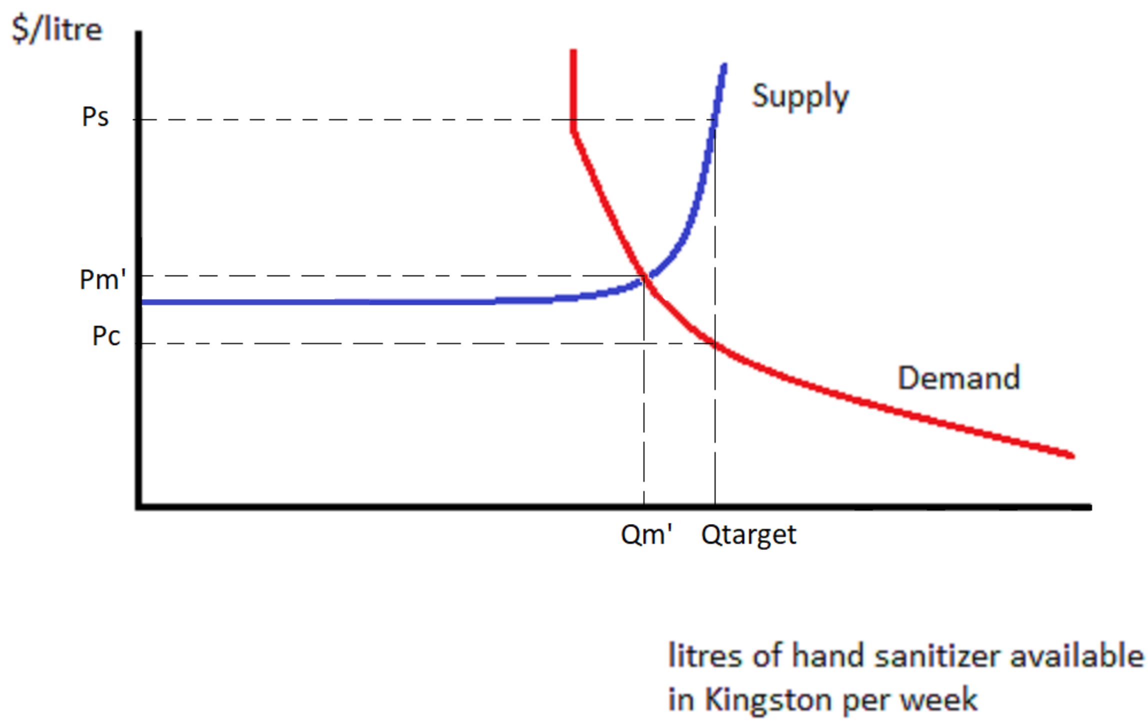
Figure 10-4. Market for Hand Sanitizer in Kingston in Early Days of Pandemic



The market price has risen to Pm’, and quantity traded is Qm’.

Let’s explore what happens if the government subsidizes hand sanitizer to the point where Qtarget litres of hand sanitizer are purchased each week. That can be shown by drawing a vertical line at Qtarget. It’s not necessary to ask whether consumers or suppliers are receiving the subsidy. We could draw Demand shifting to the right until it meets Supply at Qtarget, or we could draw Supply shifting to the right/down until it meets Demand at Qtarget: the result is the same.

Figure 10-5. Result of Subsidizing Hand Sanitizer in Early Days of Pandemic



What we see is that, at Qtarget, consumers are paying Pc which is a bit less than Pm'. Suppliers are receiving Ps which is a lot more than Pm'. Each of them is doing better than they would do if there were no subsidy. They are sharing the subsidy. Suppliers are receiving a larger share of the subsidy due to the Supply curve being less elastic than that of the Demand curve at Qm'. It is more difficult for Suppliers to respond to price than it is for Consumers.

To sum up, policies designed to help consumers may help firms more, if supply is inelastic. The inelastic party benefits more from a subsidy. The government might subsidize milk in order to get consumers to drink more milk. But if the supply of milk is inelastic, milk suppliers will raise the price and capture most of the benefit of the subsidy.

Similarly, the inelastic party is hurt more by a tax. A tax designed to curb consumer behaviour may have more of a financial impact on firms instead, if supply is inelastic relative to demand. An example of this might be a tax on sugary beverages. If consumers are happy to switch to sugar-free drinks, the suppliers of sugary beverages will have to lower their prices by almost the entire amount of the tax, so that the tax-inclusive price is not much different from the original price. The good news is that at this lower price, fewer sugary drinks will be supplied.

Pricing and comparing projects that save lives

We have learned how to design good policies. They respect human rights. They are also well-targeted and effective, so they are likely to have a high ratio of benefits to costs. We may wish to formally evaluate a policy or project by comparing its benefits to its costs. When the project saves lives or prevents sickness and injury, we quantify the health-adjusted life years saved (HALYs), also known as quality-adjusted life years (QALYs).

For each person saved from death, their life years remaining are credited as benefits of the project. The life years remaining to a person saved depends on that person's age at the time the policy or project was implemented. Thus projects that save young lives will be regarded as more beneficial than projects that save older people's lives. Each year of life remaining may be scored between zero and 1, or conceivably even less than zero, according to how healthy and able that person is expected to be. (The same procedure of scoring health is used to form the Health-Adjusted Life Expectancy, discussed in Chapter 6.) The health scores for different illnesses and disabilities are based on interviews.

For each person saved from disease or injury, we add up their life years saved, scored for health. So we add up all the life years added to people's lives because of the policy or project, adjusted for health.

Having quantified the saving of life, do we need to affix a price to each HALY saved?
 ?;
If we use **Cost Effectiveness Analysis**, we can avoid pricing HALYs. Instead, we will calculate the net cost of the project per HALY saved. The number of HALYs saved will be in the denominator, and in the numerator we will put the sum of all project costs minus the sum of all project benefits other than HALYs saved. The costs and benefits in the numerator will be measured in dollars according to their **present value**.

In Figure 10-6 we see a HALY/QALY supply curve for a hospital. The hospital can save lives and prevent disease and disabilities by implementing a variety of projects, be they policies, treatments, or other plans. Their first choice will be to spend as much money as they can afford on project A, which has the lowest net cost per HALY. We see the cost per HALY rising a bit over the course of project A, perhaps because it begins to be applied to people who are less amenable to its treatment. After project A cannot be expanded any further, or becomes too expensive, the hospital switches to project B.

Figure 10-6. A HALY or QALY Supply Curve

Source: Reinhardt (2014)

Using Cost Effectiveness Analysis in this way is appropriate when the paramount goal of the planner is to save HALYs. When other benefits are important, Cost Benefit Analysis is more appropriate.

For **Cost Benefit Analysis**, we must price all the benefits (in dollars, present value) and subtract off all the costs (in dollars, present value.) This means that we have to find a dollar value for a HALY.

Remember that, in the Life Table, we calculate the deaths of an initial cohort of newborns at each stage of life. At each stage of life, we don't know which newborns will die. We only know what fraction of newborns will die. That's our lived experience. We don't know if we're going to get hit by a car if we jay-walk; we just know the odds. We don't know if we will experience a workplace accident; we just have a rough idea of the odds.

If we were to to accept an increased risk of dying on the job, say an increase of 1 in 100,000 chance of dying, in exchange for one extra cent of wages per hour, then that means that for $0.01 x 2,000 hours per year =$20 per person, multiplied by 100,000 people (of whom one will die), we have accepted $2,000,000. We have accepted $2,000,000 for one statistical death. This is the "**Value of a Statistical Life**" (VSL). Economists and others have estimated the VSL after statistically teasing apart wages by occupation, education, experience, risk of accident, and other factors.

This may seem a very crass exercise indeed. But do we not, in a way, make this calculation every time we take a risk walking or driving or eating junk food?

We should never interpret the VSL as permitting us to kill someone for that price. We would spend much more than the VSL saving the life of someone known to be in trouble e.g. a child fallen down into a well. We only use the VSL to put a price tag on an increased chance of dying or to put a dollar value on an anonymous life year possibly saved.

The VSL represents the sum of the present value of each of a person's life years remaining. Thus having estimated the VSL for people age 40, who typically have 36 HALYs remaining, say, we could compute the value of a HALY from the perspective of people age 40. The VSL for older people will necessarily be less than the VSL for younger people, ***ceteris paribus***, because younger people have more expected life years remaining.

Discussion Idea

Cost Benefit Analysis doesn't discriminate among different people's life years, but since young and healthy people have more life years remaining, Cost Benefit Analysis will prioritize projects that save young and healthy people's lives over projects that save older or sicker people's lives, as happened during the COVID 19 pandemic. Does this amount to discrimination on the basis of age and health? Do you feel that this violates Human Rights, or do you feel it is appropriate in some circumstances?

It's tough to deal with the fact that some life-saving treatments and projects will be rejected by Cost Benefit Analysis as being too expensive. But it's good to know that there may be more affordable ways to save lives, as identified by Cost Effectiveness Analysis. We can craft our policies wisely and organize our spending efficiently to save as many lives as possible.

Exercises: Chapter 10

1. In order to reduce mortality rates, the Canadian government decides to send Canadians a rebate of $50 per bicycle purchased. Analyze the incidence of this subsidy. Analyze the likely effectiveness of this subsidy at reducing mortality rates in Canada.

2. Under what conditions will heightened COVID-19 safety protocols increase the price of food at burger chain restaurants?

Chapter 11: Measuring Fertility

Through fertility, new individuals are added to the human population. Human life continues despite mortality. Fertility shapes us profoundly as individuals, families and communities. It also shapes the overall size, growth rate, and age composition of the population, with implications for the economy. Economic conditions in turn impact the fertility rate. In this Chapter we speak of men, women, mothers and fathers in the reproductive sense.

Photo by Jon Pinder, 2011, flickr.com.

Let's now explore the different fertility rates and what they have to say.

The **general fertility rate** is measured differently from the birth rate. The birth rate's denominator is the mid-year population, but the general fertility rate's denominator is the mid-year population of females of child-bearing age.

The denominator should indicate what number of people in the population are (typically) capable of giving birth.

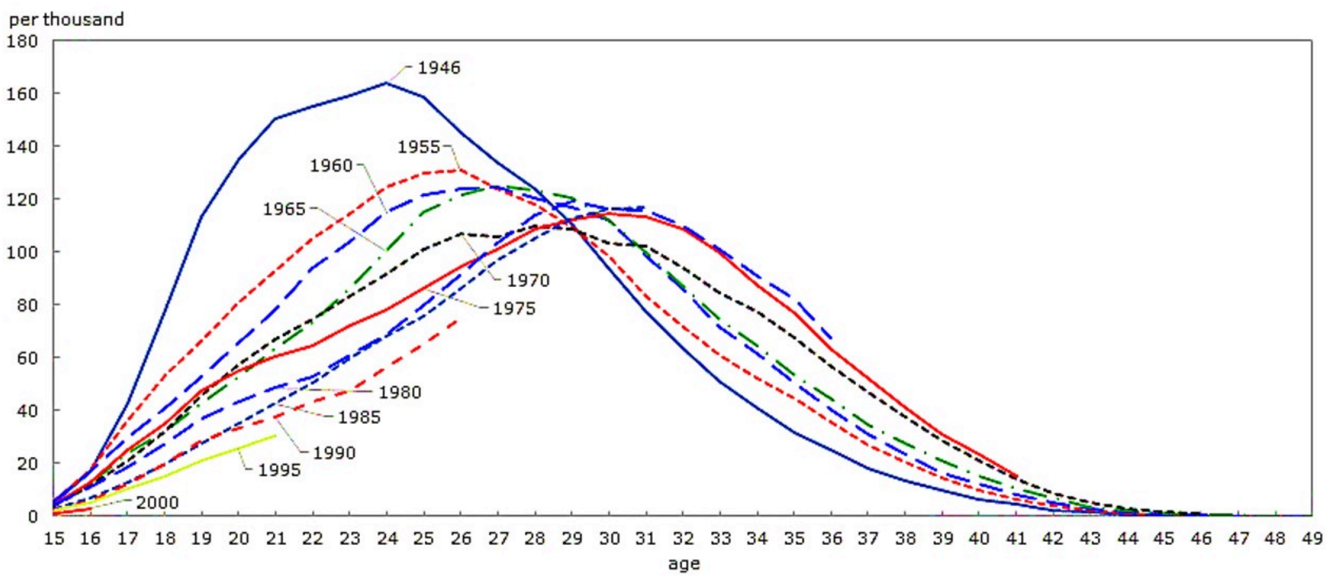
General fertility rate

= (#births / midyear population of females aged 15-49) x 1000

Age-specific fertility rates (ASFR) give even more precision as to the age of mothers. For example, the (age-specific) fertility rate for females 15 years old = number of live births to 15 year-olds during the year divided by the mid-year population of female 15 year-olds, all multiplied by 1000.

In Figure 11-1, each line represents a different cohort of mothers. The top, dark blue line is for women born in 1946. They experienced their highest fertility when they were 24 years old. This does not mean that women born in 1946 had their first child at age 24. It means that women born in 1946 were more likely to have a baby at age 24 then at any other age, whether to the first, second, or higher order child. Since the late 1970s, the average age of mothers in Canada has been rising. As the dark red line shows, women born in 1975 had their highest fertility at age 30. We cannot yet tell at what age women born in 2000 will have their highest fertility. Not enough time has gone by for them to complete their fertility experience.

Figure 11-1. Age-specific fertility rates by cohort, Canada



Source: Figure 11 of Provencher et al. (2018), using data from Statistics Canada, Canadian Vital Statistics, Births Database, 1921 to 2016, Survey 3231 and Demography Division, Demographic Estimates Program (DEP).

Once a woman, or a group of women born the same year, is no longer of child-bearing age, we record how many children were actually born to that woman or that cohort of women. We can compute the **completed fertility rate** (CFR).

CFR = # of children born to a birth cohort
÷ number of women in the birth cohort

For example, for Canadian women born in 1946, the completed fertility rate was 2.1, i.e. 2.1 children per woman. This includes women who never had children.

Photo by Phey, 2005, flickr.com. CC BY-NC 2.0

But that is looking into the past. To get an idea of how many children today's women will have, demographers compute a hypothetical statistic called the **Total Fertility Rate**. The total fertility rate is the number of children which would be born to the average woman IF the average woman will experience today's age-specific fertility rates at each age of her life.

Just as life expectancy at birth for infants today is calculated assuming that infants today will have today's age-specific mortality rates as they go through life, TFR today assumes that today's young women will go through their lives bearing children at today's age-specific fertility rates. So, TFR is hypothetical, an estimate based on today's age-specific fertility rates.

$$\textbf{TFR} = \sum_i n_i * ASFR_i \div 1000$$

where ASFR is age-specific fertility rates, and n represents the number of years in each age category. Age groups are usually 5 years in length e.g. 15-19, 20-24, 25-29 etc.

Why do we divide by 1000? Well, the ASFR gives you the number of children per 1000 women of that age, say 130 children. Now one woman cannot have 130 children. Only 1000 women can. So we divide by 1000 to get the number of children per woman.

Figure 11-2a. Total Fertility Rate, (births per woman), Canada (1960-2019)

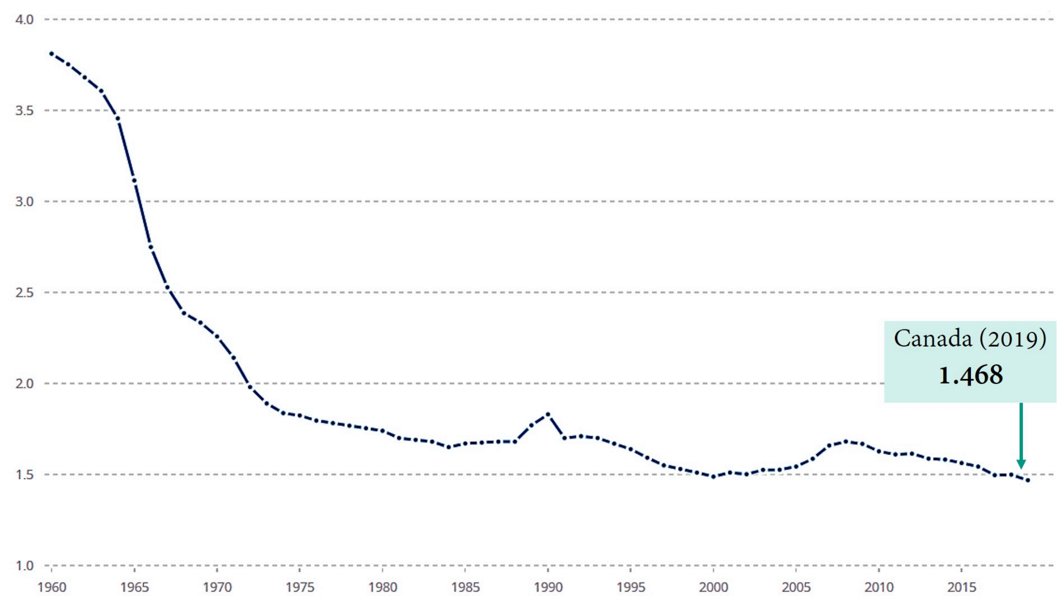


Figure 11-2. Canada's Total Fertility Rates. Source: data.worldbank.org. CC BY-4.0

If we were to count only the female babies in our ASFR, and then compute female baby TFR, we would have the **Gross Reproduction Rate**, which is the number of female babies each woman can be expected to have, if present day fertility rates persist.

If we added the step of multiplying each female baby ASFR by the probability of a female baby living to its mother's age group, we would have the **Net Reproduction Rate**. A population is self-sustaining if its Net Reproduction Rate is greater than or equal to one.

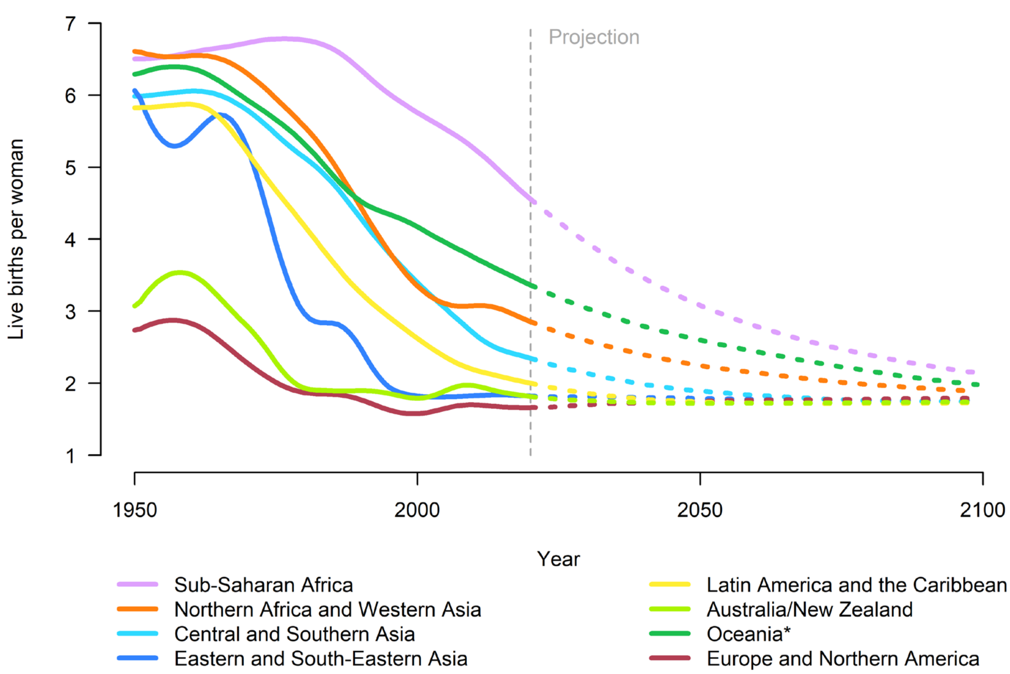
Photo by Subhash Roy, flickr.com, CC BY-NC-ND 2.0 DEED

A TFR of 2.1 is roughly equivalent to a Net Reproduction rate of 1.0. To get one female baby surviving until she reaches the age her mother was when she was born, we need at least two babies to be born per woman, so that one of the babies will be female (on average) and survive to her mother's age. *At least* two because more boys are born than girls, and some of both sexes die before reaching reproductive age.

Thus a TFR of 2.1 represents the **replacement** rate or "replacement fertility". As Figure 11-2a shows us, the last time Canadian TFR was computed to be above 2.1 was in 1972, when women born in 1946 were twenty-eight years old. Those women were the last women, to date, to achieve a CFR of 2.1.

Figure 11-2a above shows us that Canada's TFR has been below replacement since the early 1970s. Figure 11-2b below shows us that all the regions where TFR was above replacement in 2019 are projected to experience decreases in fertility, so that by 2100, TFR for the world as a whole will likely have fallen from 2.5 children per woman in 2019 to 1.9 children per woman in 2100.

Figure 11-2b. Estimated and Projected TFR by Region, 1950-2100



*Oceania excludes Australia and New Zealand. *Source: Figure 15 of UN (2020). Data from UN (2019).*

Tempo-Adjusted TFR

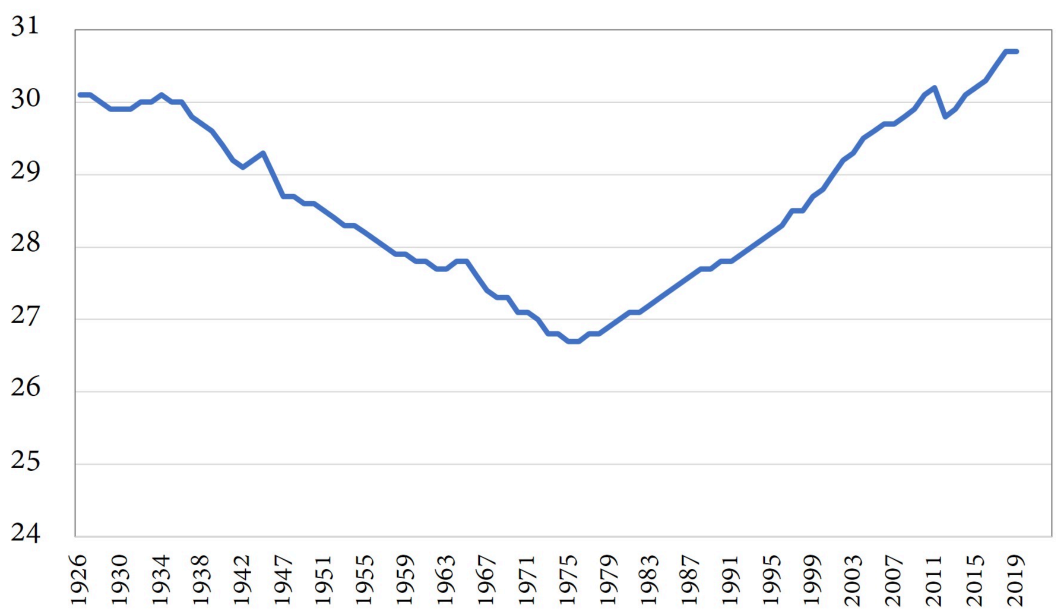
Recall that TFR is computed by assuming that present fertility rates persist. In particular, it assumes that what is going to happen in the future is set. But sometimes parents will hurry or delay their childbearing, without changing the overall number of children they would like to have eventually.

For example, because of the COVID-19 pandemic 2020-2022, many people of various ages delayed having children. That means that various age-specific fertility rates dropped. This caused TFR to drop immediately; however, TFR may increase after the pandemic.

When people delay having children, TFR drops, since it assumes that once today's women age x become age x+t they will have babies at the same rates as today's women age x+t, which is lower due to the delays. But in reality, today's women age x who are delaying childbearing may have children at higher rates than today's women age x+t, once they reach age x+t.

As Figure 11-1 above showed us, women in Canada, and in many other countries, have over time pushed back the age at which they have children. They have delayed, not because of a pandemic, but for other reasons such as deciding to pursue higher education. This steady increase in the age at which a typical woman has her first baby has led to TFR underestimating the eventual completed fertility rate.

Figure 11-3. Average age of a mother at childbirth, Canada (1926-2019)



Source: Statistics Canada/Table: 13-10-0417-01 (formerly CANSIM 102-4504)

To minimize the discrepancy between TFR and the eventual number of children women will actually have (CFR), demographers have developed a **tempo-adjusted TFR**.

$$\textbf{Tempo-Adjusted TFR}(t) = \mathrm{TFR}\,(t)/(1 - \mathrm{r}(t))$$

TFR(t) means TFR in year t , for example, TFR in 2020.

r(t) measures the influence of postponing fertility. This r(t) is a completely arbitrary way to measure changes in maternal age. Let's use the Bongaarts-Feeney formula, where:

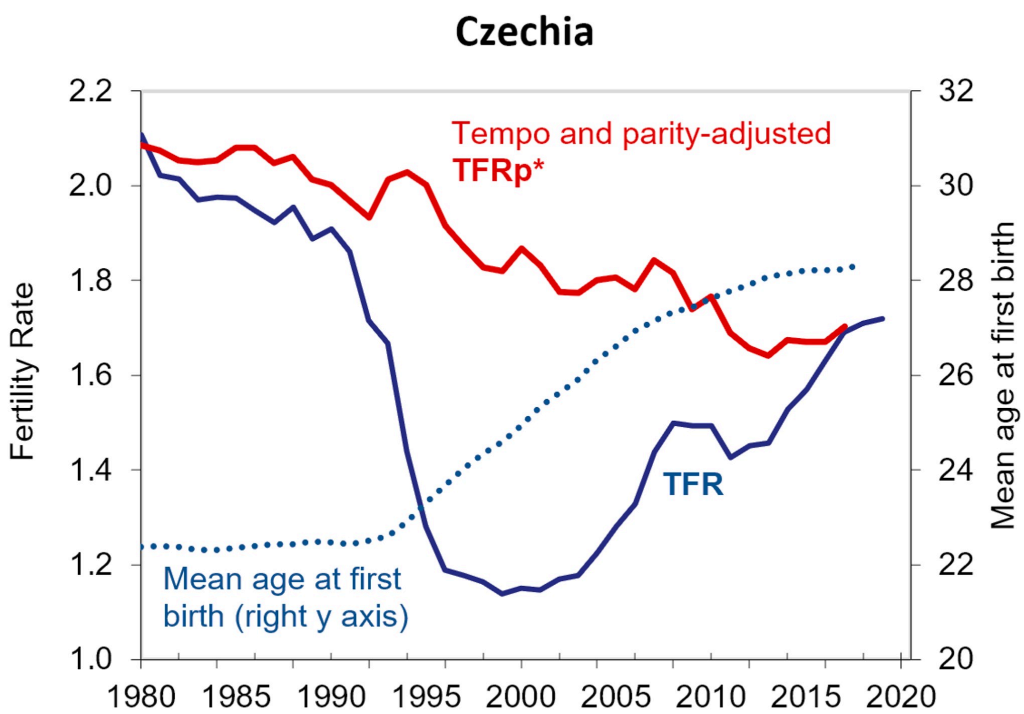
$$\mathrm{r(t)} = \frac{(average\ age\ of\ mother\ at\ time\ t{+}1\,) - (average\ age\ of\ mother\ at\ time\ t{-}1)}{2}$$

Figure 11-5 features an even more refined measure by Bongaarts and Feeney called **Tempo- and Parity-adjusted TFR** or TFRp*. TFRp* measures not only the fact that women are delaying births (the tempo effect) but also incorporates details about how many women have already had their first, second, etc. child (the parity effect).[1]

In this graph of Czechian fertility, TFRp* measure is the measure of choice:

1. https://www.humanfertility.org/Docs/Symposium/Bongaarts_Sobotka.pdf

Figure 11-5. Fertility trends in Czechia, 1980-2020



Source: Vienna Institute of Demography (VID) 2022. Credits to: Sobotka, T. & Zeman, K.

Figure 11-5 shows us that, between 1980 and 2020, TFR in Czechia fell steeply, then rose steeply. Changes in TFRp* were more moderate, and likely more accurate. We will know the Completed Fertility Rate, how many kids each cohort of women actually had, once each cohort of women becomes too old to have children.

Male Fertility

Since men are equally essential to procreation as are women, why not compute male fertility? Male fertility measures the number of live children born to the average man.

Male fertility can give us information about male health including reproductive health, as well as information regarding men's choices around family formation. Like female fertility, it can help us predict population change in a country or region.

Some nations collect information on male fertility using the census and other surveys, birth certificate records, and even Life Tables. The Life Table's mortality information can be used to look for "extra" people as well as missing people. The United Nation's *UN Demographic Yearbook* reports birth rates by age of father.

Photo by mimi coco, 2015, flickr.com. CC BY-NC-ND 2.0

Data collection challenges

There seem to be very few academic sources that have compiled and analyzed data on male fertility. This may be due to the data collection challenge. Whereas the mother of a child is obvious at the instant of birth, the father may be absent and not listed on the birth certificate. In some countries, birth certificates are not issued.

The presence of men temporarily in a region will lead to extra babies being born, but unless these men generate as many babies on average as local men, the presence of migrant men will actually reduce the male fertility rate in that region. For example, the male TFR of Qatar was registered as 0.6 children per male in 2010 in the UN Demographic Yearbook, but the Multiple Indicator Cluster Survey (MICS) in 2012, which excluded migrant workers, counted 2.6 children per male.

There are many different methods of computing male fertility including own-children method, reverse-survival method, date-of-last-birth method, criss-cross method etc., all of which are too involved for the purposes of this text.

Generally, male fertility is reported to be higher than female fertility. Can this in fact be true?
Certainly, the reproductive potential of a typical man exceeds the maximum number of live births an individual woman could experience. According to the Guinness World Records, the most prolific woman ever was Valentina Vasilyeva, who during the 18th century gave birth to 69 children as a result of 27 successful pregnancies.[2] However, that legacy pales in comparison to that of Moulay Ismael the Bloodthirsty, Sharifian Emperor of Morocco (1672–1727), who sired 1,171 children with over 500 women over 32 years.[3].

It is a mathematical reality, however, that if the number of men and women in the relevant age groups is

2. Guinness World Records (2021)
3. Oberzaucher & Grammar (2014)

equal, then the average number of live births must be the same for men and women. Male fertility rates must be equal to female fertility rates.

After all, every child born comes from one sperm and one egg. If only a few people with sperm are responsible for a large number of babies, then there must be many people with sperm who are not making babies at all. By the same logic, if the number of heterosexual men and women is equal, it is not possible for the number of heterosexual partners to be higher for men than for women, even though men typically report having more sexual partners.

David Gale proved this with his "High School Prom Theorem" as follows:[4].

> "We suppose that on the day after the prom, each girl is asked to give the number of boys she danced with. These numbers are then added up giving a number G. The same information is then obtained from the boys, giving a number B.
>
> Theorem: G=B
>
> Proof: Both G and B are equal to C, the number of [unique, heterosexual] couples who danced together at the prom. Q.E.D."

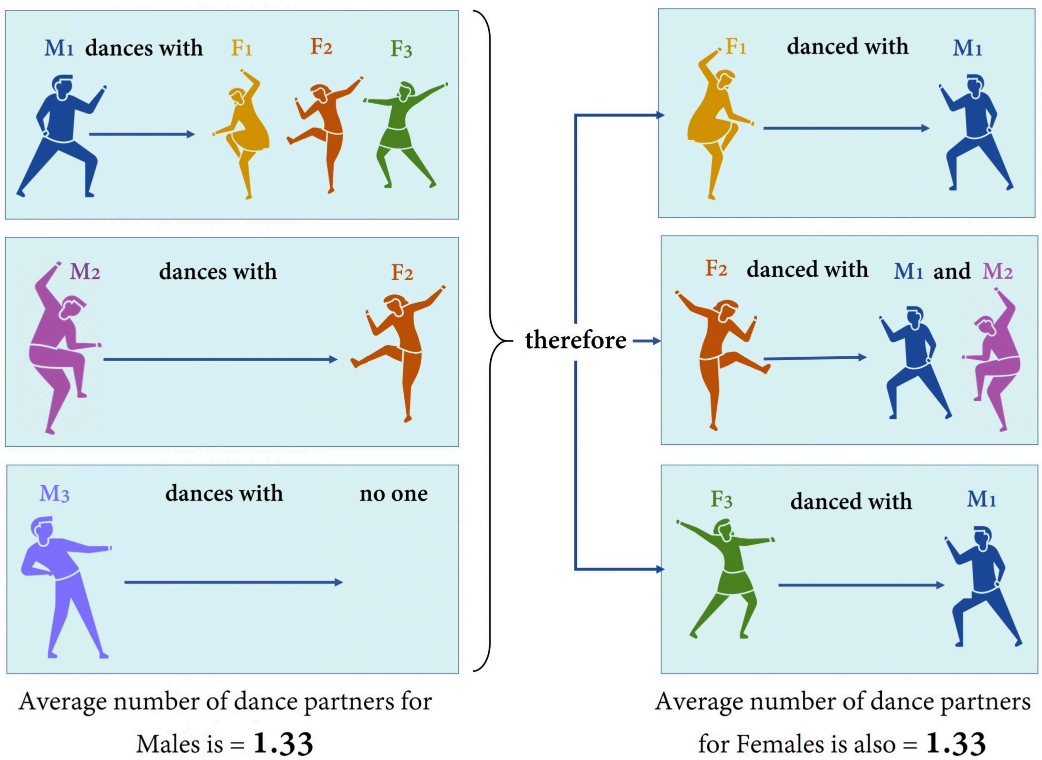
Now, the average number of partners for the girls is G divided by the number of girls, and the average number of partners for the boys is also G (because B=G) divided by the number of boys. If the numbers of boys is equal to the number of girls, the average number of partners will be the same for boys and girls.

An illustration of this is shown in the graphic below.

4. Kolata (2007)

Figure 11-6. The High School Prom

Suppose after a night of dancing the results were the following:



Graphic by Pauline Galoustian

What if, in the high school prom example, there had been only one boy at the dance, and more than one girl? In that case, it is almost certain that the boy had multiple partners of the opposite sex while the girls each had maximum one partner of the opposite sex.

When there is a discrepancy in the number of men and women potentially getting together, there can be a difference in the average number of sexual partners for men and for women, as well as a difference in the TFR of men and the TFR of women.

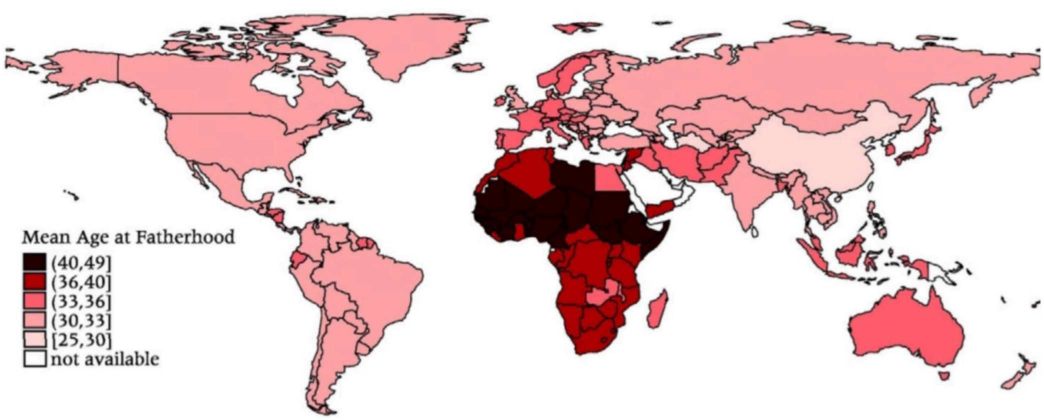
Photo by Rigoberto Garcia, 2017, flickr.com. CC BY 2.0

Large differences in the TFR for men and women can occur when there is a shortage of men able to form families. This can occur due to lack of economic opportunity for men, losses of men during war, and migration of men for work. Social norms around the age of marriage for men and women can also make a difference.

Imagine a baby born to a 21-year old mother and a 28-year old father in a country where the 28-year old male cohort is smaller than the 21-year old female cohort. The baby becomes part of the ASFR for 21 year old females, with that large cohort of 21-year old females in the denominator. The same baby becomes part of the ASFR for 28-year old males, which has a smaller number (the number of 28-year old males) in the denominator. Since TFR is made up of the ASFRs at each age, we can see how TFR for men can be higher than TFR for women.

One of the few large-scale studies regarding male fertility is Bruno Schoumaker's 2019 *Male Fertility Around the World and Over Time: How Different is it from Female Fertility?* According to Schoumaker, the difference in male versus female fertility rates can be attributed to the age gap between mothers and fathers, age of fathers at first birth, the physiological ability to have children (known as **fecundity**) at older ages being higher for men than for women, and the death rates for males of fertile age being higher than for females of fertile age; all these factors reduce the number of potential fathers relative to potential mothers. Schoumaker also refers to local sexual norms around heterosexual behaviour and polygamy, but the High School Prom Theorem declares that those cannot cause a gap between the total fertility rate for men and women when the numbers of available men and women are equal.

Map 11-1. Figure 1. Male Total Fertility Rates and mean ages of fatherhood, circa 2011 in 163 countries



Source: Figure 1 of Schoumaker (2019). He used data from the United Nations Demographic Yearbook 2016 (United Nations 2017) and his own computations from data in DHS, MICS, and PAPFAM surveys and censuses. For China, the TFR is obtained from Keilman et al. (2014), and the mean age at fatherhood was computed using the 2000 census.

The subject of male fertility is interesting as it shifts our thinking about fertility to focus on the role of the man/father/sperm donor and his/their point of view and needs. Measuring children per man will expand the ways that the economics and sociology of procreation and parenthood is understood.

Exercises: Chapter 11

1. Based on the following table:

N	Age group	Mid-year population of that age group	Mid-year population, entire population	Number of live births
10	15-24	30,000	1,000,000	**1,280**
10	25-34	28,000	1,000,000	**3,000**
10	35-44	32,000	1,000,000	**5,500**
5	**45-49**	**28,000**	**1,000,000**	**800**

a) What is the crude birth rate for this population?

b) What is the general fertility rate, using 15-49 as the age range of women of reproductive age?

c) What is the total fertility rate?

d) What different information would you need to calculate the completed fertility rate for women who are now age 50?

e) Assuming that the sex ratio at birth is 1.05 for all ages of mother, what is the gross reproduction rate?

2. Use the following table to compute the tempo-adjusted TFR for Canada in 2001 and 2004. Can you predict which will be higher, 2001 or 2004, before performing the calculation?

Year	Average age of mother at childbirth	Total Fertility Rate
2000	**28.83**	**1.64**
2001	**29.04**	**1.6**
2002	**29.18**	**1.6**
2003	**29.1**	**1.61**
2004	**29.2**	**1.61**
2005	**29.2**	**1.61**

Data sources: Human Resources and Skills Development Canada (2011), indexmundi.com (2011).

Chapter 12: Determinants of Fertility

In this chapter we will explore the factors that increase or decrease the number of children people have. These things are all "existential" by definition and may trigger strong emotions.

What determines fertility?

Fertility depends on three things: opportunities for intentional or unintentional reproduction; intentions around family size; and ability to carry out those intentions.

In almost all cultures, the parents of a young man or woman traditionally have arranged the marriage, encouraged the couple to have children, and supported them with housing and childcare. A woman may have been compelled to have more children by her husband or in-laws.

Today, western young people typically choose their own partners, choose their desired number of children, and find their own housing and childcare arrangements. Women typically have veto power when it comes to engaging in sexual intercourse or having an additional child. Across the world, greater personal freedom, greater social tolerance of non-traditional family arrangements, and advancing medical technology are uniting to make it possible for people to have as many or as few children as they wish.

Opportunities

Fertility rates are higher when people have more opportunities to meet and mingle. Factors which influence opportunities to meet and mingle include the degree of social isolation; the sex ratio; the usual age at marriage or cohabitation; degree of absence of spouse; likelihood of bereavement, separation, or divorce; and time between unions (if separation or widowhood occur).

Social and religious norms, income, geography, and political crises influence the opportunity to partner. The COVID-19 pandemic of 2020+ greatly interfered with the ability of people to meet partners. Generally speaking, prosperity, peace, urbanization, and secularization mean greater opportunities for partnering and conception.

Photo of Edinburgh Festival Carnival by byronv2, 2014, flickr.com. CC BY-NC 2.0

Intentions

Sadly, intentions around sex and fertility are sometimes violated by acts of rape. On a lighter note, we sometimes succumb to consensual passion and forget our intentions.

For the most part, people in many nations today have quite a bit of freedom when it comes to having children. Our target number of children depends on personal preferences, family/social/religious norms, and economic considerations. We'll discuss the economic considerations in detail later in this chapter.

The target number of children may change as parents raise their first or subsequent children, and as life experiences impact the family. The desired number of children also depends on a person's experience of childhood and on their notion of what the future holds.

When infants or children die, the family may try to conceive more children.

Sometimes a family has more children in order to achieve a target number of children with particular characteristics. In the past, one had to "keep trying" until one had the desired number of boys, girls, healthy children etc. Now genetic testing in utero is making selection easier, and reducing overall fertility. (More on that in our next chapter and in our chapter on son preference.)

Ability to achieve intentions

Once people have an idea of how many children they would like to have and when they would like to have them, they can begin to plan accordingly. Our plans do not always work out the way we expect.

Conception cannot be taken for granted. The age of the parents, breastfeeding, malnutrition, disease, excessive exercise, lack of exercise, and stress can interfere with conception and pregnancy. If conception and pregnancy are not successful, the would-be parent(s) may turn to medical treatments to enhance fertility, *in vitro* fertilization[1], or hiring a surrogate mother[2]. These are usually expensive options.

Adoption and fostering are alternative ways to build a family. Adoption and fostering do not contribute to "fertility" because they do not create new individuals, but adoption and fostering do build families and contribute to a healthier, more emotionally resilient population.

Economic prosperity makes it easier for people to manage their health and to access assistive reproductive technologies. But it also helps people afford birth control, which has the opposite effect on fertility.

Photo by Doctor Themed Cupcakes, 2010, flickr.com. CC BY-2.0

Birth control is about preventing live births, and it includes **abstinence**, **contraception**, **abortion**, and **sterilization**.

1. *in vitro* fertilization means uniting an egg and sperm outside the human body, then implanting the embryo inside the would-be mother's uterus.
2. a surrogate mother is someone willing to carry a baby from another family in her uterus.

Infanticide after a birth has been recorded, neglect, and abandonment may be forms of delayed birth control, but they do not decrease fertility; they increase mortality.

Some potential parents, while wishing to reduce family size, reject some or all methods of birth control for moral, religious, or medical reasons. Other potential parents are uninformed about birth control methods, or find birth control unavailable or prohibitively expensive.

Does rising income lead to more use of birth control? Or does it tend to help people increase the size of their families? It all depends on what people want, and for a few centuries people have tended to want to reduce family size.

Even before modern birth control methods were available, in the days when contraception was limited to herbal concoctions, abstinence, and withdrawal, people were able to reduce their family size significantly. For example, births per year per married woman in France fell from **0.775 in 1740** to **0.410 in 1891** and then to an even lower **0.273 in 1931** (Wrigley, 1985).

Scholars collaborating on Princeton University's *European Fertility History Project* (1971- 1986) concluded that secularization, more than anything else, was associated with falling fertility rates. Secularization meant that people wanted smaller families, and they achieved smaller families even without a lot of money or modern technology. Fertility fell in European provinces even where infant mortality was still high, and where income per person had not yet risen appreciably, if those provinces were integrated with more secularized provinces sharing the same language and culture.

Secularization of a culture occurs as society organizes itself along non-religious lines. The government, the courts, schools, and other institutions adopt a neutral religious stance. Secularization encourages education and personal decision-making without reference to religious authority. It encourages individualism, sometimes at the expense of community. Secularization, affecting intentions around fertility, has likely been the strongest driver of fertility decline.

Surprise Impediments to Fertility

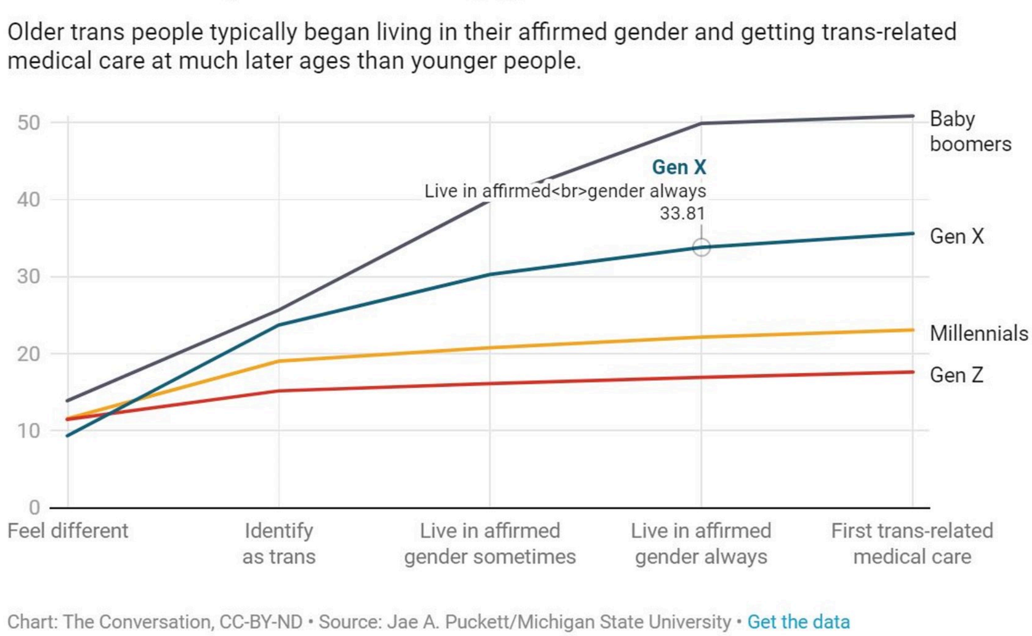
People who delay fertility are sometimes unable to achieve their desired number of children. This is called the **Fertility Trap**. This can happen on an individual level or at the level of society as a whole. An individual may delay fertility, only to realize that they are no longer able to reproduce. A society may discourage fertility, and then later, when it seeks to encourage fertility, it may find that people are not used to having large families anymore. Social norms and material realities may have changed in such a way that having large families has become difficult.

Aside from changes to the cost of raising a child, how has western society changed in such a way as to make having a large number of children inconvenient or difficult?

Fertility intentions may be thwarted by decisions which were taken when younger. Of special note is the decision to undergo hormone treatment or gender-affirming surgery. In order to have biological children, trans persons may need cryopreservation of eggs or sperm, fertility treatments, and/or a surrogate mother to bear the child. Many of these measures are expensive.

Given that the age of people who are coming out as transgender and undergoing transitions is becoming younger, as shown in Figure 12-1, we should ask whether adequate consideration is being given to the possibility of wanting to have children later in life.

Figure 12-1. Trans identity milestones by generations



Source: Jae A. Puckett (2021) (CC-BY-ND)

A "**fertility gap**" is sometimes measured, which is the difference between the number of children people say they desire to have, and the number they actually end up having.

Economic Influences on Intended Family Size

Discussion Idea

What benefit or cost considerations affect the number of children people desire to have?

Although non-economic factors like secularization and social trends seem to have the greatest influence on family size, we will take time to look at economic influences.

The cost of children

Children are born helpless. Even before a child is born, the pregnant mother must make lifestyle and work changes to keep the child safe. Prenatal care is important for mother and baby. Birth is a difficult process which as recently as 1900 gave American women a 0.6-0.9% of dying.[3].

After birth, babies require frequent and careful feeding, diapering, and safekeeping. Lively and meaningful interaction with adults is extremely important to their emotional and intellectual development. Traditionally, the (reproductive) mother has taken on most of this work. Other traditionally female work includes cooking, cleaning, care of relatives and community members, arranging celebrations, keeping in touch with family and friends, and purchasing household goods and gifts.

This traditional female role is often deeply fulfilling and freely chosen. It also delays, complicates, and interrupts education and workplace careers. Claudia Goldin, who won the Nobel Economics prize in 2023, has studied the male-female wage gap and believes that child-related career disruption is its most important explanation of the gap.[4]

Men too make sacrifices for their children. People who aspire to the role of traditional father work hard, taking on most of the responsibility for securing the family's income. They see most of their earnings go to the family's needs, and they defend the family and the nation from danger, even at the cost of their own lives.

Modern parents need not and typically do not completely conform to traditional roles, but as a parental unit they must figure out how best to care for their children. From infancy to young adulthood, and even beyond, children benefit from the time, attention, and money that parents provide.

3. CDC (1999)
4. See for example Bertrand, Goldin, and Katz (2010).

Duncan, Frank and Guevremont (2023) reported that, based on behaviour recorded between 2014 and 2017, Canadian parents spend about $293,000 in 2017 dollars in direct costs raising a child from age zero to age seventeen. The lower income group spends $238,190 while the higher income group spends $403,910.

The material costs of raising children have risen over the years as standards of care have risen. It is now normal for western children to have multiple sets of clothing, music lessons, sports lessons, summer camp experiences, and birthday parties. On the other hand, these things have become more affordable and accessible. Health care, primary education, and high school are all free of charge. The government of Canada offers the Canada Child Care Tax Credit to lower income families, continuing a tradition that began in 1944. Many nations have "baby bonuses" paid to the parents of young children.

Aside from the direct costs of raising children, there is the opportunity cost of raising children. As the career potential of women and other equity-seeking groups has improved, their opportunity cost of raising children has increased. We discuss this in more detail later.

Children providing material benefits

In various times and places, children may have been and continue to be a net material benefit to parents over the lifetime of the parents. Children can work for the family, and children can care for their parents when parents are no longer able to work themselves.

Children of about eight years of age and older have worked in sweatshops and on plantations as long as poverty has existed. Today their tiny fingers weave carpets in Afghanistan and their small bodies wriggle through mining tunnels in Tanzania. They may not be paying their own way, but they are at least contributing to their families' incomes.

Photo by inmediahk, 2015, flickr.com. CC BY-NC 2.0

It seems to be generally the case that children cannot earn as much as it costs to look after them, until they are teens. In her book on British children who were (sometimes forcibly) brought to Canada in the late nineteenth and early twentieth century, Joy Parr (1980) notes that the child care agency had to pay host families to take children under 11, even if those children worked on the host family's farm. Becker (1960) mentioned a finding that male slaves were a net expense to American slave owners until those slaves were about 18 years of age.

Whether or not money can be recouped from children before they reach adulthood, adult children can represent a safety net for parents. In societies where healthcare is unsubsidized, insurance is unaffordable, and pensions are inadequate, parents need children to look after them in old age. In such societies, the capital-to-labour ratio is likely to be low, and the returns to additional capital greater than the returns to additional labor. If therefore poor families could have access to bank accounts, could invest in reliable capital markets, could afford insurance, and could contribute to well-managed pension plans, poor families might dare have fewer children, and the nation's material productivity would likely increase.

In some situations, some parents look at their children as lottery tickets. One of the children might become extremely successful and greatly enhance the family's standing.

What about the economics of childbearing in more prosperous families, where children do not provide economic security to their parents?

Children providing emotional benefits to their parents

Crude as it may be, the "demand for children" has been modeled for the case where children are a net cost to parents. In these models, children provide "utility" to their parents. Parents maximize utility from children and from other things, within the constraints of a budget and a 24-hour day. The parents' constrained utility maximization results in a desired number of children as well as a desired amount of alternative goods and leisure opportunities. The key determinants of the demand for children are income, the cost of children, the cost of substitute goods, and the cost of complementary goods. This is a crass, incomplete, but suggestive approach to understanding the fertility decision.

This approach assumes that children are actually "normal goods", i.e., that more children are preferred as income rises. Is this indeed the case? It seems rather that people and nations choose to have fewer children as incomes rise, suggesting that children are "inferior goods". Although for some people it may be true that children are inferior goods, the idea that children usually are inferior goods is so unappealing that economists have set out to find a model that can contradict it, a model like that of Willis (1973).

Willis developed a detailed model of parental choice. In Willis' model, each family has two parents. The parents act as one and maximize utility. Utility depends on N, the number of children; Q, the level of childhood "quality" for each child, and S, an alternative activity such as skiing. Q and S cost both time and money. Q is more time-intensive than S. Parents choose between spending time and money skiing (S) or raising children (N*Q).

Each parental unit also faces constraints. Parents must earn income to pay for skiing and child services, and they have to allocate their limited amount of time. Willis assumes that one of the parents takes on the traditionally male role of working outside the home full-time. We'll call this parent the "traditional father". The other parent takes on the traditionally female role of remaining outside the paid workforce when and if the couple decides that children need to be cared for at home. Call this parent the "traditional mother". Each parent's wage depends on their initial skill level and their experience in the workforce, but only the traditional mother compares the costs and benefits of staying home with children. Time spent with children means lost wages now and a lower wage in the future.

Note that Willis' model is not appropriate for a very poor nation. The model assumes that all children survive and that children provide no labour or old age security.

Willis considers that the family might receive a sudden gift of cash, or the father's wage might rise. This is considered an increase in "endowment income" because it does not require the hours worked to change. The traditional father is already committed to working full-time. If there is an increase in endowment income, and if child services N*Q is a normal good, the parents will want more child services. However, we do not know whether more child services means more children, or more money spent per child. The more the parents spend per child, the more expensive additional children will be, if parents want to treat all children equally. If parents get richer, they might choose to increase Q without increasing N. We can thus have increases in income translating into fewer children without children being "inferior goods". Mission accomplished.

But what happens if the wage of the traditional mother rises? This may change how much the mother works. On the one hand, the family feels richer; it feels it can afford more N*Q, which will keep the mother busy at home. This is the **income effect** of the wage change. But on the other hand, children are now effectively more expensive, because they take time, and the opportunity cost of the mother's time has now risen. This **substitution effect** makes the family feel it can afford less N*Q.

There is no substitution effect when the (traditional) father's wage rises, because he was never considering staying at home with kids. But for the (traditional) mother who has the opportunity to work outside the home there is a substitution effect, because time is money and children cost time.

Photo by Quinn Dombrowski, 2019, flickr.com. CC BY-SA 2.0

According to Willis' calculations, the following things make it likely fewer children will be desired:

- a decrease in the cost of skiing or whatever the alternatives to child-rearing are
- an increase in the time or money cost of NQ
- a high desired Q for each child
- any decrease in the traditional male's lifetime earnings
- an increase in the traditional female's wage, assuming that child-rearing is more time-consuming than skiing, but less expensive than skiing

Higher wages and improved opportunities for women are likely to decrease the fertility rate, at least initially.

Substitution and Income Effects

At low and medium wages, the substitution effect is likely more powerful than the income effect. So a wage increase leads the parent to work more and spend less time with children. At high wages the substitution effect may be weaker than the income effect, so that the parent decides to spend more time at home or have more children.

T. Paul Schulz, a famous development economist, wrote that

> *"There is an inverse association between income per adult and fertility among countries, and across households this inverse association is also often observed. Many studies find fertility is lower among better*

> *educated women [implying that the substitution effect outweighs the income effect] and is often higher among women whose families own more land and assets [a pure endowment income effect].*"[5]

Myrskyla et al. (2009) suggested that the income effect becomes dominant for countries with high socioeconomic performance. Graphing the total fertility rate against the United Nations' Human Development Index (HDI)[6] for 240 countries, the authors observed that fertility fell as HDI increased, but only up to a score of about 0.9. For most countries whose HDIs exceed 0.9, TFR increased as the HDI increased. This conclusion has not been firmly established.

Abeysinghe (1993) studied Canadian fertility and used statistical analysis to correlate wages, income, and the number of children. He concluded that when it comes to female wages, the substitution effect outweighed the income effect of a wage increase, and higher female wages meant a lower TFR. On the other hand, there was a pure income effect which favours children: men whose incomes compared favourably to their parents had more children.

Although Abeysinghe found that age-specific fertility rates and the total fertility rate fell when female wages rose, the drop in fertility seemed to be temporary. That is, higher wages caused women to postpone childbearing rather than to avoid childbearing. Tempo-adjusted TFR would not be as sensitive to female wages as TFR itself. Abeysinghe found that the female wage rate was not much correlated with the completed fertility rate.

Not everyone who postpones having kids will find the time or find a partner, or be fertile enough to have kids later. (Recall the "fertility trap".) However, some of them will be able to have their children later on. Inasmuch as that is the case, TFR underestimates CFR.

Business Cycle Effects

If higher wages are associated with fewer children, at least temporarily, we would expect fewer births during economic boom times, and more children during recessions. For example, the New York Times reported in April 2021 that many professional dancers were finding that the cancellation of events due to COVID-19 was giving them the chance to have a baby and then get back into shape.[7] However, fertility usually falls during economic recessions. Mocan (1990) attributes most of this effect to the fact that during economic recessions the age at marriage rises and the divorce rate also rises. Otherwise, he believes, fertility would be slightly higher during recessions and lower during economic expansions.

When asked how income affects fertility, we must distinguish between four different aspects of income:

5. Schultz (2005)
6. HDI is an index of life expectancy at birth, income per person, and education levels achieved
7. G. Kourlas, "A Pregnant Pause, in Pandemic Time," New York Times, April 25, 2021.

Table 12-1. Aspects of income which affect fertility

Aspect	Affect on Fertility
Wealth	A pure income effect increases the money spent on children. Some studies suggest that the number of children rises too.
Higher wages, better employment possibilities for the caregiving parent(s)	The substitution effect prevails at lower wages. If wages become high enough, the income effect may prevail leading to greater fertility. However, higher wages are usually associated with fewer children. TFR falls but tempo-adjusted TFR might not fall as much.
Higher wages during economic boom	The higher wages might lead to fewer children if it were not the case that divorce rates fall and marriage rates rise during economic booms. Expect an increase in TFR.
Economic development apart from wealth or higher wages	•reduced reliance on children for labour •reduced reliance on children for old age security •improved infant and child survival •improved education and awareness of career options, birth control •improved access to birth control and to infertility treatment. •Secularization •Improved support for working parents Overall, economic development appears to decrease fertility until high levels of development are reached.

Having considered the factors that affect fertility at the individual, family, and societal level, we will turn to our next chapter to focus on government attempts to control fertility.

Exercises: Chapter 12

1. Give one example of how economic conditions can influence each of the three determinants of fertility.

2. What is the "fertility trap"?
3. How does secularization affect fertility?
4. One explanation of the fact that wealthier people have fewer children is that children are "inferior goods". What other explanations have been offered?
5. Explain the effect of the non-caregiving parent's wage on the caregiving parent's decision to work.

Chapter 13: Fertility Policies and Selection

> Fertility policy is much more complicated, ethically speaking, than mortality policy. Everyone knows that promoting mortality is unethical. Thus, mortality policy is concerned only with saving and extending life.

While everyone knows that good governments should promote health and safety, it's not obvious when and if governments should ever promote either increased or decreased fertility. In the case of mortality policy, it's pretty obvious whether a policy will promote health and longevity. But whether a policy will increase or decrease fertility can be difficult to figure out when it generates both a substitution and an income effect.

Fertility has been both discouraged (with "anti-natalist" policies) and encouraged (with "pro-natalist" policies) by governments at different times and places. When governments make fertility the subject of policy, it's usually in order to affect the rate of growth of the population or of the labour force. For example, Quebec promoted fertility between 1988 and 1997 with the aim of sustaining the francophone population and keeping francophone culture alive in North America.

As with all policies, we should consider whether the chosen tactic is really the best way of achieving our ultimate goal. If our ultimate goal is protecting francophone culture, or improving GDP per person, there are likely better ways of achieving this goal than trying to manipulate the fertility rate.

Many people believe that fertility is a deeply personal individual freedom that government has no business tampering with, but we are generally content to allow a government its incentives and advertising regarding fertility, so long as government does not coerce us, discriminate among us, or manipulate us.

The issue of coercion versus freedom to choose comes up in debates about whether or not abortion should be legal. The proposed right to life of a fetus/unborn child clashes with the proposed right of a pregnant person to abort a fetus/unborn child. The issue of which of these rights is valid and, if both are valid, how to balance them is an important one which cannot be addressed by Economics for the reasons discussed in Chapter 1. However, economists can point out that often governments are choosing one side of the debate or another not because of their values, but to achieve a target level of fertility in the population.

For example, Romania (1965-1989) outlawed abortion to achieve a higher birth rate. Meanwhile, Singapore legalized abortion in 1969 for the express purpose of reducing births. In the most extreme cases, governments have forced people to have abortions or to undergo sterilization to achieve population growth reduction targets or to selectively eliminate unwanted people.

Indeed, fertility policy impacts particular income classes and cultural groups differently, either intentionally or unintentionally. Thus discrimination is another issue complicating fertility policy.

Box 13-1. Sterilizations in Xinjiang, China

After China abandoned its One Child Policy in 2015, the number of forced abortions and sterilizations in China decreased significantly, according to Zenz (2020). However, the number of sterilizations in the Xinjiang Uyghur Autonomous Region, home of 12.8 million Uyghur Muslims increased from 25,723 in 2016 to roughly 248,000 - almost ten times as many - in 2018. This leads many observers to warn of an "outright genocide".

Uyghur Woman. Credits to: PSIT (CC BY-NC 2.0)

In 2021, human rights activists were warning that Uyghur people in Xinjiang, China were being sterilized against their will. In February of 2021, the Canadian Parliament unanimously upheld the United Nations General Assembly *Resolution 260* , which officially recognizes coerced sterilizations, re-training camps and other interventions as "genocide" (Turnbull & Aiello, 2021).

Canada, however, is not innocent of such things. Canada has downplayed the forced sterilization of Indigenous women (Lombard 2021). In a 2021 report by the Canadian Senate, *Forced and Coerced Sterilization of Persons in Canada*, the number of women who have been subject to coerced sterilizations in Canada is described as "unclear" (Standing Senate Committee on Human Rights, 2021) despite several in depth-investigations. Dr. Karen Stote of Wilfried Laurier University has testified that between 1962 and 1972 over 1,200 Indigenous persons were coerced into being sterilized or were forcibly sterilized (Ibid.). Though forced sterilization was illegal everywhere in Canada after 1972, between 1972 and 1974 over 582 women were sterilized in NWT, Yukon, British Columbia, Alberta, Manitoba, Saskatchewan and Ontario healthcare institutions. (Avery Zingel 2019). ***95% of these women were Indigenous.***

More recently, over 60 Indigenous women have come forward to testify that that they were coerced into agreeing to sterilization procedures during their labour, without proper consent, or under false pretenses (International Justice Resource Centre, 2019). Indigenous women have also been threatened with having their children taken away from them unless they consent to be sterilized. A class action lawsuit against the province of Saskatchewan, organized in 2018, is pursuing these charges.

Rally in support of the class action lawsuit against the coercion and sterilization of Indigenous women in Saskatchewan, 2019. Credits to: ICI Saskatchewan

Eugenics

It is tempting for health care practitioners, the general public, and governments to think they understand who should be having babies and what kind of babies should be born. In the early twentieth century, leading citizens around the world embraced **Eugenics**, the study of directing human fertility in such a way as to breed human beings for desirable characteristics. Many leading figures of that time believed in Eugenics, including President Theodore Roosevelt, Planned Parenthood founder Margaret Sanger, and celebrated economist Irving Fisher.

Winners of a Fitter Family contest stand outside the Eugenics Building at the Kansas Free Fair in Topeka, KS, where families are registered for the contests (1920s). Credits to: American Philosophical Society. (Fair Use [Non-commercial, education use only]; CC BY-NC 2.0.

The forcible sterilization of mentally ill and cognitively impaired people was widely seen as acceptable in North America and northwestern Europe in the early twentieth century. In Canada, the Eugenics movement was prominent in Alberta, where a Eugenics Board, with the authority to sterilize people deemed defective, operated between 1928 and 1972. Forced sterilizations were also approved in British Columbia.

In large part because of the horrors perpetuated by Nazis, western opinion and government policy moved away from Eugenics after World War II. Today in Canada, the 1986 Supreme Court decision *E. (Mrs.) v. Eve* requires that no matter how intellectually disabled a person is, they cannot be sterilized without their understanding and consent unless the sterilization is needed for medical reasons. Medical reasons include things like cancer of the uterus or a person's phobia of blood which would be triggered by menstruation.

The United Nations' *Convention on the Rights of Persons with Disabilities* and *International Covenant on Civil and Political Rights* supports the fertility rights of disabled persons.

Although sterilization for non-therapeutic reasons is against the law in Canada, the United States has no similar law. It relies on the American College of Obstetricians and Gynecologists to set guidelines to protect dependents from coercive procedures. Laws or guidelines may not be sufficient. Even thirty-year-old celebrity Britney Spears claimed in 2021 that her father had prevented her from removing a contraceptive device. (He had obtained legal guardianship over her due to her mental health issues. He no longer has legal guardianship.)

While governments have shifted away from Eugenics, pre-natal screening and liberal abortion laws allow many parents to apply Eugenics principles themselves. Ironically, just when we are embracing diversity and supporting the empowerment of people with disabilities, we have the means and often the will to make sure that many children with disabilities are never born.

Putting Eugenics in the hands of parents is a lot safer than having the government decide which kids can be born; there is a diversity of parents who will welcome children like themselves, preserving diversity. However, it is clear that children with disabilities, and in some societies, girl children (see chapter 24 on son preference), are less welcome. In the future it may become easier to select for all kinds of apparent abilities and advantages.

Economics cannot be relied upon to dissuade parents from this course of action, especially if children with unwanted characteristics cost more to raise and governments are not willing to share the financial challenge. However, Economics can remind us that diversity has been a source of strength, providing new perspectives, therapies, and innovations. Our society's strength, our government's strength, our economy's strength, arise from diversity, cooperation, and competition, rather than in conformity, coercion, and cronyism.

Let's now have a look at specific fertility policies that have been implemented at various times and places. Recall our principles of policy design from Chapter 10: Do not coerce or discriminate, target the ultimate goal, target the binding constraint, target the correct margin, and be aware of who will pay most of any tax or subsidy.

Lump-Sum Monetary Incentives

Money, gifts and lotteries have been offered to people to get them either to have more children or to be sterilized. Several questions are relevant here.

- Coercion: Is this financial offer actually coercive? Will some people feel they have no financial choice but to participate? Are they being trapped into doing something they will later regret? Will government be there to financially support them later on?
- Discrimination: Is this financial offer actually discriminatory? Will it, and is it intended to, affect mostly the fertility of people who have less income, people of a particular ethnicity or social class?
- Targeting: Why is the government wanting to alter the fertility rate? Is there a better way to achieve the ultimate goal of the government?
- Constraints: Is money actually the binding constraint? Is lack of money what is holding people back from what the government desires them to do? If not, this policy will be useless in achieving the government's goal.
- Margins: What margin is most relevant? For example, if the government wants people to have more children, and most people have one child anyway, it would make economic sense to offer monetary incentives only for the second child and subsequent children.
- Tax/Subsidy incidence: Will the extra money in the hands of recipients be captured by landlords, relatives, or fraudsters?

Subsidies

Sometimes the government offers money for particular expenditures. As usual, we must ask what the government's ultimate goal is. Is the government discriminating or being coercive? Is money really the binding constraint? What margins of choice are being affected?

Recall from our discussion of tax and subsidy incidence in Chapter 10 that a subsidy does not always very much benefit the group we had in mind. For example, if the government subsidizes the price of daycare, and if the price elasticity of demand for daycare is higher than the price elasticity of supply for daycare, most of the subsidy will go to daycare suppliers, not to parents. This is because the surge in demand caused by the subsidy outpaces the ability of the industry to increase the number of available daycare spaces, and so the price of daycare goes up.

Even if daycare will certainly become cheaper, it is not certain that births will increase. The case of daycare is complex. Daycare fees are a cost to a parent of being employed outside the home. For the parent absolutely committed to working outside the home, a daycare subsidy reduces the parent's child-related expenses and encourages the working parent to have children.

But for a parent at the margin of deciding whether to work outside the home or not, subsidizing daycare makes the effective take-home pay higher, increasing the opportunity cost of staying at home and making it more likely that the parent will go to work outside the home. So we expect that labour force participation will increase when daycare is subsidized, and this has a depressing effect on fertility inasmuch as labour force participation interferes with child rearing. The effect of daycare subsidies on fertility depends on how committed parents are to the workforce.

Parental Leave and Career Disruption

Parental Leave is a right given to employees to take time off work upon the birth or adoption of a child. Some or all the parent's usual wage may be paid by the government. In Canada in 2021, 15 weeks of **maternity leave** for a mother after giving birth and 35 weeks of **parental leave** for either parent to take care of a newborn or adopted child were available at 55% of regular wages, to a maximum of $595 per week.

Employers could elect to contribute to the compensation, for example by topping up employment insurance contributions to so that the parent received as much as 95% or 100% of the previous wage.

Parental Leave will be most effective at increasing fertility when time is the binding constraint, that is, when parents don't feel right about having kids unless they are able to devote a lot of time to newborns.

There is concern that women are the people most likely to take parental leave and to end up with gaps in their employment history. This results in lower earnings and fewer career promotions for women than men. At the same time, many women including the author have been willing to trade career progress for time spent with their children because they find caring for their children meaningful and rewarding.

In the interests of reducing the workload of women, and to promote father-child bonding, parental leave includes fathers as well as mothers. In Canada, both parents can take leave at the same time. Anecdotal evidence from Queen's University in Kingston suggests that when professors take parental leave at the same time, mothers are doing most of the caregiving, while fathers are using the time off from teaching to further their research. If this pattern holds more generally, then the double parental leave actually aggravates the career disadvantage for women.

The Case of Singapore

Singapore's fertility policy over the last fifty years has changed a great deal. Wong and Yeoh (2003) show how the government of Singapore was unable to control fertility in the face of strong economic and cultural pressures, and how it changed its mind about what it even wanted to accomplish.

In the late 1960s and during the 1970s, Singapore wanted to slow its population growth rate, and it strongly encouraged people to have fewer children. This is shown in the posters below, which imply that families should not keep trying for a boy, but be satisfied with any two children. Children should also be spaced further apart in time, according to this advertising. Spacing children further apart increases the chance that a couple's ability to have children will expire before they change their mind about having a small family; also spacing children also helps families allocate more time and money to each child.

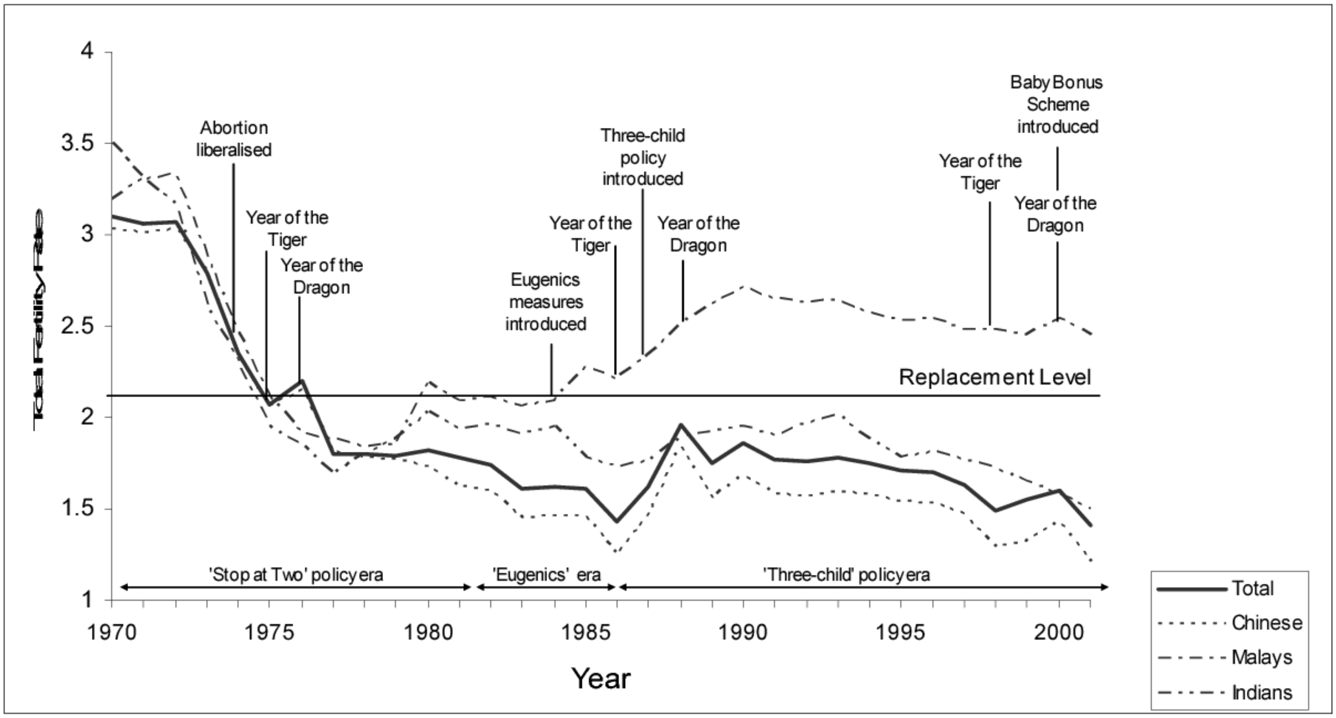
During this campaign the government of Singapore legalized abortion. It subsidized abortion as well as contraception. It imposed mandatory "family planning" counselling sessions to inform couples about birth control.

1972 – "Stop at Two" campaign. Singapore Family Planning and Population Board Campaign posters. Credits to: National Archives of Singapore/Singapore Family Planning and Population Board.

Fertility rates did come down, mostly among Chinese Singaporeans, who had the highest education levels and the best jobs, and whose fertility might have dropped anyway as educational opportunities, work opportunities, and urbanization increased. This was not what the government had been hoping for. In 1984 Singapore began to target its fertility reduction campaign on less educated women – who were primarily Malay and Indian in ethnicity. The government offered mothers who had not completed secondary school, who had low household income, and who had only one or two children a substantial cash gift and preferential school placement for the children if they agreed to be sterilized. Meanwhile, the government offered preferential school placement to college-educated mothers who had two or more children. Both programs were unpopular and attracted few participants.[1].

1. Palen (1986)

Figure 13-2. Population Policies and Fertility trends by Ethnic Group in Singapore



Source: Figure 1, Wong and Yeoh (2003).

This "Eugenics phase" lasted only about four years. Concerned about a shortage of unskilled workers, the government stopped discouraging less-educated women from giving birth in 1987. It switched gears completely, deciding that lack of population growth was the problem. Its mantra became "Have Three, or More if You Can Afford It." The policies that developed then and persist to this day discourage abortion, encourage marriage, and make living with children more affordable. These policies have not been sufficient to prevent the Total Fertility Rate from declining further to 1.14 (2019) from 1.62 in 1987.

Figure 13-2 above shows the Total Fertility Rate for Malay, Indian and Chinese ethnic groups in Singapore from the anti-natalist days through the Eugenics phase to the pro-natalist era.

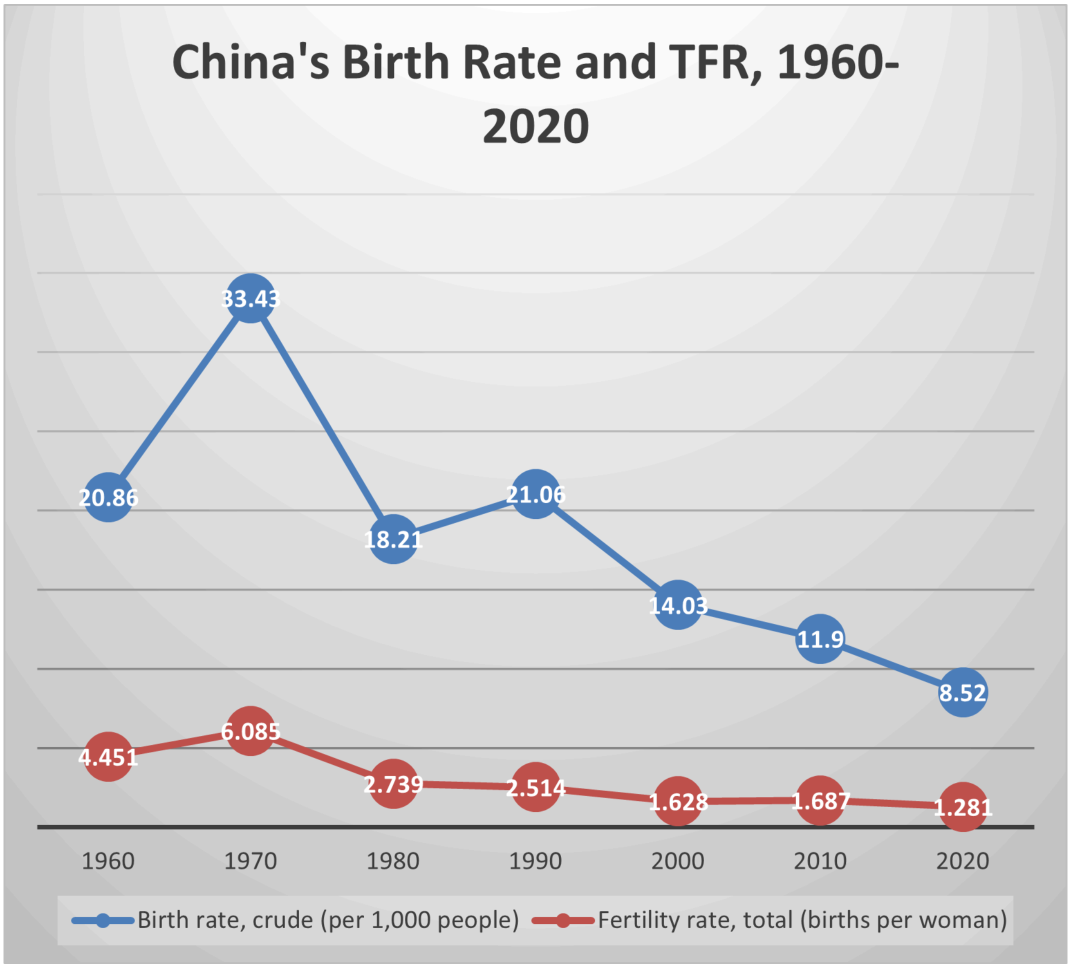
Graphic downloaded in February 2023 from the pro-family website of the government of Singapore

The Case of China's One Child Policy

As shown in Figure 3-3, China's Total Fertility Rate grew from 4.5 children per woman to 6.1 children per woman between 1960 and 1970. Its Birth Rate grew from 20.9 per 1000 to 33.4 per 1000. But during the 1970s, ostensibly due to improving economic conditions and opportunities, both rates fell, by more than they would ever fall again in the next four decades.

Even though fertility rates and birth rates were already falling, in 1979 China began a rigorous program to achieve zero population growth or "ZPG" by the year 2000. Urban couples were limited to having one child. Rural, farming families could have two children if they were spaced apart by four years, or if the first one was a girl or disabled, acknowledging the strong preference for sons. Ethnic minorities were allowed two or three children, and rural Tibetans, any number of children.

Figure 13-3



Compiled by A. Hageman from World Development Indicators, World Bank, December 22, 2022.

The legal age at first marriage was adjusted upward, from age 18 to age 25 for urban women, and from age 20 to age 28 for urban men. (The legal age for first marriage was set a few years lower for rural women and men.) Because births outside of marriage were unusual and greatly stigmatized, raising the age at first marriage reduced the life years available to have children.

Married women were regularly visited by government employees and asked about their contraceptive use. A permit was necessary for each birth. Without a permit, parents could be fined for having a child, and would lose out on subsidized housing, education, and pensions in the city, or extra work points and rations in the countryside. Worse yet, in some locations, women without birth permits were forced to have abortions and to be sterilized. Coercion was not officially prohibited until 2001. The degree of coercion can be gauged by how quickly the one-child family became the norm. It is estimated that since the 1990s, ninety percent of births have been only-child births.[2]

Fewer births, better births, 1987. Credits to: IISG. CC BY 2.0

As Figure 13-3 shows, during the first decade of the One Child Policy, TFR fell some more. The birth rate actually rose due to population momentum. After 1990, both rates fell. This decline continued during the 2000s and 2010s, despite the growing size of the cohort of people of child-bearing age (due to the high fertility rates of the past).

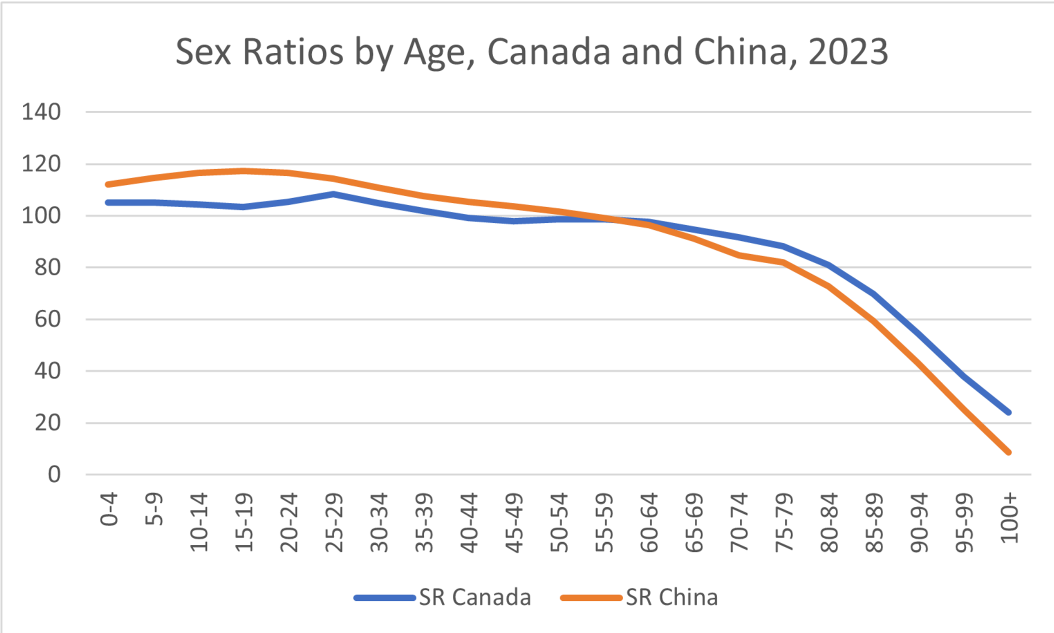
Though Zero Population Growth was not achieved by 2000, nor even 2020, the population growth rate did decline from 1.7% to roughly 1.1%. The birth rate was 8.52 in 2020, and the TFR was 1.28 children per woman.

The decline in birth rate during the 1990s, 2000s, and 2010s is remarkable, because during the same period, larger and larger cohorts of people (born in the 1960s and 70s) were reaching child-bearing age. Some of the reduction was due to economic development, urbanization, and expanding educational opportunities.

The One Child Policy is worthy of lengthy analysis, but in brief, there were significant costs and benefits. On the cost side, it caused grief on the part of would-be parents having fewer children than desired, especially in the event of premature death of a teenager or young adult who was a couple's only child; and many aborted, hidden, or abandoned female children. Today there is a high sex ratio, and an **Aged Dependency Ratio** that is higher for China than for other countries at similar stages of economic development. On the plus side, pressures on the environment, and the challenge of providing housing, education, and health care to China's initially large and generally impoverished population, were mitigated.

2. Feng, Poston and Wang (2014)

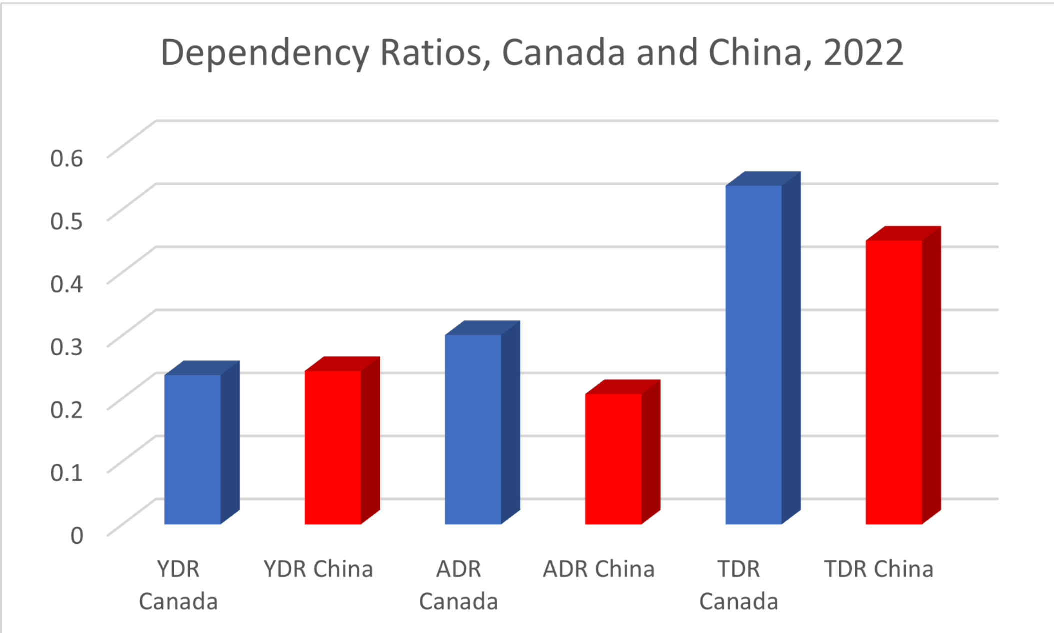
Figure 13-4



Compiled by A. Hageman. United Nations data downloaded from PopulationPyramid.net, August 11, 2023.

Figure 13-4 compares China's sex ratio at various ages to Canada's sex ratio in 2023. At that time, China's sex ratio at birth was higher than Canada's and even increased during childhood and adolescence, showing what appears to be son preference. We discuss son preference in Chapter 24. However, likely due to a lower standard of living, the sex ratio fell more steeply with age in China than in Canada. At age 55-59 the sex ratio in both countries was 99 men per 100 women. After age 59, the sex ratio was lower in China than it is in Canada, and the gap between the two countries' sex ratios widened as the age of the group increased.

Figure 13-5



Source: United Nations data downloaded from populationpyramid.net and processed by A. Hageman

Figure 13-5 shows us Canada's and China's **Young Dependency Ratio** (the number of children compared to the number of people of working age), Aged Dependency Ratio (the number of seniors compared to the number of people of working age), and **Total Dependency Ratio** (the sum of the Young Dependency Ratio and the Aged Dependency Ratio). Children are defined as being 0-14 years of age; seniors are age 65+.

We see that, while China may have higher aged dependency compared to other nations with similar GDP per capita, in 2022 China still had lower aged dependency than Canada did. China had a Child Dependency Ratio which was just slightly higher than Canada's, but with a significantly lower Aged Dependency Ratio, China had a lower Total Dependency Ratio than Canada did.

> **Class Discussion**
>
> After almost forty years of a One-Child Policy, how could China's Child Dependency Ratio be higher than Canada's?

We discuss aging populations in Chapter 16. Concerned about its aging population, the Chinese government began to loosen the One Child Policy in 2016. By 2021, all married Chinese couples were allowed three children. During 2021, the Chinese population fell for the first time in sixty years, by 850,000 people.

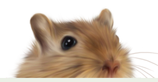
In our next chapter we'll look at how to forecast population growth or shrinkage.

Exercises: Chapter 13

1. The new Student Health Administrator wishes to reduce unplanned fertility among first-year university students. Is this a violation of human rights? Whom should you target? What is the margin? Why is accidental fertility happening? What might be the binding constraint? Suggest a policy to address this constraint.
2. Describe the fertility impact of the following on a wealthy, stay-at-home parent with two preschool children: a) increased day care subsidy; b) increased parental leave privileges; c) a monthly allowance from the government for each child; d) new one-time cash payment for a 3rd child; e) improved convenience of online education programs; f) an increase in the average real wage.
3. Imagine you are in the Chinese government in the early 1980s, and you want to end discrimination against girl children. Someone suggests giving larger working plots to rural couples who have two daughters. Evaluate this idea using our principles of policy design.

INTRINSIC POPULATION CHANGE

Chapter 14: Forecasting Population Size and Age Structure



In this next part of the course, we look at how fertility and mortality by themselves would influence population size, population growth, the age structure, and the sex ratio if present trends continued.

If fertility and mortality rates were to remain unchanged, then, in the absence of migration, the population growth rate would eventually converge to a stable rate of growth or shrinkage. This is the **intrinsic rate of natural increase.** Once the population stabilizes, the growth rate, age structure, and age-specific sex ratios are set.

The population never stabilizes in real life, because fertility and mortality change, and because of immigration and emigration which change also. However, calculating the intrinsic rate of population growth helps us understand where population is headed.

Stable and Stationary Populations

In demography we like to predict what the population will look like in the future. Since almost anything can happen to birth, death, and immigration rates, there is no way to know this for sure. We like to assume that "present trends continue." We can do this by studying a hypothetical "stable population" based on today's fertility and mortality rates.

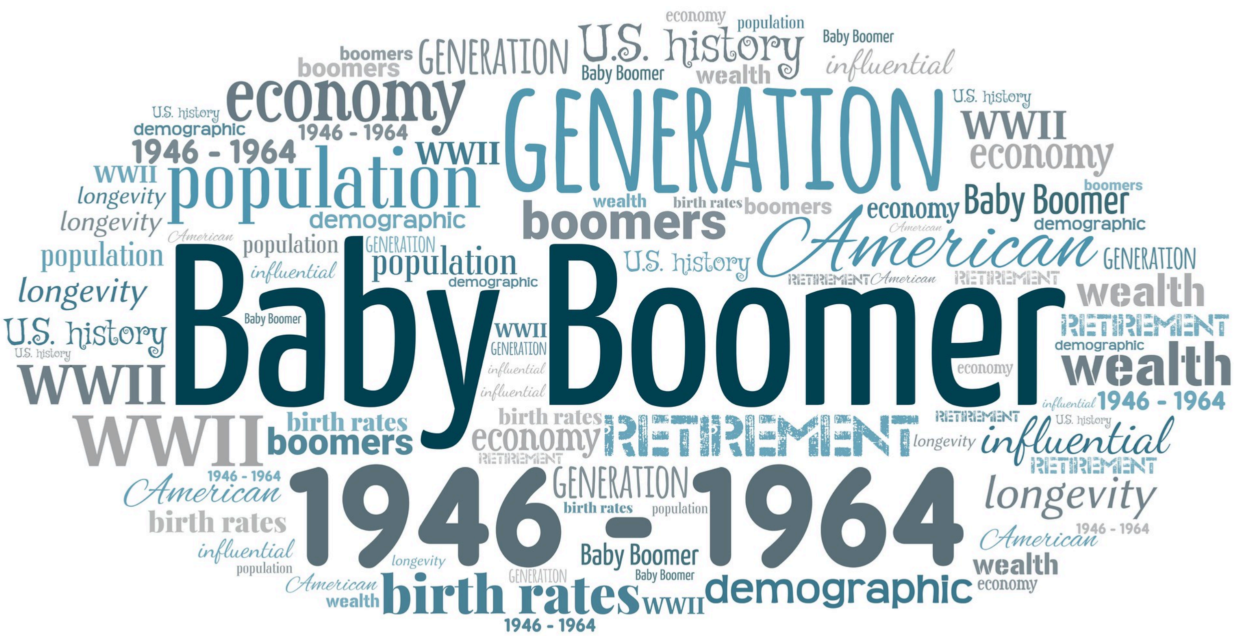
A stable population is one where:

- There is no immigration or emigration
- age-specific fertility rates do not change
- age-and-sex-specific mortality rates do not change
- enough time has passed for the age structure of the population to stabilize.

Why does it take time for a population to stabilize? Well, just because fertility rates stay the same this year and next doesn't mean that the birth rate won't change. The birth rate depends not only on fertility rates but also on the number of women of childbearing age, which could be different next year than it is this year.

Similarly, as we learned when standardizing for age, death rates depend not only on age-specific mortality rates but also on the age distribution of the population. So death rates won't stabilize until the age structure stabilizes.

Consider a population where fertility has recently fallen. The birth rate will not necessarily immediately fall. Fertility may have dropped, but there may be a larger number of women of childbearing age this year than there was last year due to higher fertility rates in the past.



Credit to: EpicTop10.com

Between 2004 and 2009, Canada experienced a small baby boom. The crude birth rate rose from 10.5 births per 1000 to 11.3 per 1000. Some of this baby boom was likely due to the fact that, during the late 1940s and the 1950s and the early 1960s, many Canadians were born – our **Baby Boom Generation**. The grandchildren of these boomers were reaching child-bearing age between 2004 and 2009. Also, many of the children of the baby boom generation had delayed having children and were having them at this time.

The birth rate and death rate are not going to stabilize until fertility rates and mortality rates have been constant for some time, long enough for the age structure to stabilize. Once the age structure stabilizes, birth and death rates can stabilize too, and the overall rate of population growth or shrinkage will stabilize.

Later in this chapter we will learn how to calculate the age structure of a stable population. We will also learn how to calculate the rate of growth (or shrinkage) of a stable population. The rate of growth of a stable population is called the **intrinsic rate of natural increase**. It's "natural" because it comes from the fertility and mortality of the population, and not because of immigration or emigration. It's "intrinsic" because it derives from the fertility and mortality rates and will eventually emerge no matter what the initial population looks like.

Stationary Populations

A stationary population is a type of stable population. As with every stable population, the fertility and mortality rates are constant, and there is no migration. As with every stable population, a stationary population achieves a stable age structure eventually, and a stable rate of natural increase. **The thing that distinguishes a stationary population from other stable populations is that its intrinsic rate of natural increase is exactly equal to zero.** This means that, once the population has stabilized, not only is the same number of people born each year, but also the same number of people die each year as are born each year.

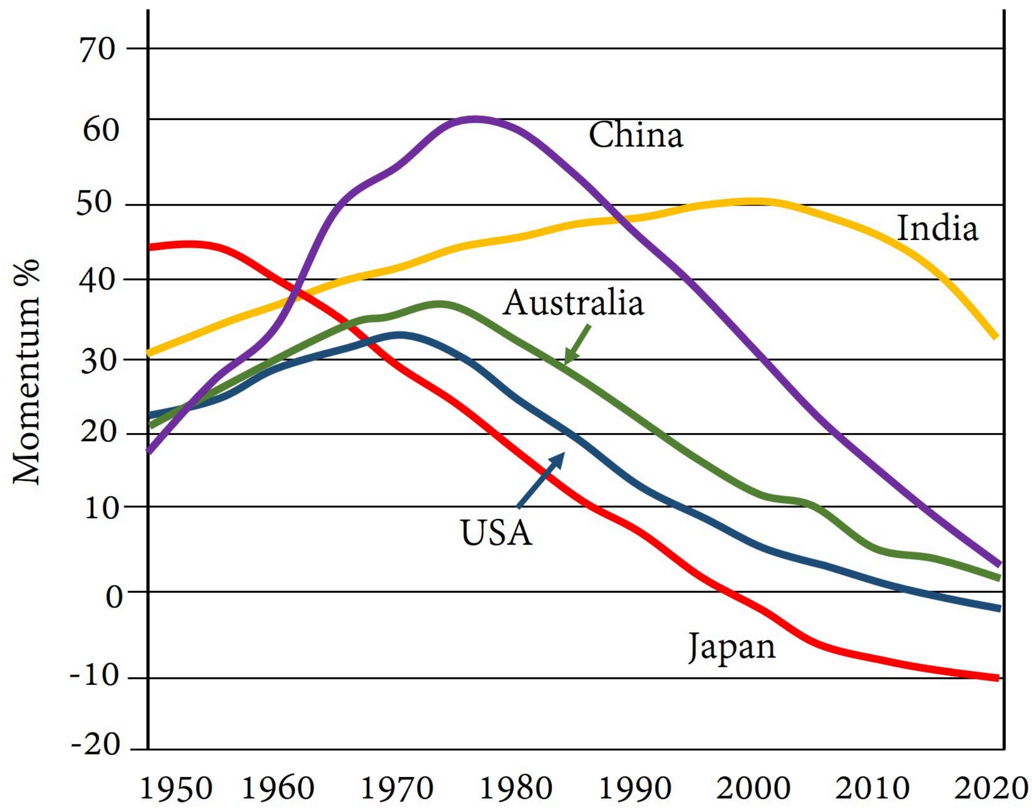
This stationary state is unlikely to exist in real life, but imagining it allows us to pursue an interesting question. If fertility rates were to drop enough so that the intrinsic rate of natural increase is zero, at what age structure would the population stabilize? And what would the population size become before population growth settled down to zero?

Once the stationary population stabilizes, there is no growth or shrinkage. But this does not happen right away. Though we have the correct fertility rates and mortality rates for eventual zero population growth (ZPG), the birth and death rates will only come into balance once the age structure has stabilized. The population keeps growing –or shrinking- for a while because the current age structure is different from the ultimate age structure.

Consider a case where the population has been growing, but now fertility rates drop to a level compatible with an eventual stationary state. The proportion of young people is, at this moment, higher than what it eventually will be. These young people can reproduce; although they may have the new, low, fertility rate, there are so many of them that the number of babies today is higher than it will be eventually. It will take a while before the number of newborns falls to the stationary level.

In Figure 14-1 below, the purple line represents the tendency of China's population to grow just because there is a high proportion of the population that is of childbearing age. This is known as **population momentum**. Figure 14-1 indicates that during the years of China's One Child Policy (1979-2021), population momentum was falling, but it was still positive. According to the graph, China's population was expected to continue to grow through 2020 because of the positive momentum provided by China's age structure. Indeed, China's population did grow until 2021.

Figure 14-1. Total Population Momentum in Select Countries, 1950 – 2020



Source: Figure 7 in Total Population Momentum in Select Countries, 1950 – 2020 in Rowland (1995). Right of use purchased. A score of 60% means the projected stationary population, assuming fertility rates immediately drop to replacement levels, would be 60% larger than the current population.

We might consider what would happen to a population that is shrinking if its fertility rates suddenly jumped to the level consistent with an intrinsic rate of natural increase equal to zero. That population would continue to shrink for a while before stationarity was achieved, because the number of people of child-bearing age is lower than what it eventually will be.

Population Momentum

Population momentum is the degree to which a population – if fertility rates suddenly changed so that its *intrinsic* rate of natural increase became zero – would continue to grow or shrink before reaching its stationary size. We could alternatively say that population momentum is expected population growth (or decline) that comes only from the maturation of different age groups before the stable age structure is achieved.

There are different ways to measure population momentum. One way is:

$$pm = \frac{\text{stationary population size}}{\text{current population size}}$$

If this ratio is a number greater than 1, population momentum is positive, and even if the population's rate of natural increase were to become zero, the population would still grow for a while before settling down to zero population growth (ZPG). If the ratio is less than one, population momentum is "negative", with shrinkage expected before ZPG could be achieved.

Figure 14-1 uses this method, but records a population momentum value of 1.6 as "60", meaning that the stationary population will be sixty percent higher than the current population at the given date.

Another way to quantify momentum is to see whether this fraction is greater than or less than one:

$$\textit{pm score} = \frac{\text{current proportion of females of child–bearing age to the rest of the population}}{\text{proportion that will be observed once the population has achieved its stationary size}} > 1\ ?$$

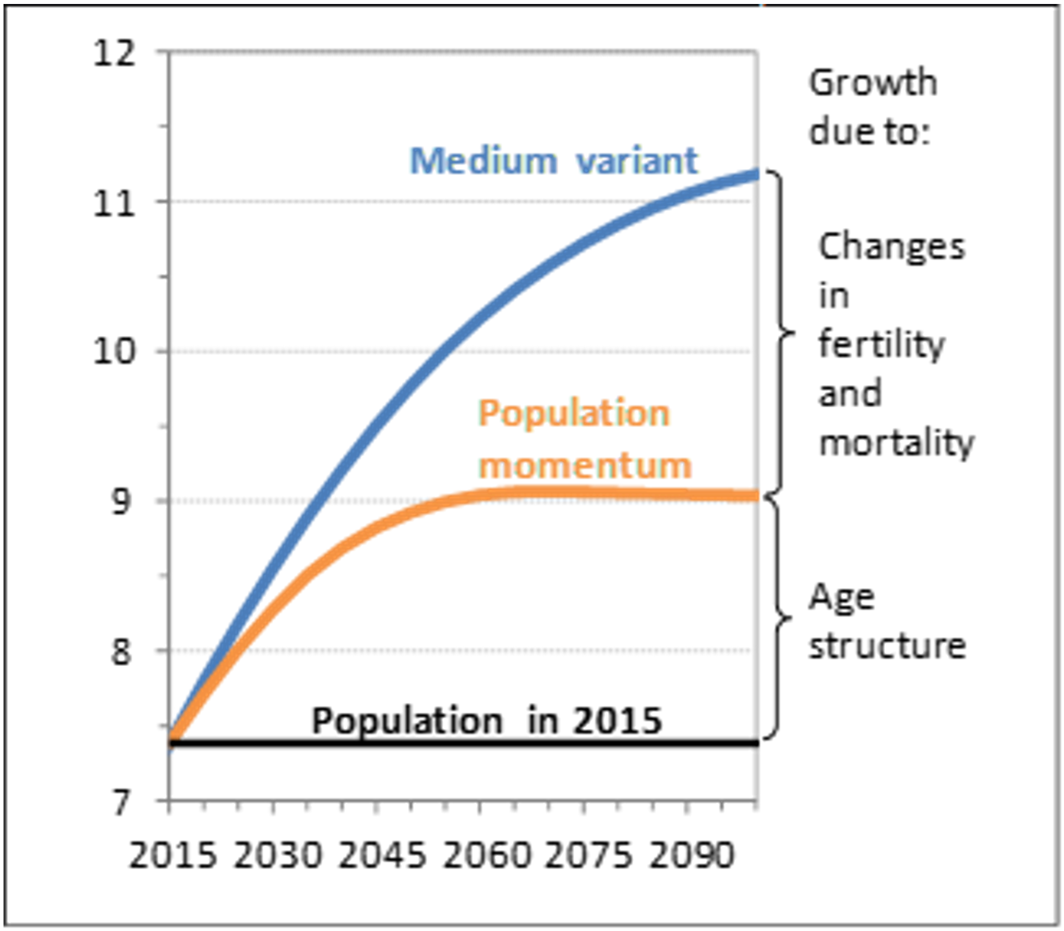
If this score is greater than one, then we have population momentum; if less than one, we have negative population momentum. If the score equals one, we have no population momentum. This approach to measuring population momentum will not be applicable to extreme situations such as the population being composed entirely of newborns.

The United Nations has used this rough ratio in the past:

$$\text{momentum factor} = \text{crude birth rate} \times \text{life expectancy}$$

Figure 14-2 below shows us that, in 2017, the United Nations projected the world population to reach over 11 billion by 2090 because of three factors: decreases in mortality, fertility rates remaining higher than those compatible with stationarity, and population momentum. Figure 14-2 indicates that even if mortality rates immediately froze and even if fertility immediately dropped to the level that would eventually stabilize the population at zero population growth, the world population would still rise to 9 billion people just because of population momentum.

Figure 14-2. Projected size of the world's population, medium and momentum variants, 2015-2100



Source: Figure 3 of United Nations (2020).

Figure 14-2 shows the "medium variant", the predicted level of population growth using medium levels of fertility and mortality rather than the highest or lowest possible values. The "momentum variant" is that portion of medium population growth that is due to population momentum alone.

Using a Matrix to Forecast Population Size and Composition

> In this section we will learn how to project a detailed population forward in time, assuming constant fertility and mortality rates.

Cute little gerbil. Credits to: Norlando Podre.

We can predict a stable population's eventual age structure. One way is to use vectors and matrices to organize and manipulate the fertility and mortality information.

Let *n(t)* be a vector with *s* number of rows and one column. Each row represents an age group at time *t*. There are *s* number of age groups. The numbers in the each row represent the number of gerbils, say, in each age group. Perhaps there are only three age groups: newborns, age 1, and age 2.

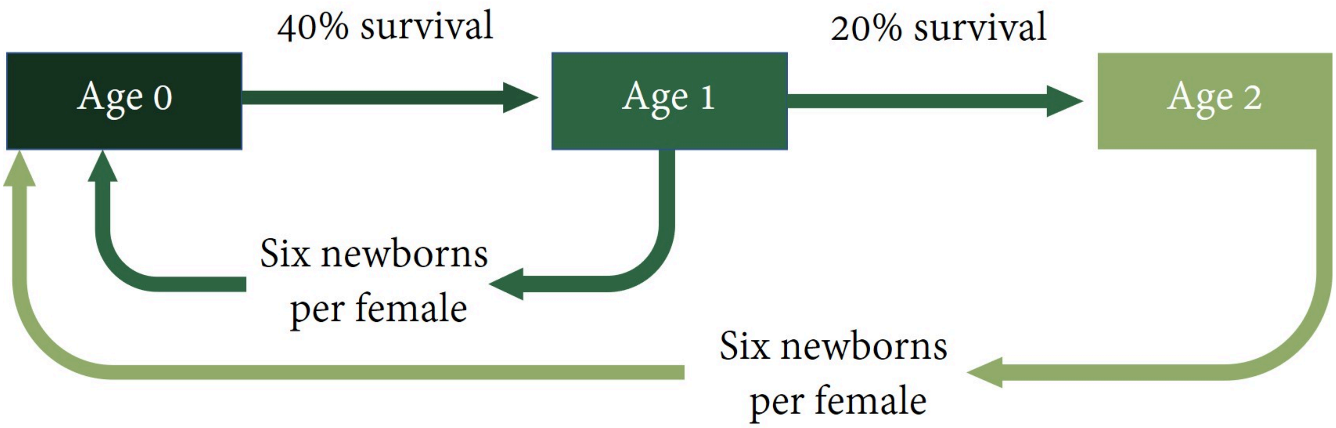
> Let there be 10 gerbils in each age group at time t. So, $n(t) = \begin{matrix} 10 \\ 10 \\ 10 \end{matrix}$

For simplicity, we will not distinguish between male and female gerbils.

To figure out how fast this population will grow, and what the stable age mix will be, we need to know how quickly the gerbils reproduce, and what their survival rates are. (Note that the survival rate is simply the number one minus the mortality rate. For example, 60% mortality during the year means 40% chance of surviving.)

Let's use a simplified description of gerbil life. Perhaps newborns have a 40% chance of surviving until age 1. Perhaps one year-olds have a 20% chance of surviving until age 2. Perhaps two year-olds have a 0% chance of surviving until age 3. Perhaps newborns cannot reproduce, but female one year-olds have on average 6 live newborns during the year, and female two year-olds have on average 6 newborns also. Figure 14-3 below illustrates this.

Figure 14-3. Age Group Relationships



In this example, all the age groups are related. Not only do surviving one year-olds become two year-olds, but one year-olds generate newborns. Such a set of relationships lends itself well to matrix algebra and will result in a stable age structure.

The fertility and survival information summarized in Figure 14-3 above can be packed into a matrix with *s* number of rows and *s* number of columns. Such a matrix, denoted by the letter "A", is called a **Leslie matrix**. We use the Leslie matrix to transform $n(t)$, the age vector for year t, into $n(t + 1)$, the age vector for year $t + 1$.

So, $\boldsymbol{n}(t+1) = \boldsymbol{A}\,\boldsymbol{n}(t)$

Based on the survival and reproduction data given above, $$A = \begin{array}{ccc} 0 & 3 & 3 \\ 0.4 & 0 & 0 \\ 0 & 0.2 & 0 \end{array}$$

The first row of the Leslie matrix contains the fertility information: 0 3 and 3. The zero in the first column means that newborns cannot have babies. The 3 in the second column means that one year-olds have 3 babies each. Note that we say 3 babies each, not 6 babies each, because although there are 6 newborns per female, only half the gerbils are female; on average there will be 3 newborns per adult gerbil. For simplicity, we are not distinguishing between males and females.

The first row tells us that newborns have 0 babies each, one year-old gerbils have 3 babies each, and two year-old gerbils have 3 babies each as well.

Basically, each column belongs to an age group, with the leftmost column representing the youngest age group. The first row is the fertility row, showing how many babies are contributed per gerbil in each age group. The subsequent rows are survival rows. The second row/first survival row shows what percentage of gerbils make it from newborn (the first age group) to one year old (the second age group). It reads 0.4, 0, 0 which communicates that 40% of newborns make it to age 1, zero one year-old gerbils turn 1, and zero two year-olds turn 1. The last row shows how many gerbils make it to the last age group, age 2. As you can see, zero newborns turn 2, 20% of one year-olds turn 2, and zero two year-olds turn 2. There is no subsequent row because all gerbils in the last age group die.

We've assumed that these gerbils never live past age two. In real life, gerbils can live longer than that.

Using the Leslie Matrix

To find how many babies there will be next year, which is the first number we need for our n(t+1) age matrix, we multiply the fertility row in the Leslie Matrix by the age vector n(t). That means we multiply the first item in the fertility row by the first item in n(t), add that to the the second item in the fertility row multiplied by the second item in n(t), and add that to the third item in the fertility row multiplied by the third item in n(t).

To get the first row of $n(t+1)$, i.e. the number of newborns next period, we multiply the first row of $\boldsymbol{A}$ by $n(t)$ like this:

$$(0 \times 10) + (3 \times 10) + (3 \times 10) = 60 \text{ newborns.}$$

Our calculation shows us that newborns do not give birth to any newborns, but the 10 one-year-olds (male or female) give birth to an average of 3 babies each, as do the 10 two year-olds.

To find out how many one-year-olds there will be next year, we multiply the second row of A by the age groups in $n(t)$.

Multiplying the rows in A by the columns in n(t) is the correct way to perform matrix algebra. **Always keep the Leslie Matrix A to the left of n(t)**, because, according to the laws of matrix algebra, the number of columns in the first object has to equal the number of rows in the second object.

Let's continue with our example, using our first Leslie Matrix with ages newborn, 1, and 2. We saw that, when we begin with 10 gerbils of each age, 60 gerbils are born and enter the newborn category.

How many one year olds will there be in n(t+1)? Since only 40% of the original ten newborns will survive to age 1, and since the original 10 one-year-olds and the original 10 two-year-olds cannot turn one, there will be four one-year olds at n(t+1).

Finally, to find out how many two-year-olds there will be in n(t+1), we must multiply the third row of A by $n(t)$ to find that there will be 2 two-year-olds next year. 0 x 10 + 0.2 (10) + 0 (10) = 2.

Our vector $n(t+1)$, will now become $\begin{matrix} 60 \\ 4 \\ 2 \end{matrix}$

and the population, just one year later, is now composed of 60 newborns plus 4 one-year-olds, plus 2 two-year-olds, for a total of 66 gerbils.

That's a big difference in our gerbil population's age distribution in just one year! Not only has the population more than doubled, but the population has become much younger! Magically, the age structure will eventually stabilize, usually in fewer than 70 periods. When the age distribution stabilizes, the population's growth rate – and the growth rate of every single age group – stabilizes too.

The point of writing the population's dynamics in matrix form is that, once it is in matrix form, it is very straightforward to compute what will happen to the population in the distant future.

To find what the population will look like in 70 years if present fertility rates and survival rates continue, compute:

$$\boldsymbol{n}(t+70) = \boldsymbol{A}^{70}\, \boldsymbol{n}(t)$$

A computer can do this easily.

One can also find, using a computer or using matrix algebra, the eigenvalues of the Leslie Matrix A. An eigenvalue is a number λ that, together with some non-zero vector $v(t)$, can "take the place of" matrix A in the equation:

$$A\,v(t) = \lambda\,v(t)$$

The largest, positive, real eigenvalue happens to be related to the intrinsic rate of natural increase! Take the natural logarithm of this eigenvalue and you have the intrinsic rate of natural increase/decrease.

Another way to calculate the intrinsic rate of natural increase is algebraic, using the survival and reproduction rates. This calculation is very complicated.[1]

The gerbils in our example settle down to their stable rate of population growth after 56 years. At that point and ever after, they experience r=0.1843 or eighteen-and-a-half percent population growth per year.

Calculating the stable age structure

Once we have the intrinsic rate of growth, r, we can predict the stable age structure. We do this in Table 14-1 for our hypothetical gerbil population. Again, we will ignore differences between males and females for simplicity. The number of individuals in any age group x is related to the number of newborns x years ago multiplied by the exponential population growth factor (e^{xr})and the relevant survival rates.

1. The intrinsic rate of natural increase can be calculated as (ln R)/ (R1/R – 0.7 ln R), where R is the net reproduction rate, and R1 is the mean length of a generation. The net reproduction rate and the mean length of a generation have to be computed from fertility and survival rates.

Call the number of newborns NN. Since the gerbil population (and every age group) is now growing steadily at $e^{0.185}$, there must have been $e^{-0.185}$ fewer newborns last year than there are this year. 40% of those newborns would have survived the intervening year, giving us NN x $e^{-0.185}$ x 0.4 = 0.3324 NN one year-olds now. That is to say, for every newborn, there are 0.3324 one year-olds. This is recorded in column 3 of the Table below.

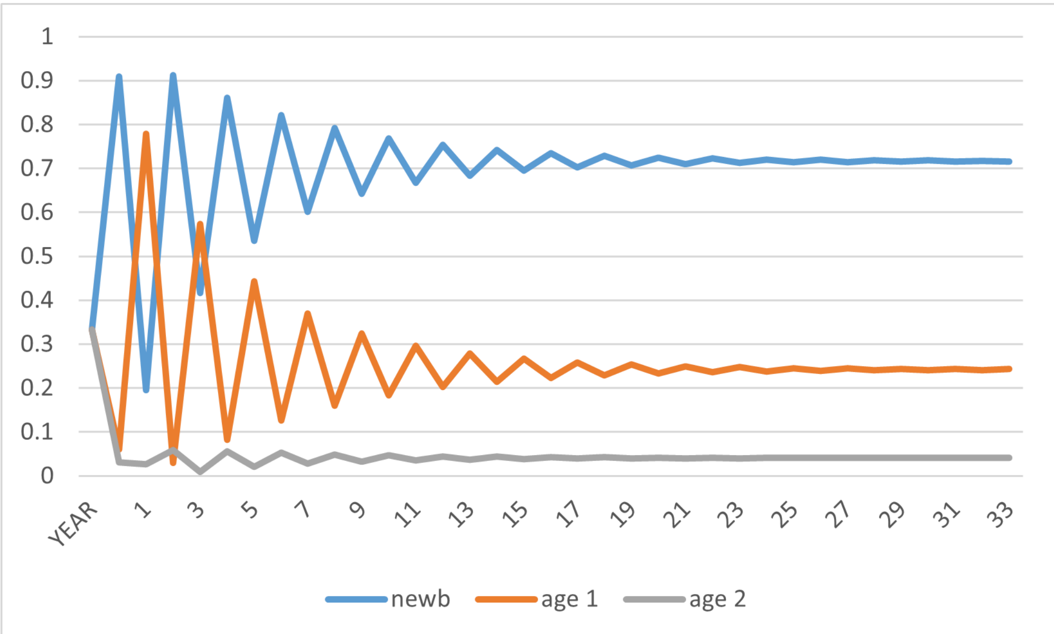
Table 14-1. Calculating Population Age Composition Using the Intrinsic Rate of Natural Increase

	Chance of surviving to next age	Number in this age group should be…	Which equals what? when r = .185	Number as a fraction of the total population
Newborns	40 %	Call this NN	NN	NN / 1.3877 NN = 0.72
One year olds	20%	.40 NN e^{-r}	0.3324 NN	0.3324 NN/ 1.3877 NN = 0.24
Two year olds	0%	(.20) (.40) NN e^{-2r}	0.0553 NN	0.0553 NN/ 1.3877 NN= 0.04
Total population	—	—	**NN(1+0.3324+0.0553) = 1.3877 NN**	**1.3877 NN/ 1.3877 NN = 1**

Column 3 of Table 14-1 gives us the number of gerbils in age category, expressed in terms of the number of newborns. Adding up the gerbils in each column 3, we see that the total population, once stability has been achieved, will be equal to 1.3877 times the number of its newborns. That is to say, the fraction of the population that is newborn is always 1/1.3877 or 0.72. The stable age distribution is 72% newborn, 24% one year old, and 4% two years old. We started with 33% of the population being newborns, 33% one year-olds, and 33% two year-olds, but once they were free to live their lives, reproduce, and die, the population converged to the 72:24:4 stable age distribution and to an intrinsic rate of natural increase of 18.5% every year.

Figure 14-6 below shows us that, after only 25 years or so, the gerbil population's age structure settles down to the 72:24:4 age distribution. The dark blue (top) line represents the share of newborns, the reddish line represents the share of one year-olds, and the bottom grey line represents the share of two year-olds. Initially, each group represented 33% of the population, since there were 10 of each age.

Figure 14-6. Population Age Structure over Time



Simulation by A. Hageman

Why does this population of gerbils gyrate up and down during the early years? It has to do with the inability of newborns to reproduce. At time zero, when one year-olds and two-year olds make up a majority of the population, many newborns will be generated for next year, so year 1 will see newborns become by far the majority (recall Figure 14-5). But these newborns cannot yet reproduce, so the fraction of the population which *can* reproduce in year one is smaller that it was at year zero. Consequently, newborns in year two will not be as dominant as they are in year one. In year two we will see more one year-olds than newborns. Meanwhile, one and two year-olds are experiencing heavy mortality, making it less and less likely over time that they can form a majority of the population.

So far we have used the Leslie matrix to predict what a population will look like once it stabilizes. But the Leslie matrix has a more general application. We can use the Leslie matrix to predict what a population will become in the future, even if fertility and survival rates are changing. We'll just have to keep updating our Leslie Matrix with the fertility and survival rates that apply to the year in question.

Application of the Leslie Matrix to the history of Ukraine

Let's move from discussing gerbils to discussing human history. Vallin et al. (2002) wanted to count crisis deaths in the Ukraine during the 1930s and 1940s. The problem was, no death statistics for Ukraine had been published between 1931 and 1954. Vallin and team found a solution. They began with a 1926 census of Ukraine. To predict how many people should have been alive in 1939, when there was another census, they applied a Leslie matrix or similar computations to the initial 1926 population age vector. For their Leslie matrix or similar computations they used survival rates from a model Life Table, representing countries which were similar to Ukraine but not experiencing crises. The difference between the projected number of people in 1939 according to their calculations, and the actual number in 1939 according to the census, gave them the number of missing people. They did the same thing between the 1939 and 1959 censuses.

There are three reasons that the actual population in a later census would be smaller than the population in an earlier census projected forward, three reasons why people would be missing.

The first reason is that some people left the country. A Leslie matrix does not deal with this possibility. The second reason is that fertility was actually lower than what was assumed when making the projection. And the third reason is that mortality was actually higher than was assumed when making the projection. Crises can cause extra deaths, extra emigration, lower immigration, and lower fertility.

Donetsk- Children digging for potatoes during the Holodomor, 1933. Photo by: Marko Zhelezniak. Credits to: HREC Photograph Directory.

Vallin et al. had used model Life Table survival rates to project the population. They had also made a conservative (i.e. low) estimate of what fertility would have been without the crises. If anything, this low-ball estimate of what fertility would have been without the crisis would underestimate the reduction in births due to the crisis. Vallin et al.'s approach can be summarized as follows.

STEP ONE

Project the population in 1926 forward to 1939 using 1926 census data for the initial population age vector, and using a Leslie matrix or similar procedure. The Leslie matrix is supplied with non-crisis age-specific survival rates from a model Life Table, and non-crisis fertility rates from similar countries.

subtract the actual population in year 1939

= *total population loss* (due to crisis deaths, births foregone due to the crisis, and net emigration)

STEP TWO

project the population in 1926 forward using 1926 census data in the initial population age vector and using a Leslie matrix with non-crisis age-specific survival rates but using estimated **actual** fertility rates

subtract actual population in year 1939

= population loss due to crisis deaths and net emigration

The difference between this and total population loss calculated earlier is the number of births foregone.

STEP THREE

Take your estimate of population loss due to crisis deaths and net emigration and

subtract estimates of net emigration

=population loss due to crisis deaths

By following these steps, Vallin's team was able to divide population loss between its three different causes. They concluded that although Ukraine's population grew between 1926 and 1939, it was smaller than it should have been, by 4.6 million people. That's on a base population of 29 million in 1926. Approximately 0.9 million people left the country, 1 million people were not born because of the crisis, and 2.6 million people died because of the crisis.

In this chapter we learned about stable and stationary populations, and how a constant age structure emerges when fertility and mortality rates are constant. We learned how to project populations forward using a Leslie matrix. We will now spend a few chapters discussing real-life changes in fertility, mortality, and the age structure.

Exercises: Chapter 14

1. You are given the following information for a population of gerbils.

a) Write the population projection matrix A that could be used to describe the mechanics of this population of gerbils.

b) If, initially, there are 100 gerbils age 0, and no other gerbils, what will the age vector, n +1, be in the next period?

Age Group	Probability of Death before Next Birthday	Number of Surviving Newborns per Female
0	0.7	0
1	0.4444	5
2	0	3

2. Given this population projection matrix,

$$A = \begin{matrix} 2 & 4 & 2 \\ 0.4 & 0 & 0 \\ 0 & 0.6 & 0 \end{matrix} \text{ and an age vector } n(t) = \begin{matrix} 100 \\ 80 \\ 50 \end{matrix} \text{, what will the age vector be next year?}$$

3. Consider a **different** population of gerbils with the same survival probabilities as have been given in question 2. You are told that the intrinsic rate of population ***decline*** for this new population is 5% per year. What is the stable age mix of this population (before it disappears!) What would the stable age mix be if the intrinsic rate of population **growth** was 5% per year?

4. If a population of gerbils is growing at 2%, and the population is stable, how fast is the population of newborn gerbils growing?

5. In a population of hamsters, 63% of the population is newborn, 24% are one year-olds, and 13% are two year-olds. Fertility is equal to 8 surviving young per female less than 1 year old, 16 surviving young per female over age 1 but less than two years old, and 4 surviving young for two year-old gerbils. This, however, is not the stationary situation. Imagine you calculate that, in the stationary situation, 61% will be newborn, 24% one year-old, and 15% two-year olds.

a) Is population momentum greater than one or less than one?

b) Will the population grow or shrink before it achieves its stationary size?

c) What kind of immigration or emigration could hasten achievement of the stationary population size?

6. If the population of polar bears in southern Hudson Bay is 1,000, and the projected stationary population is 800, what is this population's momentum? What must be true about the current age structure in the population?

7. Looking at Figure 14-1 in the text, we see that momentum was increasing in China prior to 1980. What does this mean?

Chapter 15: Demographic Transition and Changes in Dependency

Demographic History after 1750 AD

After 1750, the standard of living changed remarkably, first in England, and then in other nations.

The beginning of this new era of economic growth is usually referred to as the Industrial Revolution, as it was marked by key inventions such as the steam engine and the cotton jenny. The Industrial Revolution would be followed by a revolution in demographic trends which we call the Demographic Transition.

In a nutshell, the Demographic Transition consists of falling mortality rates followed by falling fertility rates. Population growth accelerates, then decelerates.

Having studied stable populations and stable age structures, we will now study a very unstable period of time known as the **Demographic Transition**. The Demographic Transition is powered by natural increase and decrease.

After 1750, the standard of living in market economies improved gradually, then ever more rapidly. Even today we enjoy a level of material comfort and convenience almost indescribable to our great-grandparents. This new era was kickstarted by an episode known as the Industrial Revolution. The Industrial Revolution would be followed by a revolution in demographic trends which we call the Demographic Transition.

Much scholarship has been devoted to explaining the causes of the Industrial Revolution, and to pinpointing exactly when it began. A combination of factors including literacy, social mobility, and cheap coal gelled to create an atmosphere in England that was conducive to research, innovation, and mechanization. Coal fires heated water into steam, and steam engines drove all kinds of farm equipment, locomotives, and pumps. Major improvements to cotton processing and thread spinning transformed the textile industry.

During the Industrial Revolution, England had access to cheap raw materials from its colonies. Indigenous peoples were being dispossessed, and Africans, enslaved. Population pressures in England were eased by the possibility of emigration to the colonies. Job opportunities for English young men with education were expanding.

In the early years of the Industrial Revolution, most British and European people were farmers, without insurance, banking services, education, or the right to vote in national elections. Over forty percent of Englishmen had no access to common land let alone private property[1]. Most of them worked as labourers. Naturally, many people were frightened by the development of machines – especially threshers, mowers, and other agricultural equipment – to replace manual labour.

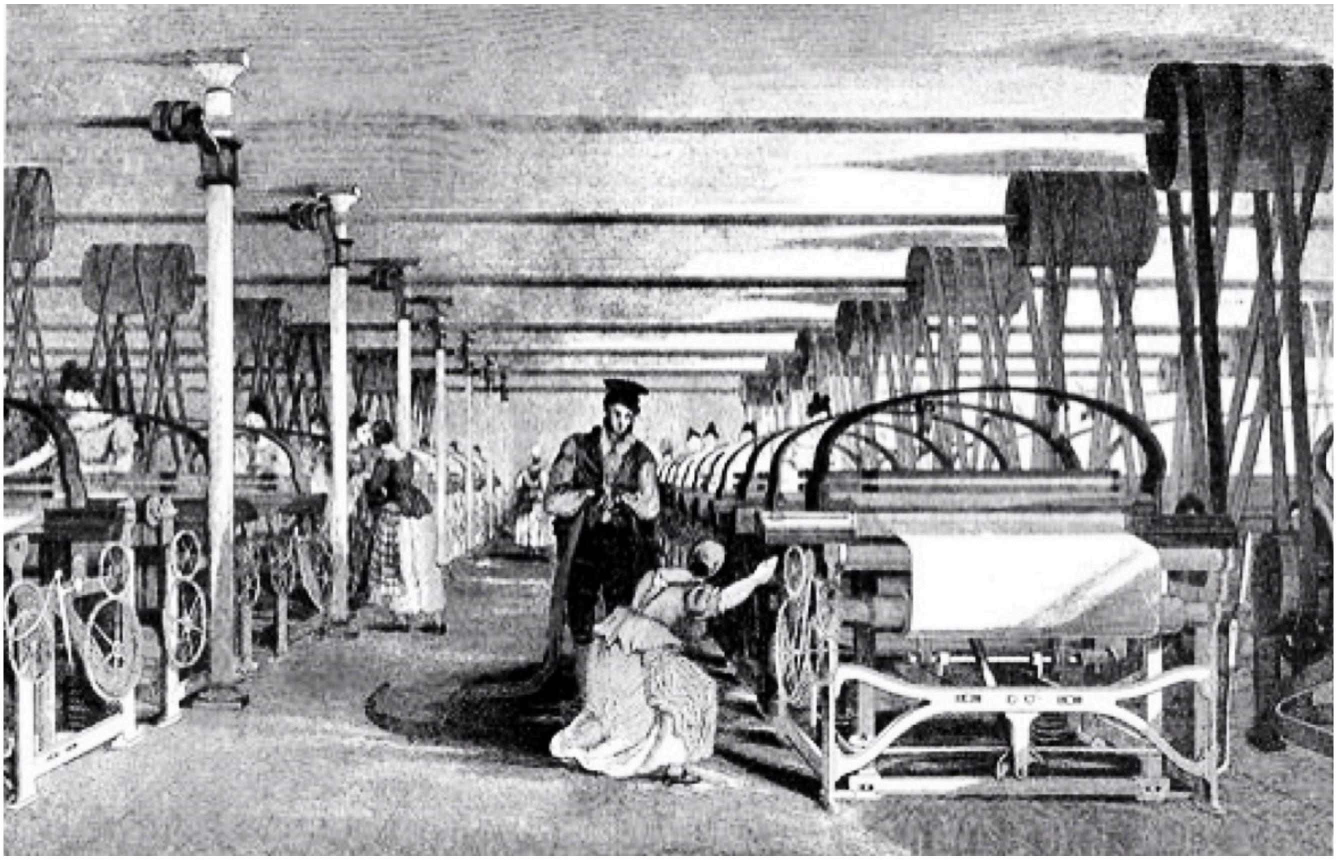
Class Discussion: How do you feel about improvements to artificial intelligence and the prospect of more AI in our lives? Whose wages and standard of living will be affected, and how? Can you relate to a peasant facing the technological changes of the Industrial Revolution?

One remarkable thing about the Industrial Revolution is that it raised the standard of living for most people. You might think that labour-replacing machines would erode the incomes of labourers. You might remember images of eighteenth and nineteenth-century London filled with beggars and shady characters from the writing of Charles Dickens and others. However, the Industrial Revolution lifted millions of people out of abject poverty. Clark (2008) presents data to show that the share of English national income going to unskilled workers actually rose during the Industrial Revolution. How could this be?

The Industrial Revolution replaced unskilled workers with machines, but it also replaced skilled workers with machines. It replaced poorer machines with more effective machines. It made machines better and more affordable. It also made land more affordable: no longer would vast acreages be needed to grow food for horses and oxen. Horses and oxen were being replaced by coal-fed machines like mechanical threshers and locomotives. Because of these changes, the premium earned by skilled workers, equipment owners, and landowners fell, helping unskilled workers. Unskilled workers benefited from opportunities in the colonies, or the cheap commodities imported from those colonies. Emigration of unskilled workers to the colonies eased downward pressures on the wage of unskilled workers in England.

1. Kumon, Y. (2021)

The Industrial Revolution was accompanied and facilitated by innovations in central banking and private finance. Loans became more plentiful and affordable, another reason that land, skilled services, and machinery became more accessible to unskilled workers.



Inside a cotton mill where power looms made fabric. Illustrator T. Allom – History of the cotton manufacture in Great Britain by Sir Edward Baines. Public Domain.

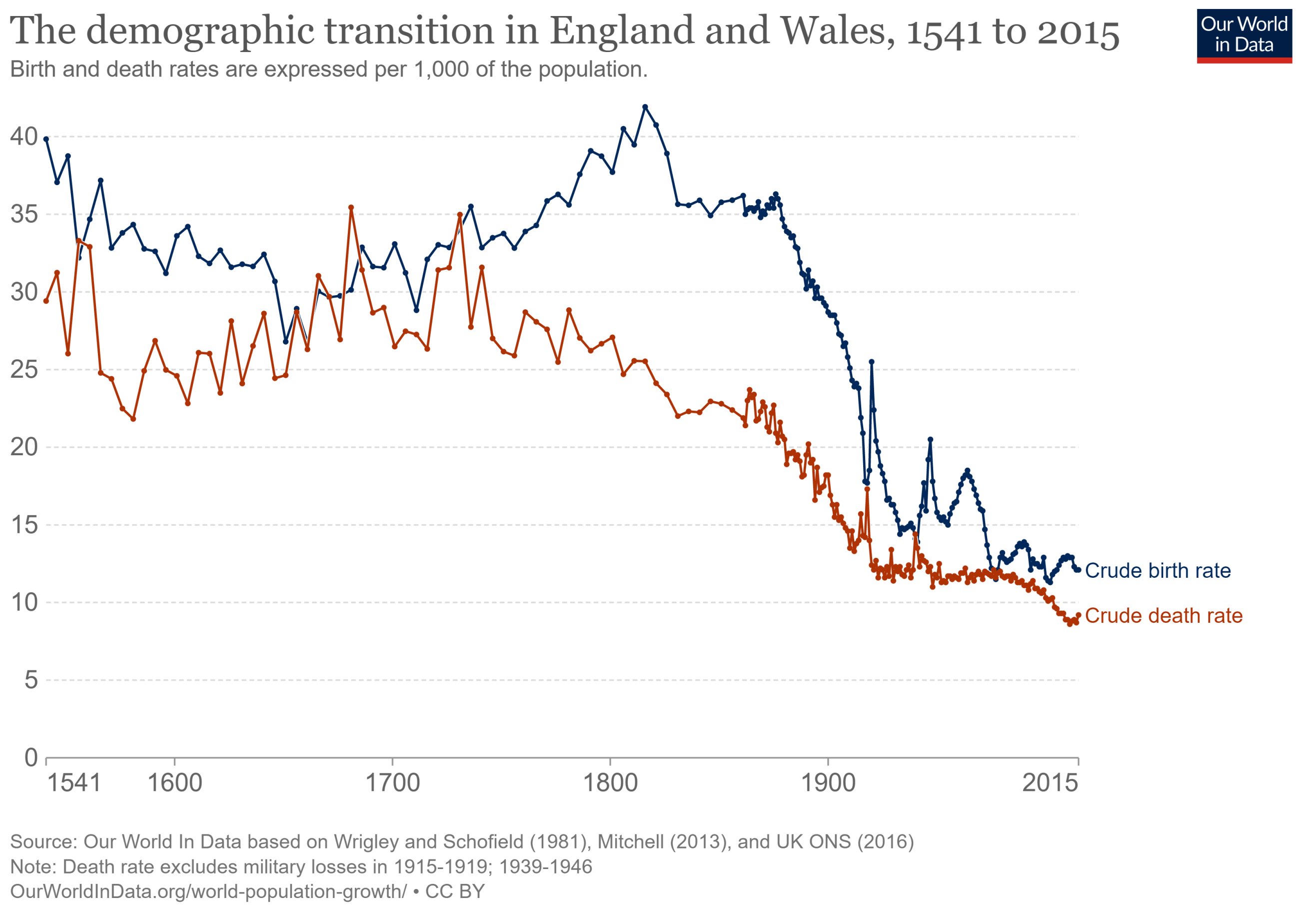
The cost of living fell as land prices and machinery prices fell. The cost of living fell as the price of soap, cotton fabric, sugar and other products new and old fell with mass production and with the importation of raw materials from colonists and slave plantations.

The Demographic Transition

In response to the rising standard of living in England, mortality rates in England began to fall, especially for children and young people. As shown in Figure 15-1, the crude death ratein England and Wales fell below the crude birth rate in the middle of the 1700s, and not until World War 1, more than one hundred and fifty years later, would the birth rate again get near the death rate. The gap between the birth rate and the death rate meant a growing population. As the number of people surviving to childbearing age began to increase, crude birth rates rose even more than they had been doing for the century before the Industrial Revolution.

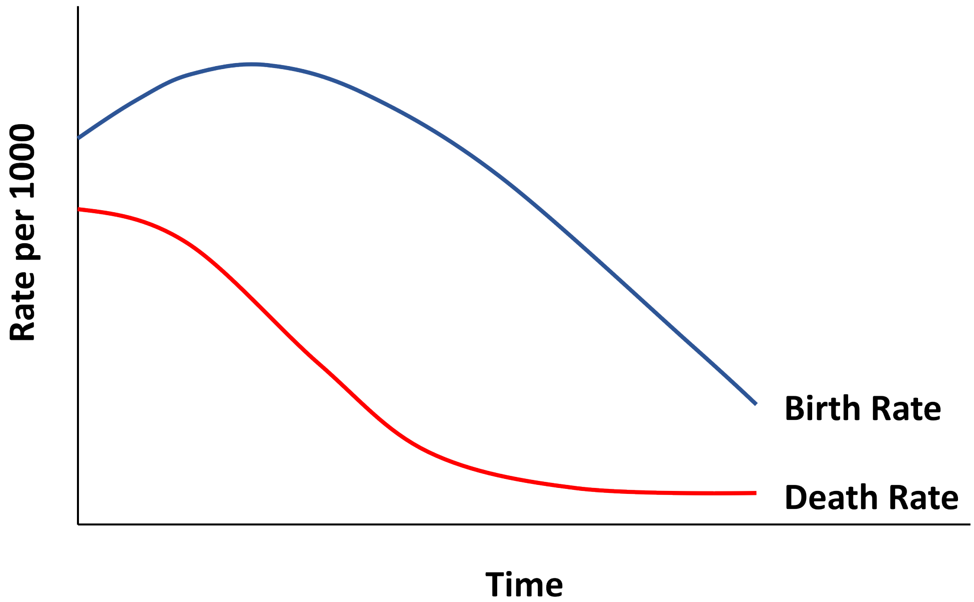
In about 1800, the birth rate in England began to fall despite the positive population momentum, implying that fertility rates were now declining significantly.

Figure 15-1



This pattern of demographic change, with death rates falling, and birth rates eventually falling whether or not they initially increased, accompanies economic modernization wherever it occurs and is known as the **Demographic Transition**. Figure 15-2 shows the typical pattern.

Figure 15-2. A Typical Demographic Transition



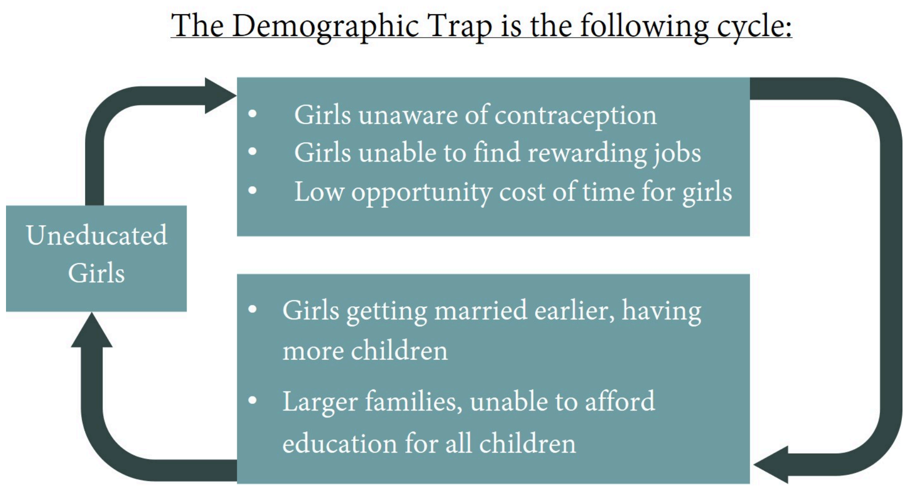
Jean-Claude Chesnais (1992) studied the Demographic Transition in sixty-seven countries. He examined data from the period 1720-1984 and concluded that "there are no two countries – even geographically and historically similar ones – that have traced the [exact] same course of transition…"

He did, however, uncover some common patterns:

1. The transition begins with a decrease in mortality. ALL transitioning countries experienced a decrease in infant mortality and child mortality before experiencing a decrease in fertility.
2. The mortality decline is usually accompanied by mass literacy, especially among females.
3. Fertility decline happens at some point. Improvements in female literacy may be necessary for fertility decline to occur. Economic development also seems to be needed for fertility to decline. (However, this was not the case for France, Bulgaria, or Sri Lanka. Recall from Chapter 11 that the *European Fertility History Project* emphasized secularization most of all.)
4. After fertility falls, marriage begins to occur later and less often.
5. Urbanization and high land prices seem to reduce fertility.
6. The higher the net reproduction rate, the higher the rate of emigration.

Notice Chenais' emphasis on female literacy. Without it, Demographic Transition may be thwarted by the **Demographic Trap**, shown in Figure 15-3.

Figure 15-3



Stylized by P. Galoustian.

Comparing societies before and after industrialization, as we do in Table 15-1, we see that innovation accelerates, mortality falls, and fertility falls. Hence our ability to feed ourselves grows as our population grows. There is no guarantee, however, that this happy dynamic will continue forever.

Table 15-1. Comparison of Pre- and Post-Industrial Eras

	Pre-modern	Modern
Technological change	Rare	Continuous
Fertility rates	High	Tend to be low
Mortality rates	High	Low
Standard of living	Precarious	A stronger base from which to weather crises and build for the future

Dependency Ratios and Demographic Transition

During the demographic transition, population growth accelerates, then wanes. The age structure of the population also changes. Dependency ratios and population pyramids help us describe the changes in age structure.

The Child Dependency Ratio a.k.a **Young Dependency Ratio** (YDR) is the number of children per working age person, commonly computed as persons age 0-14 divided by persons age 15-64. The Aged Dependency Ratio is the number of older people per working age person, commonly persons age 65 and older divided by persons age 15-64. According to the World Bank, in 2022 Canada had a CDR of 0.24 and an ADR of 0.24. Table 15-2 shows the 2022 dependency ratios in Canada compared to those in a selection of African countries, and Japan.

Table 15-2

Dependency Ratios, 2022

Country	YDR	ADR	TDR
Democratic Republic of the Congo	92	6	98
Sudan	74	6	80
Kenya	64	6	69
Morocco	40	5	52
Canada	24	24	48
Japan	20	51	71

Data Source: data.worldbank.org

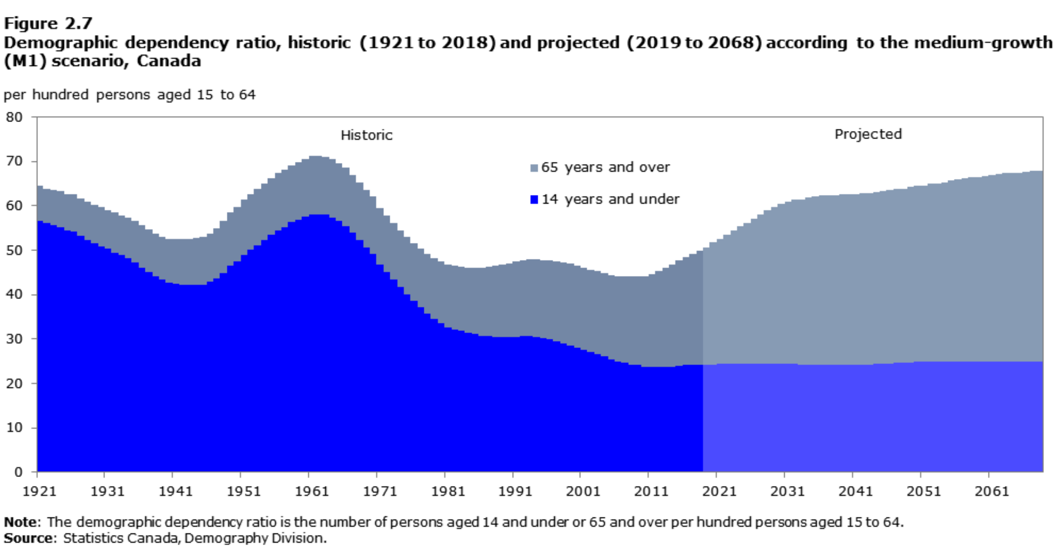
The **Total Dependency ratio**, (TDR) is equal to the Child Dependency Ratio plus the Aged Dependency Ratio. Canada's 2022 TDR was 0.48.

Depending on the situation, you may wish to modify the dependency ratio calculations.

> → For example, Canada often uses a YDR that includes everyone under the age of 20, not 15. Why?
>
> → If you have a population of seniors that is very healthy, many of whom work, you may wish to form an ADR using only older seniors in the numerator, for example people aged 75+.
>
> → If you have a population where the working age people are stricken with illness, for example during the HIV crisis in Southern Africa, you may wish to include in the denominator of your dependency ratios the number of working age adults who are healthy. This "effective dependency ratio" was used by Drimie (2004).

Looking back at Canada's recent demographic history using Figure 15-4, we see that Canada's Total Dependency Ratio rose during the 1940s and 1950s, fell during the 1960s and 1970s, and began to rise in a sustained way around 2010.

Figure15-4. Canadian Dependency Ratios, Past and Projected



Source: Statistics Canada (Sept. 2019)

Figure 15-4 shows us that young dependency in Canada was about twice as high in 1921 than it was in 2018. Young dependency fell steadily until 1941, but surged after World War II as the Baby Boom Generation was born. Young dependency reached a local peak in the early sixties, and fell until the mid-nineties when there was a bump representing the grandchildren of the Baby Boomers.

Aged dependency in Canada has been growing since the late 1970s. It is currently propelling an increase in total dependency; however, total dependency is not predicted to be much higher in 1968 than it was in 1921.

As countries pass through the demographic transition, their dependency ratios change in a fairly predictable way which can be visualized using population pyramids.

Population Pyramids

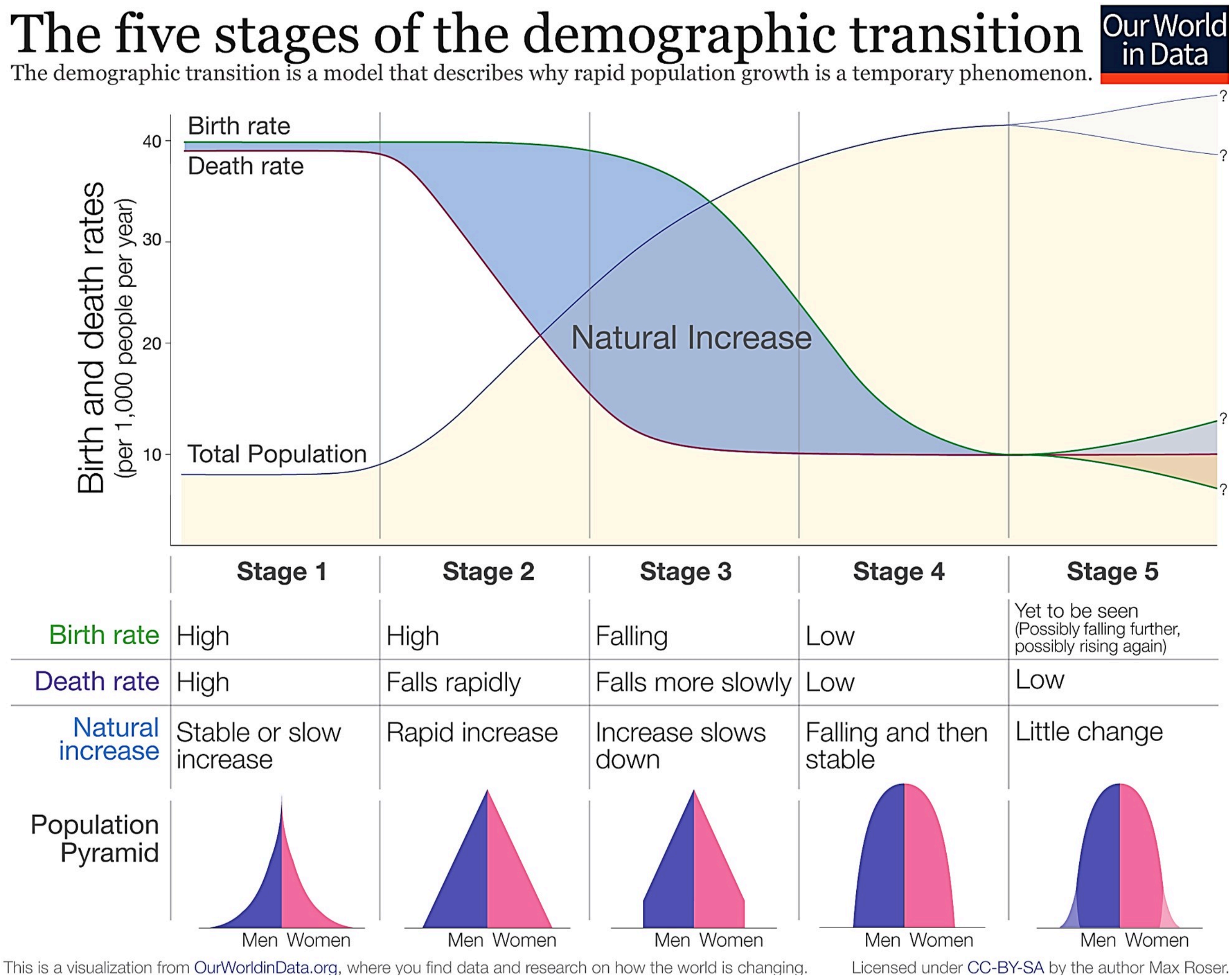
The detailed age and sex composition of a population can be seen at a glance in a **population pyramid**. The various age groups ascend the vertical axis, while along the horizontal we see the number of people or the proportion of people in each age group: to the left, we see the males; to the right, we see the females.

The five-year age groupings are popular because, in interviews, people tend to round their ages to numbers ending in 5 and 0.

Population Pyramid Shapes

Figure 15-5 below, which is highly stylized, shows us how a nation's population pyramid changes as it goes through the Demographic Transition.

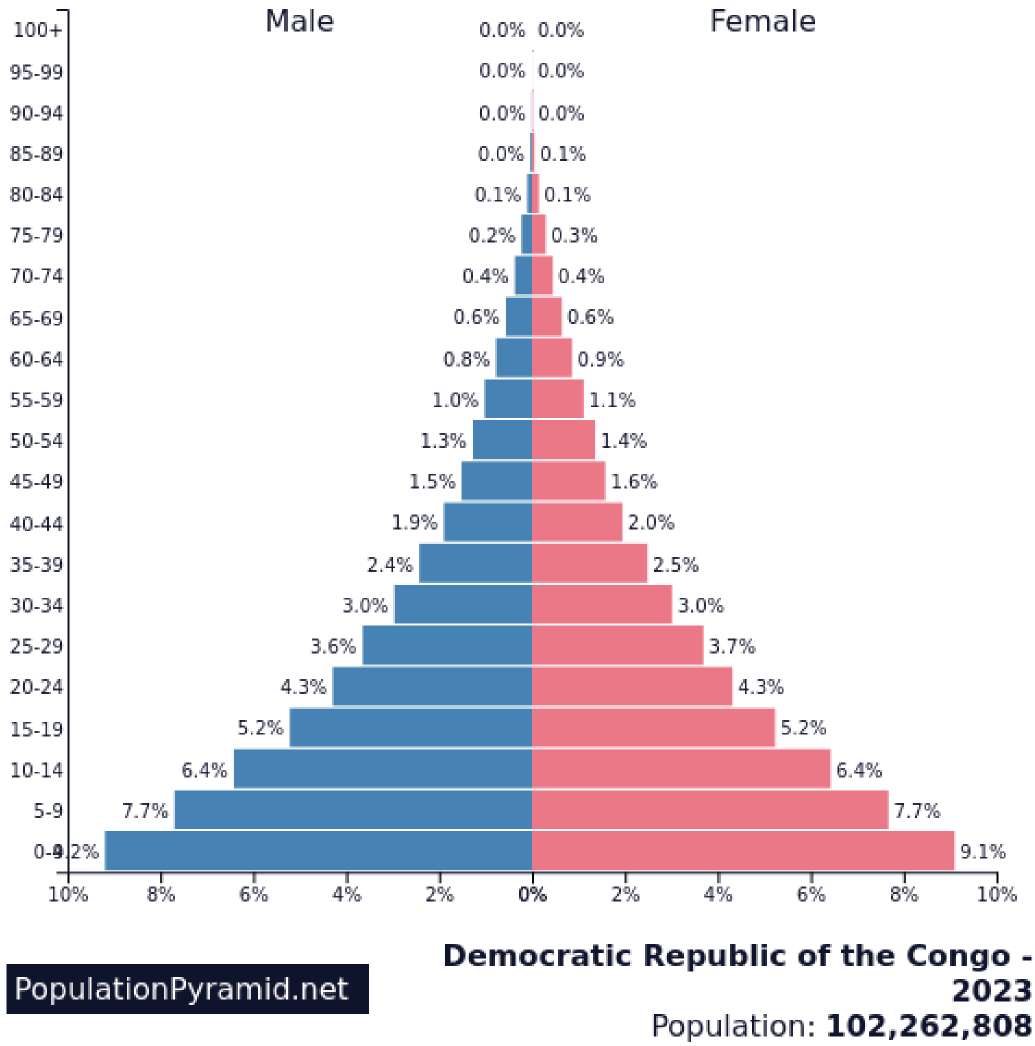
Figure 15-5



In Stage 1, before the Demographic Transition really begins, human societies have high birth and death rates, and especially high infant and child mortality rates. This means that the bottom of the pyramid is wide (many newborns), and that the width tapers off rapidly (many deaths in infancy and childhood). Young dependency is high because there are many newborns but far fewer adults. Aged dependency is low, because not many people survive to older ages. Total dependency is high.

Figure 15-6 is an example of the Phase 1 shape. It was expected that 18.3% of the population of the Democratic Republic of the Congo would be under five years of age in 2023. In 2022 there were 92 children under 15 years of age for every adult of working age. Each successive age group was smaller in number, and the convexity of the pyramid indicates high death rates even for younger people. Less than five percent of the population is over sixty years old. Over 55% of the population is under twenty years of age.

Figure15-6. Population Pyramid of Democratic Republic of the Congo, 2023 est.



Downloaded 2023

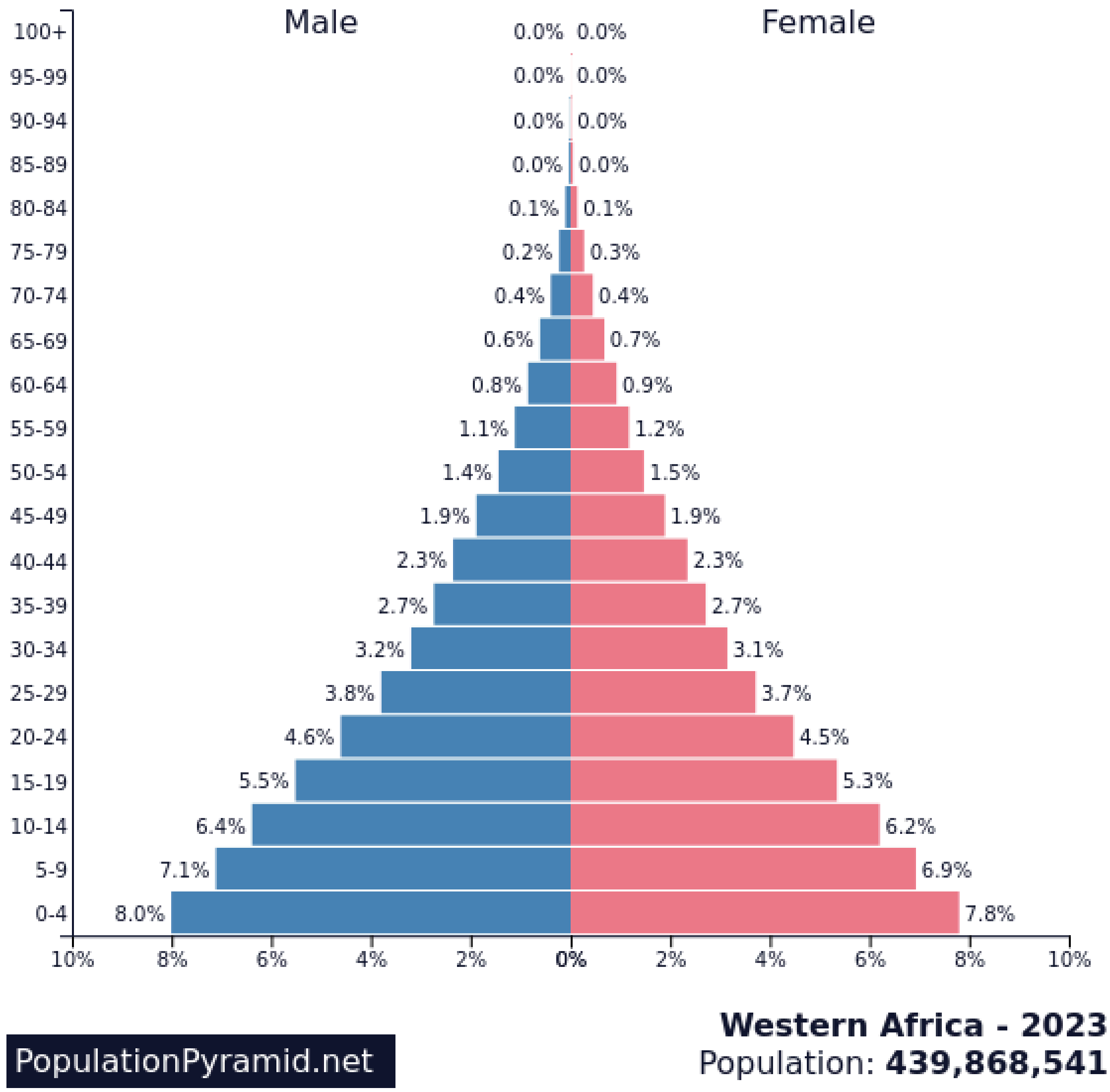
Stage 2 of the Demographic Transition

In the early phase of the Demographic Transition, the death rate falls, mostly because of decreases in infant and child mortality. You may remember this from Chapter 9. These decreases will tend to increase the Young dependency ratio (YDR), and consequently, the total dependency ratio (TDR). If birth rates are increasing too, YDR and TDR will increase even more.

This pressure will ease somewhat as more youths survive into adulthood and working age.

In Figure 15-7 we have a population pyramid that is less convex overall. In Western Africa in 2023, it is mostly the older age groups that seem to have high death rates. The fraction of population that is under the age of 5 is still high, but less so than it was in DRC. The fraction of the population than twenty years old is less, though still over fifty percent. The fraction of the population over age sixty is about the same.

Figure15-7. Population Pyramid of Western Africa, 2023 est.

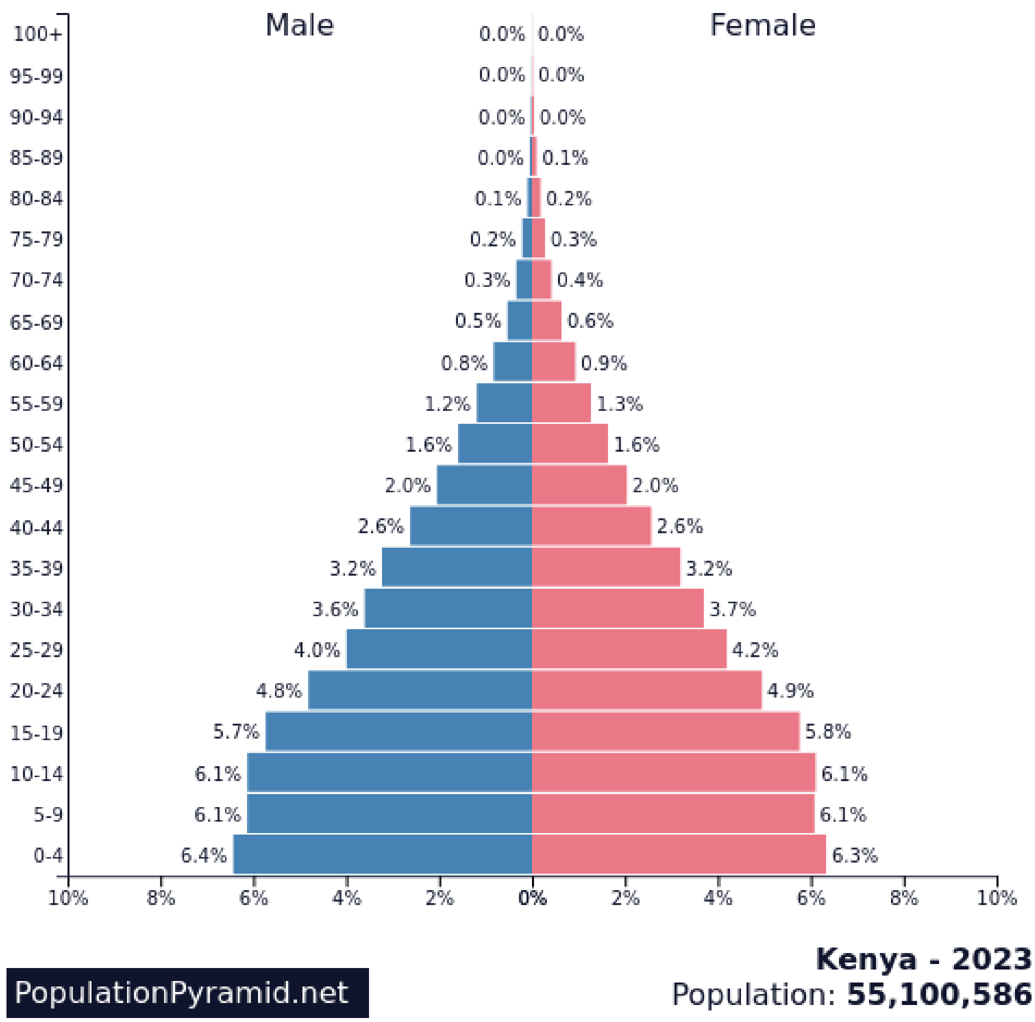


Stage 3 of the Demographic Transition

In the middle of the Demographic Transition, birth rates fall and the base of the pyramid shrinks, settling into a rectangular shape. Child dependency falls, but ADR is not moving much since there are not yet that many people surviving into old age. Old-age mortality is the last category of mortality to experience reductions. Total dependency falls. It is at this point that society has the potential to earn a **Demographic Dividend**, as will be discussed in more detail in Chapter 17.

Kenya is a good example of this, as shown in Figure 15-8. Again, less than 5% of the population is over the age of sixty, but only 13% of the population is under the age of five. Slightly less than half the population is under the age of twenty. In 2022, there were only 5 people over age 65 for every 100 working age people.

Figure15-8. Population Pyramid of Kenya, 2023 est.



Downloaded 2023.

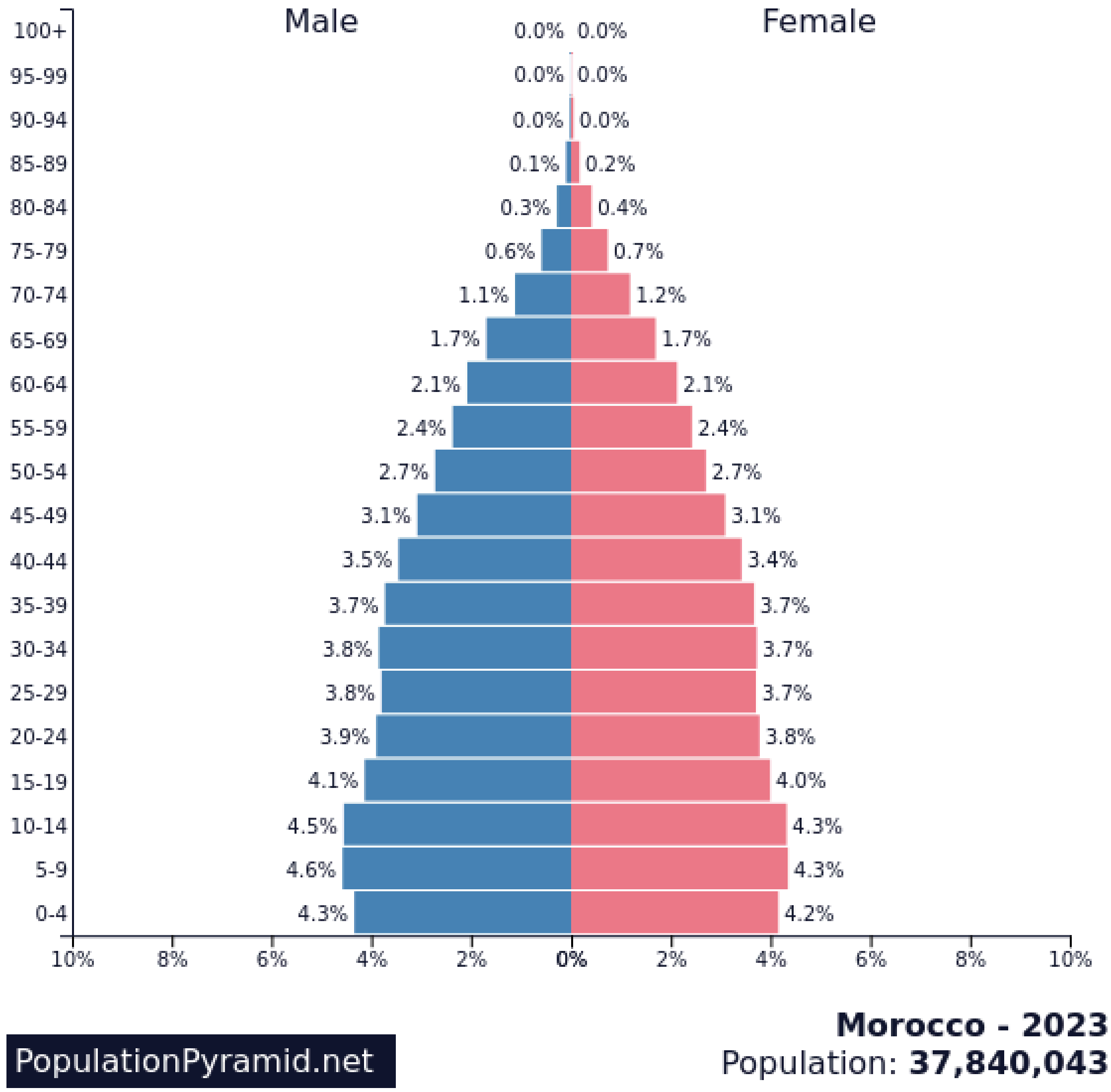
Stage 4 of the Demographic Transition.

In the late phase of the Demographic Transition, infant and child mortality remain low, and the birth rate continues to drop. Now that more older adults are surviving, the population is aging. The Aged Dependency Ratio rises. It may rise to the point where the Total Dependency Ratio is rising as well.

The population pyramid may begin to resemble a **muffin** as young cohorts are smaller and the older cohorts are persistently large. If fertility continues to decline, the muffin may stretch into a kite. Eventually, a Stage 4 population with stable birth rates will be tall and rectangular.

Figure 15-9 shows us the population pyramid predicted for Morocco in 2023. There is not much tapering going on until middle age, and convexity is not seen until age 70. Finally, more than five percent of the population is over sixty years of age; in fact, more than twelve per cent is over sixty years of age. Less than thirty-five percent of the population is below the age of 20. In 2022 the Total Dependency Rate was 62 dependents for every 100 working-age people.

Figure15-9. Population Pyramid of Morocco, 2023 est.



Downloaded 2023.

Stage 5 of the Demographic Transition

The most economically-developed nations of our world have passed through the demographic transition, and their rates of population growth have greatly declined. In fact, more than half of the world's population lives in regions where fertility is less than replacement[2]. However, many of the word's less economically-developed nations are still in Phase 2 of the Demographic Transition where death rates have fallen but birth rates remain high.

According to Sciubba (2022), the world's population growth rate is slowing down. Whereas in 1950 there were 1.73 more births per thousand than deaths, by 2022 natural increase had fallen to 0.84 per 1000. It is now taking us longer to add successive billions of people to our planet.

The United Nations estimated in 2019 that we will reach a plateau of about 10.9 billion people in 2100, assuming continued mortality reductions, reductions in fertility in countries where the Total Fertility Rate is still high, and a slight increase in fertility in countries where the Total Fertility Rate is below 2.0 children per woman. [3]

What will happen for the world population beyond 2100, or even before then in individual nations? Will Stage 5 feature population shrinkage, with birth rates below death rates, and countries competing for immigrants? We will have to wait and see.

In the 1930s, demographers worried about declining birth rates. The baby boom that occurred after World War II put an end to their worries. Thirty or forty years ago academics and the media were worried about exploding population and environmental collapse. In the last ten or twenty years, attention has turned to the aging populations of the West and Japan, and the spectre of a shrinking labour force.

We should never panic, but remember that fertility and other decisions which bring about population change depend on the individual decisions of millions of fundamentally unpredictable people who singly and collectively influence and are influenced by social norms and economic pressures, and who may have a spirituality and sense of purpose capable of transcending any status quo.

Exercises: Chapter 15

Use the data in the chart below to answer questions 1-6.

2. United Nations (2020), World Population Prospects - Highlights, p. 2.
3. Ibid., p. 5.

Age	Male	Female
0-15	105	100
16-36	89	80
37-67	65	75
68+	55	60

1. Construct an age-sex pyramid for this population. Let the horizontal axis show the percentage of the total population, rather than the raw numbers. (If using a spreadsheet, put a negative number in front of the numbers in the Male column to generate the left-hand-side of the pyramid.)

2. What is the Child Dependency Ratio, the Aged dependency ratio, and the Total Dependency Ratio?

3. How do these dependency ratios compare to Canada's?

4. Roughly speaking, this pyramid most closely resembles what phase of Demographic Transition? (The grader would be looking more at your reasoning than at your assertion.)

5. What can you guess by looking at the sex ratios at each age?

6. What would the effective dependency ratio be if 20% of people between 16 and 36 years of age are addicted to heavy drugs?

Chapter 16: Age Structure and the Economy

During a demographic transition, the age structure of a society changes, with implications for the economy. Let's trace these out.

In our previous chapter we learned how the age structure of a population changes during the demographic transition. Here we will examine the impacts of those changes on the economy.

Age Structure is not everything

Though the age structure can influence the economy, a country's economy is influenced even more by its past history, its capital stock, and its current governance than by its current demographics. For example, let's compare Bangladesh and Japan. In 2020, according to the World Bank[1], Japan had a population which was 25% smaller than Bangladesh's. Japan also had a lower fraction of its population between the ages of 15 and 64 (58% versus 68% in Bangladesh). Its Aged Dependency Ratio was .51 compared to .08 for Bangladesh. Yet somehow Japan's workforce was measured to be roughly the same size as Bangladesh's, 69 million for Bangladesh vs. 71 million for Japan.

Class Discussion

What can explain the proportionately large labour force in Japan compared to Bangladesh?

Despite having two million fewer people working, and despite those workers being older on average, Japan

1. data.worldbank.org

had a GDP which was more than thirteen times higher than that of Bangladesh, or more than five times higher when adjusting for the difference in the cost of living between the two countries.

Though age structure is not the most important consideration when explaining national income or national income per person, in this chapter we take a look at what role it may play.

Age Structure and GDP per person

Let's use Y to represent output like gross domestic product (GDP), or GNP, NDP, NNP, Green GDP, Green GNP, etc. This model is going to be real, measured in stuff, not dollars. It won't show prices or inflation.

N represents population size. So Y/N is output per person.

Output per person, Y/N, can be broken down into three components like this:

Equation 16-1. $Y/N = Y/H * H/L * L/N$

In other words,

output per person = output per worker hour * hours per worker * fraction of the population which works

There are then three ways to improve output per person: by increasing output per worker hour (known as labour productivity), by increasing the number of hours worked per worker, and by increasing the fraction of the population which is working.

Please note the following important point:

Output per person has nothing to do with the absolute size of the labour force.

Fiscal Dependency

What about the amount of money that governments spend on health care and other supports for older adults? Might that reduce GDP?

Spending does not necessarily affect income. Just because you are spending a lot on your elderly parents doesn't mean your income has declined.

While money spent on particular groups affects the amount of money left for other groups, it doesn't mean that income has declined. Taxes and transfers cancel out; they don't reduce GDP per person unless they discourage productive activity or productive investments.

Age structure and hours worked per worker (H/L)

What is the affect of aging on H/L, hours worked per worker? We can expect that to lessen as workers age, though some older workers will be working more hours than very young workers or workers who also have caregiving responsibilities to children and elders.

Age structure and the fraction of the population that works (L/N)

The fraction of the population that works is inversely related to the Total Dependency Ratio, so we expect it to be lower for very young and very old populations. It will be highest in Stage 3 of the Demographic Transition, when both birth rates and elder survival are low.

Defining the Total Dependency ratio as the number of Canadians less than 20 years old and older than 65 years old divided by the number of Canadians between the ages of 20 and 65, Denton and Spencer (2019) estimated that the Total Dependency Ratio will increase from 0.383 in 2016 to 0.45 in 2036, then stabilize for at least ten years. Tracking the population by age and sex and likely employment rates, they calculated that, due to increasing aged dependency, GDP per person in 2036 will be only 91% of what it was in 2016, all other things being equal.

But not all things need remain equal. Denton and Spencer show that increasing the labour force participation rate for those over age 65 by 50%, reducing unemployment rates by 33%, and increasing hours worked for each worker by 20%, all by 2026, would be enough to keep GDP per person constant.

There are natural limits to how high we can get the labour force participation of 20-65 year-olds and 65+ year olds; there are structural limits to how low we can get the unemployment rate; and there may be natural, cultural, and political limits to how high we can get hours worked per worker.

So it is likely that aging will be associated with a falling fraction of the population that works, as well as reduced hours per worker.

Knowing what we do now about H/L (hours worked per worker) and L/N (fraction of the population that works), and realizing that multiplying them together gives us hours worked per person

Equation 16-2 H/N= H/L *L/N

let's fill in the middle column of our chart.

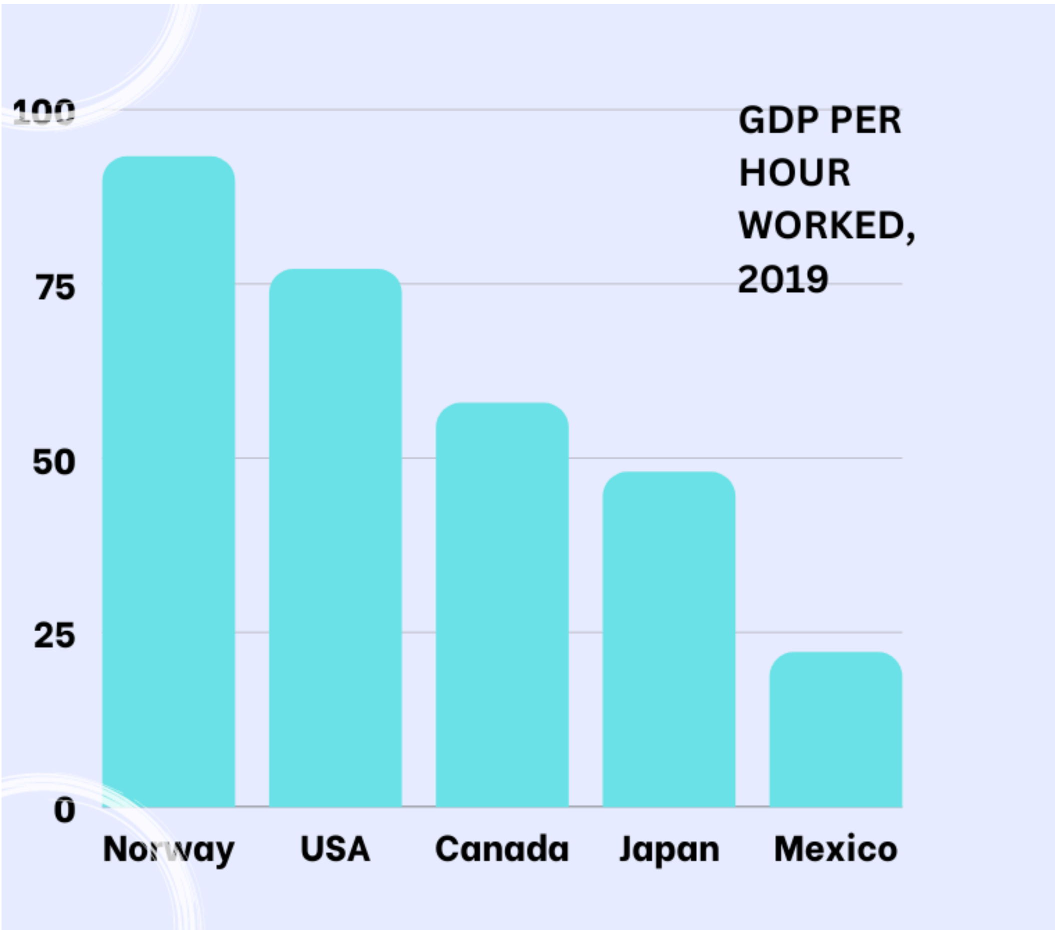
Table 16-1. Output per Person and Demographic Transition

Stage of Demographic Transition	Y/H Output per hour	H/N Hours worked per person	Y/N Output per person = Y/L * L/N
Stage 2: Young population		Falling due to rising child dependency	
Stage 3: Relatively large Labour force		Rising due to falling child dependency and low aged dependency	
Stage 4: Older population	.	Falling due to rising aged dependency	

Age structure and labour productivity (Y/H)

Besides possibly increasing the fraction of people working or the hours worked per worker, we may be able to increase output per person by increasing **labour productivity**. Labour productivity is output per worker hour.

Figure 16-0



Graphic created by A. Hageman using canva. Data source: "Cross-Country Comparisons of Labour Productivity Levels" in Compendium of Productivity Indicators, OECD (2021)

We see in the graphic above that in 2019, Norway's GDP per hour worked was more than four times that of Mexico's. The GDP is measured in US dollars and adjusted for differences in each country's prices, so it measures physical output. Norway was literally producing four times as much in marketed goods and services **per hour** than was Mexico.

Going back to our comparison of Bangladesh and Japan, Japan's higher labour productivity has allowed Japan to enjoy a high level of output per person despite decreases in the fraction of the population working and an aging workforce.

It's usually assumed that a worker's personal productivity rises, then falls, over the course of their working life. Denton and Spencer (2019), in their study of the Canadian labour force, estimate that decreases in productivity due to the Canadian workforce becoming older could slightly aggravate the loss in GDP per person due to a smaller fraction of the population being working age. For example, instead of GDP in 2036 being 91% of its 2016 level, it would be 90.7% if older workers are less productive.

They go on to estimate that, instead of improving employment rates and increasing hours worked to keep

Canada's GDP per capita steady to 2036, it would be sufficient to increase overall labour productivity by 0.62% per year 2016-2026 and by 0.33% per year 2026-2036. These rates are manageable when compared to the 0.76% average annual growth in labour productivity achieved during 2006-2016.

How to improve Labour Productivity? Labour Productivity is known to depend two things: the capital-to-labour ratio, and the efficiency with which capital and labour are combined.

Efficiency, denoted by "A", can be improved with new technologies and techniques. It can also be improved by increasing the degree of competition, increasing worker motivation, and improving infrastructure. It is not the quality of labour or the quality of capital; it is not labor efficiency or capital efficiency; it is *overall* efficiency, sometimes called "**multifactor productivity**" or "**total factor productivity**".

As the workforce ages, it may become less innovative and less able to cope with technological change. So labour productivity may decline due to a loss of efficiency. On the other hand, an older workforce embodies a lot of experience and institutional knowledge.

The capital-to-labour ratio or capital:labour ratio tells us how much capital is available per worker-hour. Call it K^+/L. K normally represents physical capital like tools, equipment, computers and software, buildings, laboratories and roads. However, other forms of capital are also important to labour productivity, such as human capital (skills, knowledge, attitudes, health), environmental capital, and financial capital. Let's include all the different kinds of capital in K^+.

The capital-labour ratio likely increases through the Demographic Transition, *ceteris paribus*. In Stage 2, public and private savings that could be used to invest in capital are diverted to looking after the growing fraction of children and youth. The labour force begins to grow, and capital may not be able to keep up. This is called **capital shallowing**.

In Stage 3 of the Demographic Transition, dependency is low. Savings can be channeled to investments in the productive capacity of the economy. The labour force is growing rapidly, but capital might be able to keep up if the nation can borrow at affordable interest rates, if savings and borrowing are invested in the domestic economy, if the economy is well-run, and if foreign investors are not easily spooked.

In Stage 4 of the Demographic Transition, dependency begins to climb as older adults become an increasing share of the population. Though people in their sixties begin to spend their savings, people over sixty-five typically still have a fair amount of savings which can be invested in the productive capacity of the economy. That is one reason that interest rates have been so low in the western world in recent decades. Meanwhile, the labour force is not growing much, so the capital:labour ratio can stay strong.

Let's fill in the first column of our table with what we've learned.

Table 16-2. Output per Person and Demographic Transition

Stage of Demographic Transition	Y/H Output per hour	H/N Hours worked per person	Y/N Output per person = Y/L * L/N
Stage 2: Young population	Efficiency high but savings diverted, leading to capital shallowing.	Falling due to rising child dependency	
Stage 3: Relatively large Labour force	Efficiency high. Labour force growing rapidly but savings available to obtain capital if possible.	Rising due to falling child dependency and low aged dependency	
Stage 4: Older population	Efficiency may be lower, but plenty of capital per worker.	Falling due to rising aged dependency	

Finally, let's fill in the last column to come to some conclusion about output per person.

Table 16-3. Output per Person and Demographic Transition

Stage of Demographic Transition	Y/H Output per hour	H/N Hours worked per person	Y/N Output per person = Y/L * L/N
Stage 2: Young population	Efficiency high but savings diverted, leading to capital shallowing.	Falling due to rising child dependency	Some demographic stress on the economy.
Stage 3: Relatively large Labour force	Efficiency high. Labour force growing rapidly but savings available to obtain capital if possible.	Rising due to falling child dependency and low aged dependency	Possible Demographic Dividend of rising output per person if savings can be invested productively and jobs can be created.
Stage 4: Older population	Efficiency may be lower, but plenty of capital per worker.	Falling due to rising aged dependency	Some demographic stress on the economy.

In summary, both young populations and aging populations are potential sources of stress on the material standard of living due to rising dependency and indeterminate effects on labour productivity. By contrast, Stage 3 of the Demographic Transition, where dependency is low and there is a large fraction of the population of working age, offers potential benefits known as the **Demographic Dividend**.

Discussion Idea

What could a four-day workweek mean for the standard of living and for well-being?

Age Structure and Wages

Anytime the age structure of society changes, various markets are affected – the labour market and wages, the loanable funds market and interest rates, the housing market, and the education market in particular.

When the labour force is rapidly growing, as in Stage 3 of the Demographic Transition, we expect wages to come down and jobs to be more difficult to find. In Stage 4, with labour force growth slowing down, there should be more job opportunities and higher wages. What about Stage 2, when the population is beginning to grow, and the labour force is not yet a large fraction of the population? A shortage of capital may limit the number of jobs or how well-paid they are.

Age Structure and Interest Rates

Interest rates are the prices for various kinds of loanable funds. Interest rates are going to be high anywhere that loans are expensive.

In the second stage of Demographic Transition, there may be a shortage of loanable funds because savings are being diverted to provide for children and youth. As well, most of the people in the population are young and not at the stage of life where they save. Meanwhile, there will be a growing demand for mortgages as the growing population seeks housing. Expect interest rates to be high.

In the third stage, where the working force is a large part of the population, things are more balanced. While there is still strong demand for housing and for business loans and equipment, there is now a strong supply of loanable funds as the number of people working and saving has increased and the dependency ratio is low. Expect interest rates to fall, other things being equal.

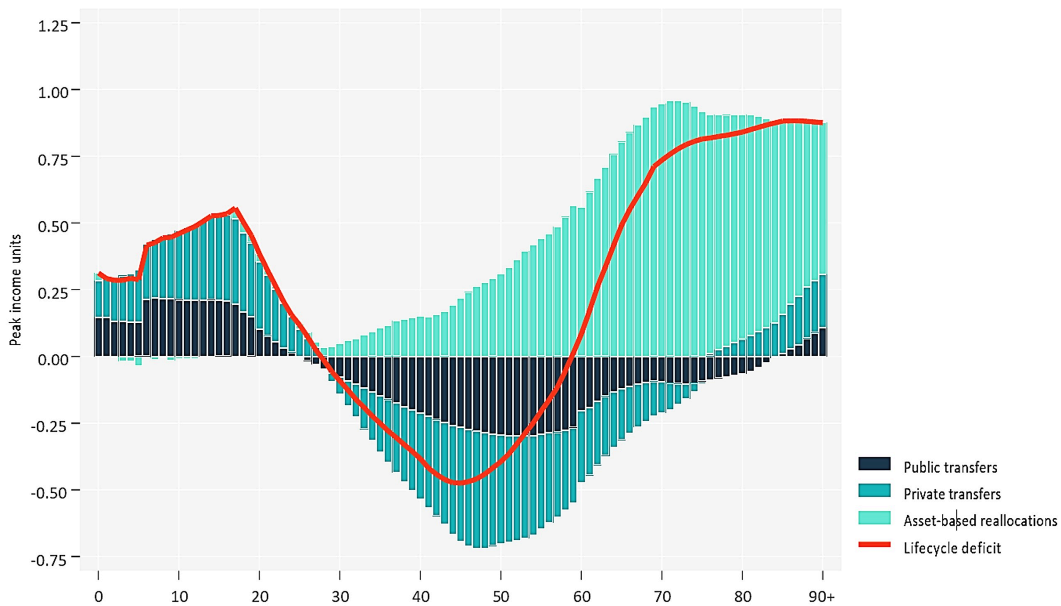
In the fourth stage, where the population is aging, interest rates may be lower yet. Demand for mortgages and business loans may be lower, as the population and the workforce is growing more slowly. Supply of loanable funds is still high as older workers save more than younger workers, and retired workers spend their savings only gradually.

Spending over the Life Cycle

Figure 16-1 shows us consumption and income for a typical person at each age in South Africa, in 2015. The red line shows the difference between consumption and income. Instead of dollar amounts being shown, all amounts have been divided by the average labour income for 30-49 years-olds ("peak labour income").

We see that South African newborns, children and youth of course consumed more than they earned in 2015, since children typically cannot earn. Their consumption was paid for by the government (dark blue bars) and their family (medium blue bars). They saved some money (light blue/turquoise bars).

Figure16-1. Financing the Life Cycle Deficit, South Africa (2015)



Source: Figure 2 of Oosthuizen (2019)

South Africans in their late twenties were paying their own way by consuming about the same value as what they earned. South Africans age 30ish to age 60ish were net earners; consumption was less than income, which is why the red line is in the negative region of the graph. People ages 30-60 paid taxes to the government (dark blue) and spent money on their family (medium blue). They also enjoyed returns on their investments (light blue), such as living rent-free in a home they owned. Between ages 60 and 75, South Africans consumed more than they earned (red line is above zero), even though they continued to pay taxes and support family. Investment income, and also the liquidation of savings, made this possible. Investment income was also the chief source of support for South Africans in their late fifties and older.

We see that, in this example,

- most taxes were paid by people in their forties and fifties
- most government transfers were received by people under the age of 25 and over 85
- people between the ages of 30 and 69 earned more than they consumed. Individuals ages 38 to 57 earned the highest incomes.

If we graphed savings by age, we would see that savings is done mostly by people who have been working for some time. The amount saved grows as workers age, and peaks right before retirement. After that, the amount saved may decline as retired adults begin to use up some of their savings. The decline in savings is steepest near the end of our lives when we require nursing care. The outline of savings over the life cycle would look similar to the outline of investment income over the life cycle in the graph above.

In 2019 the average net worth (savings[2] minus debt) of Canadians under 35 was $48,800; for Canadians ages 35-44 it was more than four times higher, at $234,400; for Canadians ages 45-54 it was $521,100; for Canadians ages 55-64 it was the highest, at $690,000 (about three times as high as it was for 35-44 year olds); and for Canadians 65+ it was $543,200.[3]

In our next chapter we'll summarize the special challenges of young populations and of aging populations, and we'll discuss the issue of intergenerational fairness.

Exercises: Chapter 16

1. The United States typically has higher GDP per person than Canada. Imagine why using Equation 16.1.
2. Trace the possible consequences of immigration on GDP per person using Equation 16.1.
3. How would a prolonged period of high interest rates affect a young, growing population?

2. savings equals all owned assets including the fraction of the family's home that is not mortgaged
3. Statistics Canada (2020), *Survey of Financial Security*.

Chapter 17: Aging and Inter-generational Fairness

After reviewing the economic implications of demographic transition, we focus on aspects of Aging Populations. What tax and subsidy schemes are fair across generations?

The Demographic Transition poses economic and social challenges at each stage.

Young populations are typically rapidly-growing because the birth rate is high. The large number of children set to approach childbearing age means the birth rate will be high for some time. In this context, and especially if the economy is only beginning to modernize, loanable funds may be scarce and interest rates may be high. The capital stock may not be able to grow as quickly as labour, so worker productivity may be low.

Young populations face high young dependency. Governments and parents must budget for housing, schools, opportunities, and early childhood vaccinations.

Photo by Bilal Kamoon, flickr.com CC BY 2.0 DEED

The Demographic Dividend

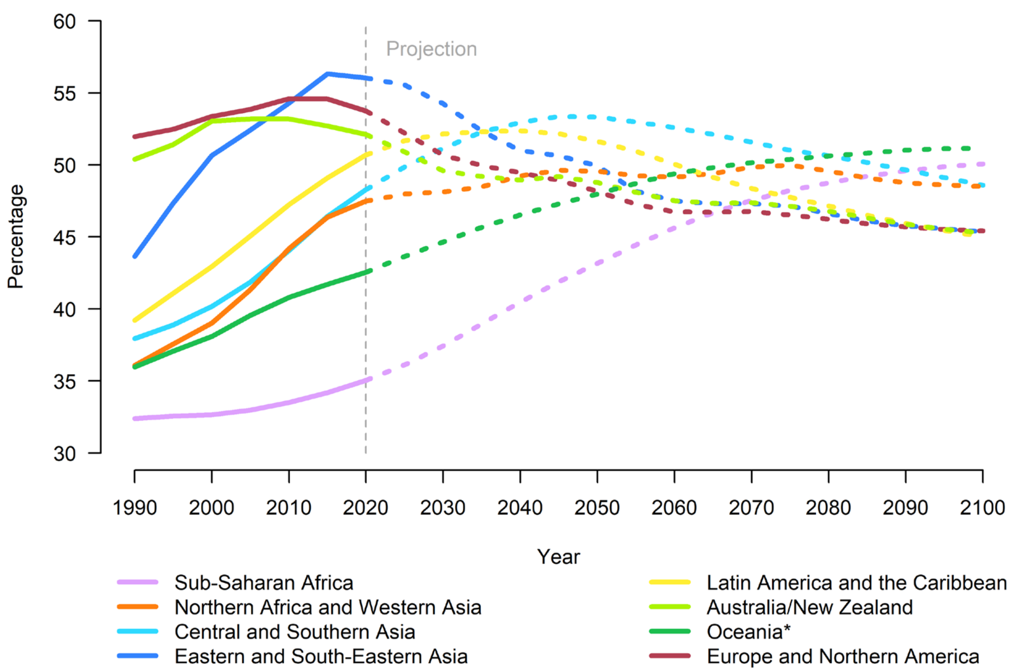
The Demographic Dividend is possible when society is experiencing a drop in the Total Dependency Ratio. This typically occurs when the birthrate begins to fall and there are not yet many older adults needing care. At this point the working-age population and its government have an opportunity to invest their savings into infrastructure, research, and other productivity enhancements.

If jobs are available, banks are accessible and safe, inflation is low, and savings can be channeled into productive investments, this will be a time of economic growth. Policies that support this outcome are policies that make it easy for businesses to become established, get loans, and hire workers. The labour force needs to be healthy and have the necessary knowledge and skills.

With so much competition for jobs, young workers face more economic stress. Wages may be low due to the large labour supply or due to low productivity (if capital is scarce relative to labour). If young peoples' expectations are not realized, they may become frustrated. There are more potential recruits for the army, and there are also more young people ripe for radical politics and tempted to act out their frustration.

The time of Demographic Dividend for today's economically developed nations was between the mid 1960s and the early 2000s. While these countries may still have a large fraction of their population between the ages of 25 and 64, their opportunity to collect a Demographic Dividend is fading. Figure 17-0 show us that Europe, North America, Australia, and New Zealand, as well as East and Southeast Asia, are experiencing decreases in the fraction of the population that is of working age i.e. increases in total dependency. By contrast, the rest of the world is experiencing falling total dependency.

Figure17-0. Estimated and Project Percentage of the Population Aged 25-64 by Region, 1990-2100



Source: Figure 11 of World Population Prospects 2019 (UN(2020)). Data Source: UN (2019). Oceania excludes Australia and New Zealand.

As indicated in Figure 17-0 above, Latin America, the Caribbean, North Africa, Central Asia, Southern Asia and Western Asia will achieve roughly their projected maximum L/N (fraction of population working) by 2050. Sub-Saharan Africa and Oceania will need more time than that to achieve a high L/N and hopefully experience the Demographic Dividend, because fertility rates and child dependency are still high there.

Morné Oosthuizen (2019) took a close look at South Africa's age structure in the year 2015. As you might expect given South Africa's racist history, different racial groups in South Africa were at different phases of the Demographic Transition in 2015. White South Africans were probably already experiencing the Demographic Dividend at the household level while many Black South Africans, who were on average younger, less socioeconomically privileged, and having more children, were likely not. It was unclear to Oosthuizen whether South Africa as a whole would soon experience a Demographic Dividend.

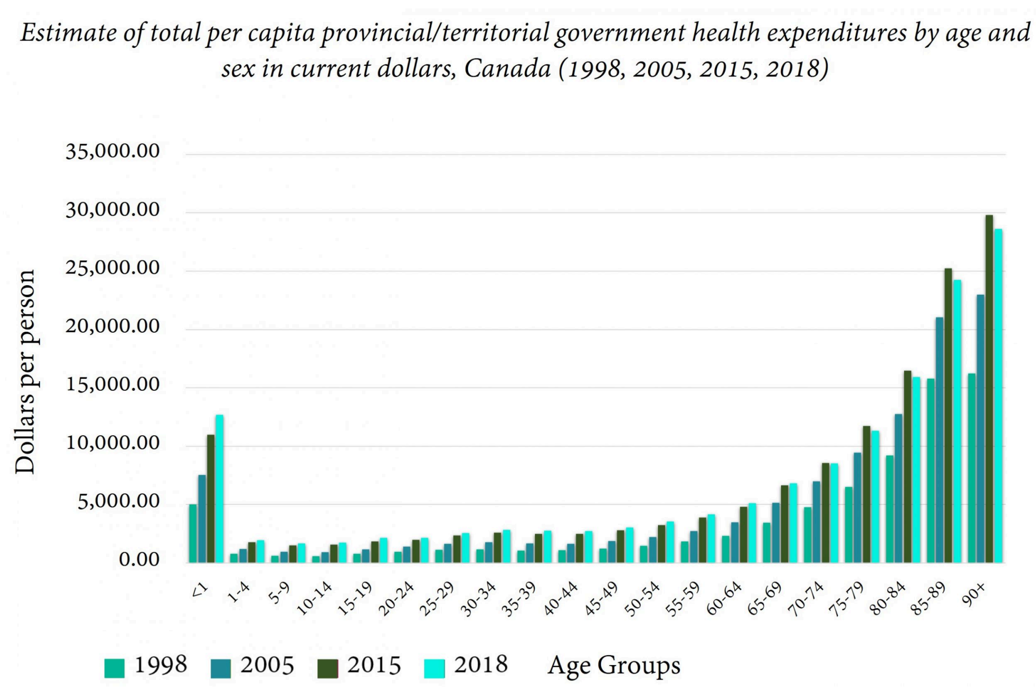
The Challenges of Aging Populations

Societies where the birth rate has come down almost to the death rate are growing slowly and have a large share of older adults in the population. Wages may rise as workers become more scarce. There may be some reduction in house prices as older adults sell their houses and move to smaller accommodations.

Interest rates should remain low as retired persons do not immediately deplete their savings, and because the average worker is older and is saving a great deal. The government must spend more on pensions, medical care, and residential care, while the number of workers to tax may be falling.

We think of older adults as requiring a great deal of medical intervention; it is true that, around the world and in Canada, more money is spent per older adult on health care than per younger adult. Figure 17-1, which totals federal and provincial/territorial spending, illustrates this.

Figure17-1. per Capita Health Spending, Canada

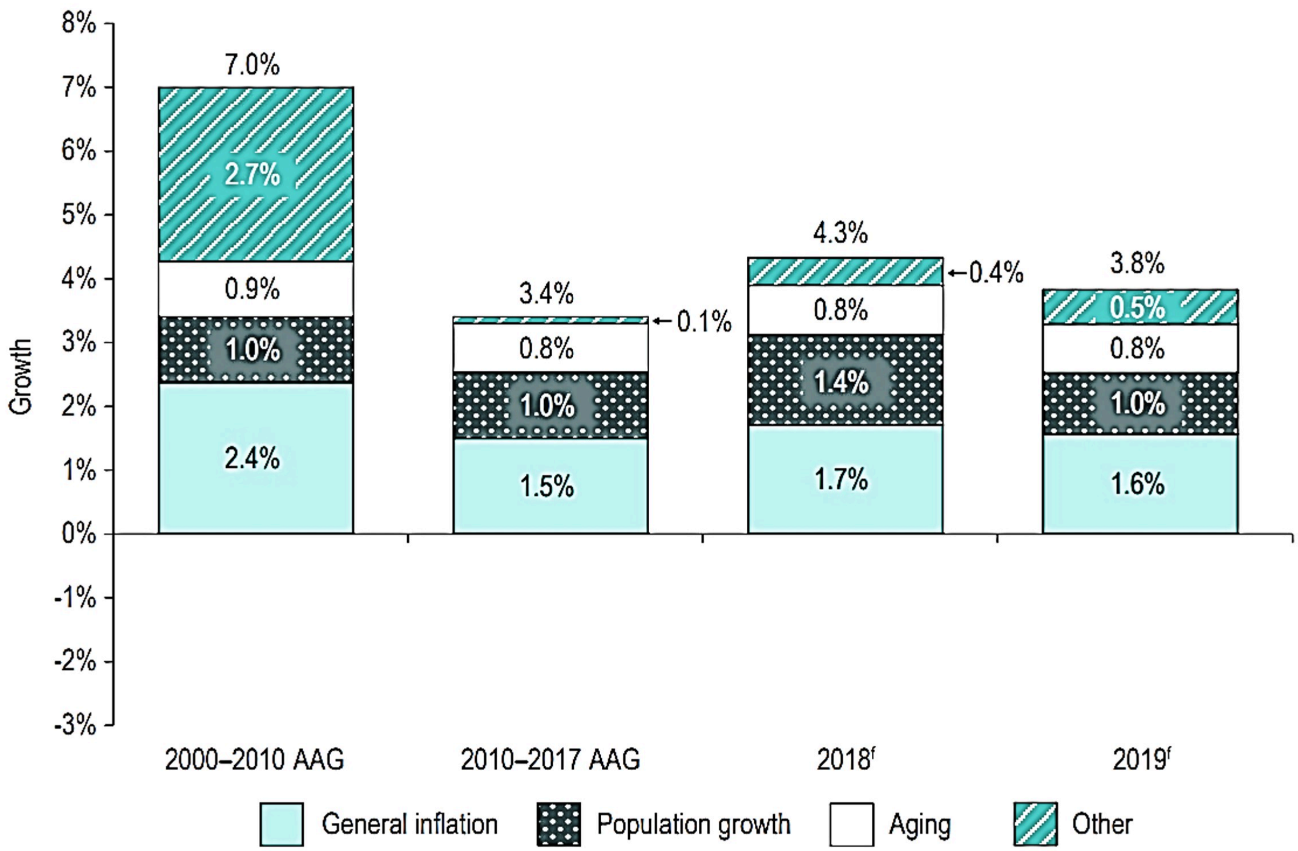


Source: Series E1, Canadian Institute for Health Information (2022)

While it is true that health care expenses rise with age, the extra expense due to the aging of the population is not as runaway as it may seem. The next diagram shows that annual health care spending by the different levels of government in Canada rose about 1% because of aging and 1% because of population growth between 2000 and 2019. While old people are more expensive medically, aging is not happening so quickly as to be the leading cause of rising medical costs.

Figure17-2. Health cost drivers, 2000-2019

Cost driver shares of average annual growth in public-sector health spending, 2000 to 2010 and 2010 to 2017, compared with annual growth in 2018 and 2019



*Source : Figure 16 of Canadian Institute for Health Information (2019)*In their study of rising health care costs in British Columbia between 1996 and 2006, Morgan and Cunningham (2011) noted that most of the increase in cost could be explained by the increased use of specialists and the increased use of diagnostic tests. They also found that improved survival rates for older people reduced hospital spending by 0.3%. When older people are healthier, the medical interventions they eventually need are compressed into the last months or weeks of their lives.

If older people find that they have inadequate supports and opportunities to maintain their standard of living, they may become more conservative in their politics. There is a tendency for older voters to support nationalist, anti-immigration parties. This may also be part of cognitive and emotional changes that occur with aging. Older people may feel more vulnerable as their physical strength diminishes and as technology and social norms change rapidly. They may find themselves targets of scams that exploit deafness, confusion, unfamiliarity with technology, and concern for family.

Benefits of Aging Populations

Let us remind ourselves that, in the words of Bloom et al. (2003), “an aging population is, fundamentally, a mark of development success.” We’ve all wished to live a long life, and we’re having it. Many have wished that population growth would slow down, and it is. Aging is a consequence.

Knowing that we have more life years remaining to us may motivate us to invest in our human capital, our relationships, our societies, and our natural environment. Haiming Li and Xiuli Zhang (2015) show that increases in life expectancy at birth were correlated with increases in human capital investment, labour force participation, and savings in China between 1982 and 2012.

A society’s older adults often help hold families together: they can provide love, child care, advice, financial support, and a sense of one’s place in history. In cultures indigenous to Canada, and in many other cultures, Elders are honoured for their roles as keepers of tradition, masters of craft, and witnesses of history. Research by Rachel Caspari (2011) regarding prehistoric human communities indicates that only the most recent human societies had a relatively high Aged Dependency Ratio, and she speculates that there was a positive feedback loop between the standard of living and the survival of older adults.

Photo by Azzazello, 2006, flickr.com. CC BY-NC 2.0

Aging Trends

According to Statista.com, the median age in the entire world was 30.9 years of age in 2020, up steadily from 21.5 years of age in 1970.

As we saw in Chapter 6’s Figure 6-1, life expectancy has been improving all over the world. In 1950, life expectancy at birth for the average person was 46.5, compared to 72 in 2020[1].

The Aged Dependency Ratio is increasing in much of the world, especially in Central and Eastern Europe (from Germany to Russia), China, Taiwan, Japan and South Korea, and the Northern Mediterranean (Italy, Serbia, Greece, Romania). Often, **double aging** is occurring: the proportion of people over the age of 65 is increasing, and the average age of people over the age of 65 is increasing also.

In Canada, in 2022, almost one in five workers was nearing the age of retirement (Zimonjic, 2022); the consequences of aging on the labour market were slightly mitigated by the fact that people were retiring later.

The government, the media, and the average citizen in Canada have for some time believed that continued labour force growth is necessary to our prosperity, a belief challenged in our previous Chapter.

1. Worldometer, www.worldometers.info

Aging and Intergenerational Fairness

We mentioned that older adults may become more conservative in their politics if they feel economically vulnerable; conversely, young people may embrace populists who promise freedom from the economic burden of providing for retirees. How can a society promote goodwill and fairness among generations?

A baseline level of fairness is achieved when we offer every person basic human rights from birth until death. In Canada, that package of rights includes publicly funded education, publicly funded healthcare, and income support for people below the poverty line. Each successive generation, assuming it lives longer than the previous one, will enjoy this package for longer than the previous generation, so the young people working to pay for these benefits should have at least as much to look forward to.

This assumes that younger generations have confidence that the program is sustainable. When governments have to borrow in order to pay for health care or pensions, young people may rightly question whether the programs will last long enough to serve them.

Professor Paul Kershaw (2023) of UBC has concluded that Canada's baby boom generation, born between 1946 and 1964, did not pay enough taxes during their lifetime to cover everything they can expect to receive from the government in retirement. Before we blame them, let's consider that during their working lives, no one could foresee how long they would live, how medical science would improve, and what entitlements would be offered to them.

Governments in the West have gotten used to living beyond their means, partly because they can borrow at favourable interest rates, sometimes below the rate of inflation. Citizens of less economically advanced or less politically stable countries are eager to acquire western currencies and financial instruments, especially the US dollar and US Treasury bonds.

Another reason that western baby boomers – and the governments they elected – didn't live within their means is that they assumed that tax revenues would always grow because of productivity improvements and population growth. Tax revenues did grow automatically as the labor force grew and as its productivity grew, thus individual workers did not need to pay much tax. This was the logic behind Canada's pensions system before its revision in 1998.

Two Basic Types of Government Pensions

Many people collect pensions from their former employers, but here we will discuss pensions that come from the government. If the money for these pensions comes out of current tax revenues, we call the pension plan a **pay-as-you-go pension**. Working-age people are taxed, and the money collected from them is used to pay people who are currently retired.

A pay-as-you-go plan is affordable so long as the population is young and growing. With each working age cohort larger than the previous one, workers do not have to be taxed very much to provide for the much smaller cohort of retirees.

Canada, the United States, and western Europe have been criticized for saving too little for pensions and health care for retirees. We got used to our tax revenue increasing every year just because the working-age population was growing. We could "grow our way out of deficits."[2].

In 1998 the Canadian government realized that the rate of population growth was falling and that the ratio of workers to retirees was falling also. Workers would have to be taxed more and more to provide the promised pensions. So Canada began to convert its pay-as-you-go pension plan to a **fully-funded pension plan**. In a fully-funded plan, the workers are taxed but their money is set aside in a fund to earn interest and provide for their own pensions in the future. The affordability of this plan depends on the interest rate being high enough. In fact, it can be shown that, if the interest rate is higher than the rate of population growth, the fully-funded plan requires less taxation of earnings than the pay-as-you-go plan. If the interest rate is lower than the population growth rate, the pay-as-you-go pension plan is the more affordable one.

Canada was not able to switch from a pay-as-you-go plan to a fully-funded plan overnight; indeed, as of 2023 the plan was still not fully funded. In 1998, the existing retirees still needed to be paid, and there was no money saved up for them. So, beginning in 1998, the Canadian government increased the amount of money collected from workers, using much of it to pay for current retirees' pensions according to the usual pay-as-you-go plan, and using the rest of the money to save for future retirees.

2. David Foot, interviewed on The Agenda (TVO), March 29, 2010.

Box 17-1. Canada's pensions

Canada's federally-administered pension programmes

The CPP or Canada Pension Plan, begun in 1964, covers all provinces except Quebec (which administers its own plan). Employers deduct about 5% of your wages/salary above a base amount (like $3,500) and below a ceiling amount (like $41,100). They pay twice that sum to the government. On the basis of how much you have contributed, a pension will be paid to you each year upon retirement. If you have not earned enough in your prime, your CPP payments will be low but you will be eligible to receive supplemental payments called Old Age Security and the Guaranteed Income Supplement.

Unlike the CPP or OAS, the GIS is not subject to income tax. OAS and GIS are similar to income-support programs, while CPP is more of a bona fide pension plan. All Canada's public pension payments are indexed to inflation.

The Math Behind Pensions

We can calculate what the pension contribution should be in a pay-as-you-go pension scheme. We'll use the math from Chapter 14, the math we used for a stable population growing at rate n. Let s(x) be the survival rate from birth to age x. Then for any NN newborns, there will be NNe^{-n} s(1) one year-olds, NNe^{-2n} s(2) two years-olds etc. For simplicity, we'll also assume that everyone over age 18 works and that everyone works fulltime.

The number of people of working age is:

$$\int_{18}^{65} NNe^{-nx}\, s(x)\, dx$$

Similarly, the number of retired people is:

$$\int_{65}^{Max\ age} NNe^{-nx}\, s(x)\, dx$$

If we want to give each of these retired people one dollar by charging each of the working age people a pension contribution of *p*, we'll have to set:

$$\$p * \int_{18}^{65} NNe^{-nx}\, s(x)\, dx = \ 1 * \int_{65}^{Max\ age} NNe^{-nx}\, s(x)\, dx$$

Rearranging,

$$\$p = \frac{\int_{65}^{Max\ age} e^{-nx} s(x)\, dx}{\int_{18}^{65} e^{-nx} s(x)\, dx}$$

You can see that, the more retired people there are relative to working age people, the higher the pension contribution must be.

In fact, the pension contribution rate **\$p = the Aged Dependency Ratio.** In a pay-as-you-go system, the higher is the ADR, the higher pension contributions must be.

Also, the higher the population growth rate n, the lower the fraction of retirees will be, and the lower the pension contribution needs to be.

No big surprises there. The big surprise is that we can do almost exactly the same math for the case of a fully-funded pension. For a fully-funded pension, the relevant parameter is not the population growth rate "n" but the interest rate earned on savings, call it "r". For a fully-funded pension, it's not relevant how fast the population is growing. What's relevant is how fast the savings are growing.

If we're tracking money through time, we have to incorporate the fact that money now is actually worth more than money later, because money now can be invested. Just as \$1 at birth might be equivalent to receiving \$5 eighty years later, receiving \$1 at age 80 might be equivalent to receiving 20 cents at birth. Shrinking the \$1 received at age 80 down to a value of 20 cents at birth is called **discounting**.

We are going to express the value of any pension contribution or pension payment in terms of what it is worth at the date of birth. We have to pick one date, so it might as well be birth.

This time we're not using NN (the number of newborns) and shrinking that down by e^{-nx} to give us the size of the group which is age x. Instead, we are shrinking the value of money received at any age x by e^{-rx} to give us its value at the time of birth.

$$\$p * \int_{18}^{65} e^{-rx}\, s(x)\, dx = 1 * \int_{65}^{Max\ age} e^{-rx}\, s(x)\, dx$$

Again, *x* is your age, the number of years that have gone by. *s*(*x*) is your survival rate to age *x* because there's some chance you won't make it to age *x*. If you don't make it to age x>64, the government won't have to pay you a pension. Using survival probabilities allows us to generalize the individual case to the wider population.

If you want to receive one dollar every year that you are retired, how much does your annual pension contribution $*p* have to be during your working years? Rearranging the previous equation, we get:

$$\$p = \frac{\int_{65}^{Max\ age} e^{-rx} s(x)\, dx}{\int_{18}^{65} e^{-rx} s(x)\, dx}$$

The longer you can expect to live after working, the higher the pension contribution must be. And the higher the interest rate *r*, the less you need to contribute and save.

The math for both pension schemes is identical, except that one uses the population growth rate and one uses the interest rate on savings. So, roughly speaking, a fully-funded pension scheme will require a lower pension contribution rate than a pay-as-you go pension if the rate of interest is higher than the rate of population growth.

How much should pensioners receive?

Our math tells us the minimum amount we need to collect from workers for every $1 we want to give to retirees. But it doesn't tell us how much we should give to retirees. Pension payment decisions are just one kind of the many decisions governments make that affect our lives.

We use **generational accounts** to explore whether the government's overall system of taxation (including mandatory public pension contributions) and transfers (including public pension payments) is fair.

A generational account at year *y* for a person age *x*, represented by *GA*(*y*,*x*), is the **present value** (at year *y*) of all the taxes and all the transfers the average person age x will have to pay as time t progresses from date y to the end of the person's life at Max Age.

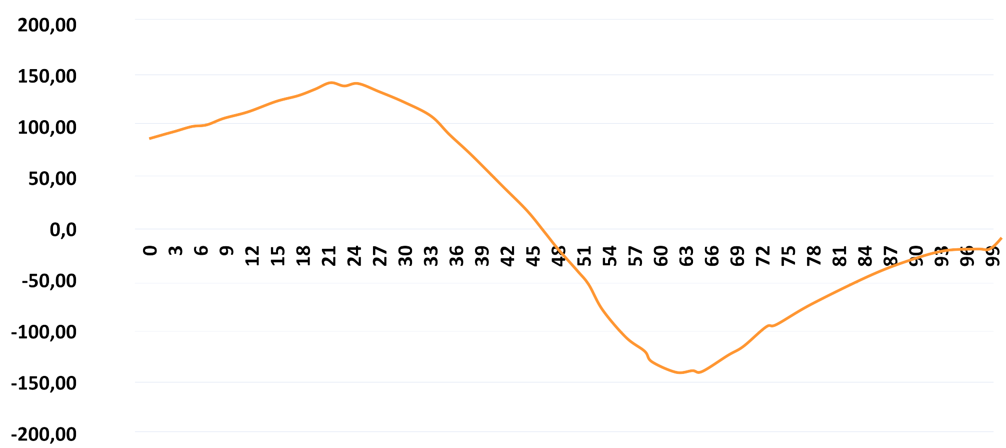
Using the math we are becoming familiar with, we can write this as:

$$GA(y,x) = \sum_{t=y}^{Max\ Age-x} Net\ Taxes(x,y)\, e^{-rt}\, s(x)$$

where *Max Age* – x is the remaining years of life for an individual age x, and $s(x)$ is the survival probability to age x.

Check out Figure 17-3. It plots the Generational Accounts for Portugal in 2010 by age.

Figure17-3. Generational Accounts, Portugal (2010) (thousands of dollars)



Source: Figure 11 of Jorge Pinheiro (2020)

Think of this graph as a graph of "net tax payments remaining" for a person age x. What do we see here? We see that the present value of all the taxes a baby born in Portugal in 2010 could expect to pay over their lifetime, net of subsidies, was about $80,000 USD, assuming that today's tax and subsidy rates persist. This is not necessarily unfair. A positive amount of net tax being paid over one's lifetime means that the government has money to spend on public goods like research, environmental protection, and national defense.

According to Figure 17-3, people about to enter the workforce in Portugal faced the steepest net tax bill, because the tax-paying phase of their life was near. By contrast, a 46-year old living in Portugal in 2010 could expect to pay zero net taxes for their remaining life. Anyone older than that would receive more transfers than taxes for the rest of their life. But people older than 63 had lower expected net transfers to collect because they had fewer years of life remaining.

It might occur to you, that, to be intergenerationally fair, the generational account should be the same at each age. This is not possible: the tax potentially paid by a newborn cannot be the same as the tax potentially paid by someone who has hardly any time left to live.

What if the generational account for newborns never changes, regardless of when they are born? Then the GA function never changes from generation to generation.

Let's use that definition of Intergenerational Fairness:

Intergenerational Fairness can be said to exist when each generation faces the same tax costs and subsidy benefits over its lifetime.

We don't have the raw data on which Figure 17-3 is based, but imagine that we multiply the Generational Accounts by the number of people in each age group at the time (2010). So $80,000 for each newborn multiplied by the number of newborns, then the level of the graph at age 1 multiplied by the number of one year-olds, and so on. Add up all that money to get the present value of the net amount that the government of Portugal can expect to collect from all the Portuguese people alive in 2010. If that amount is equal to or greater than the Portuguese government's debt in 2010, fine. If not, the Portuguese government is going to have to find some more money to pay the difference; it's likely that future generations will have to pay this net debt. Bernd Raffelhüsen (2001) estimated that, in 1995, European Union countries were living above their means: future generations would have to pay 54% more in net taxes to pay off the net debts of their countries.

If future generations will have to pay more tax than the current generation, then our tax and subsidy system is not intergenerationally fair. To achieve intergenerational fairness we will have to do some combination of paying off our debts, raising taxes, and reducing subsidies. This is what Canada began to do in 1998 when it raised pension contributions (from workers' pay) and saved some of that money for the next generation of retirees.

The editors of the Globe and Mail ("A long-term plan for long-term care," March 14, 2023) have proposed that the Canadian government now institute an additional 1.5% payroll deduction , matched by employers, to be saved on behalf of each worker in a public Long-Term Care insurance (LTCI) fund. Their idea is that the government would use the money in this fund to pay for mobility aids, home care, nursing-home care, and palliative care when and if needed. People whose LTCI savings do not add up to enough to pay for their care would not be denied necessary care.

Environmental Sustainability

Another aspect of intergenerational fairness is whether the current generation is using natural and environmental resources sustainably. We will examine that issue in our next two chapters. For now, we can assume that, if we are not using resources sustainably, then taxes or borrowing will have to go way up in the future as we face the cost of environmental remediation, clean-up, substitute technologies, and sourcing of scarce natural resources.

Exercises: Chapter 17

1. What is required for a baby boom to yield a demographic dividend?
2. What's good about an aging population?
3. How does aging affect GDP per capita?
4. How does aging affect a nation's "net debt" as defined in this chapter?
5. How can a nation prepare for rising aged dependency?

Chapter 18: Population Growth and Sustainability

We've learned that a growing population can put downward pressure on the standard of living through high rates of child dependency and capital shallowing. In this chapter we'll explore the neoclassical growth model and its predictions for the sustainability of consumption in the presence of population growth.

In our previous two chapters we explored how the age structure of the population affects the economy. Now we focus on how the rate of population growth affects the economy.

Solow model

The model of economic growth by Robert Solow (1956) is very well-known, simple, and easy to manipulate, so we'll have a look at it and see what it predicts about the economic consequences of population growth. Its message will not be about efficiency, because efficiency is held constant in the Solow model. It will not be about hours worked or about the fraction of the population that works, because in the Solow model, labour is measured as the number of people in the population: everyone is assumed to work full-time.

The Solow model's message will be about the capital-labour ratio, K/L, and the importance of accumulating capital to keep up with the number of workers.

The Solow model uses the aggregate production function Y = A F(K,L)

Y = aggregate output of the economy. There's just one thing produced.

A = efficiency. This is held constant.

F(K,L) = the production function. The production function exhibits constant returns to scale; that is to say, if you double K and double L, F(K,L) doubles in size.

K = physical capital. This time we are not using K+ as we did in Chapter 16. K+ represents a number of different kinds of capital, and different kinds of capital may present mathematical complications. For example, if we include human capital, we might reasonably expect that human capital accumulation would affect efficiency, A, and we'd need an equation to show how that happens. If we included non-renewable natural resource capital, we'd need an equation to show how the resource stock is being depleted.

L = labour. This is identical to the number of people in the population. It grows at rate n.

Why is efficiency A held constant? We might think of including an equation that shows how efficiency grows, either exogenously (automatically) or endogenously (in response to something in the model, such as population growth). However, if A is allowed to grow, then output Y exhibits *increasing* returns to scale. Doubling K and L while increasing A would result in more than double the output. If increasing returns to scale were in place, output Y and consumption could grow forever in the presence of population growth. Sustainability would be too easy, at least mathematically.

Because efficiency growth such as technological change makes sustainability so easily to achieve, it's more interesting to hold technological change constant and see what happens when technology and other forms of efficiency don't improve.

We think of efficiency A as possibly changing depending on the age structure of the workforce, but in the Solow Model there is no change to the age structure.

This model is almost as simple as the Malthusian model. One difference is that in Solow's model the population growth rate never changes. A second difference is that in Solow's model, there is not only labour, but also physical capital. People can either eat the output Y or save some of it. The saved Y is invested and is transformed into capital. Think of Y as corn, which you can either eat or save for planting next spring.

The production function F(K,L) can be any positive monotonic function of K and L so long as

- Both K and L are essential to production. If one of them is equal to zero, then output must be equal to zero.
- There is some degree of substitutability between K and L.
- F(K,L) demonstrates diminishing marginal returns to K and to L.
- F(K,L) exhibits constant returns to scale. As noted above, if you double the inputs, you double the output. Similarly, if you divide the inputs by some number, you divide the output by that same number. This makes it possible easily to express the production function in terms of output per worker, dividing by L.

Assuming constant returns to scale, Solow divides everything by the number of workers so that there is one production process y=f(k) which uses capital-per-worker k to produce output-per-worker y. Capital-per-worker is denoted by lowercase k and is called the capital-to-labour ratio or capital:labour ratio.

Figure18-1. Output Per Worker and Capital:Labour Ratio

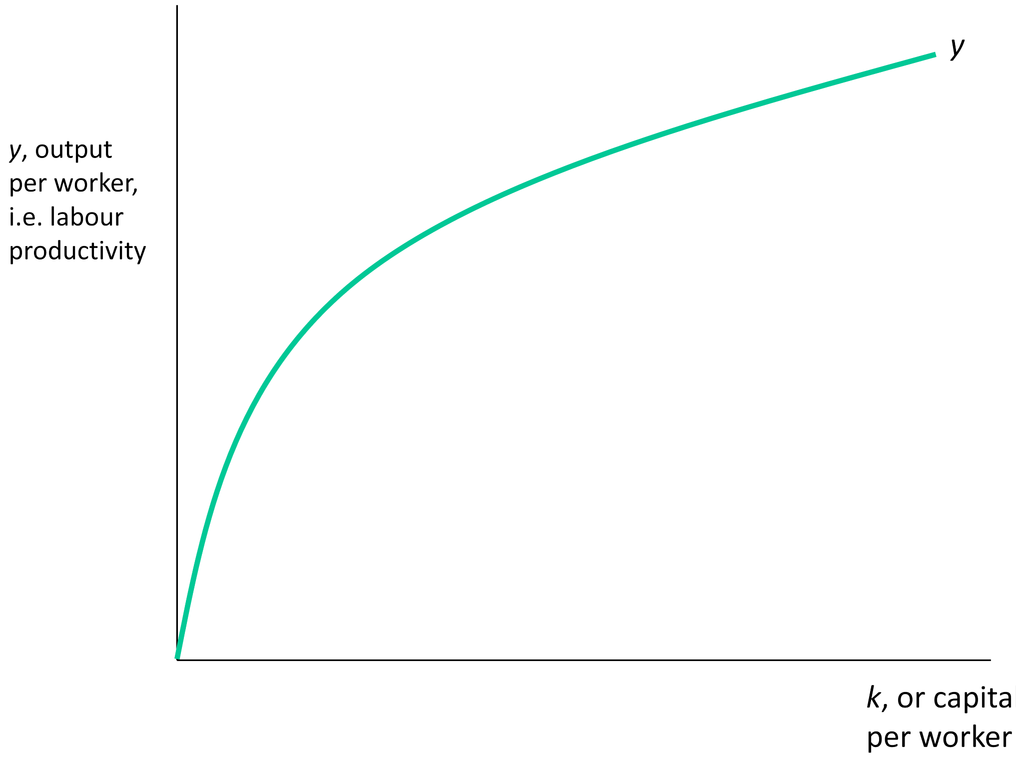
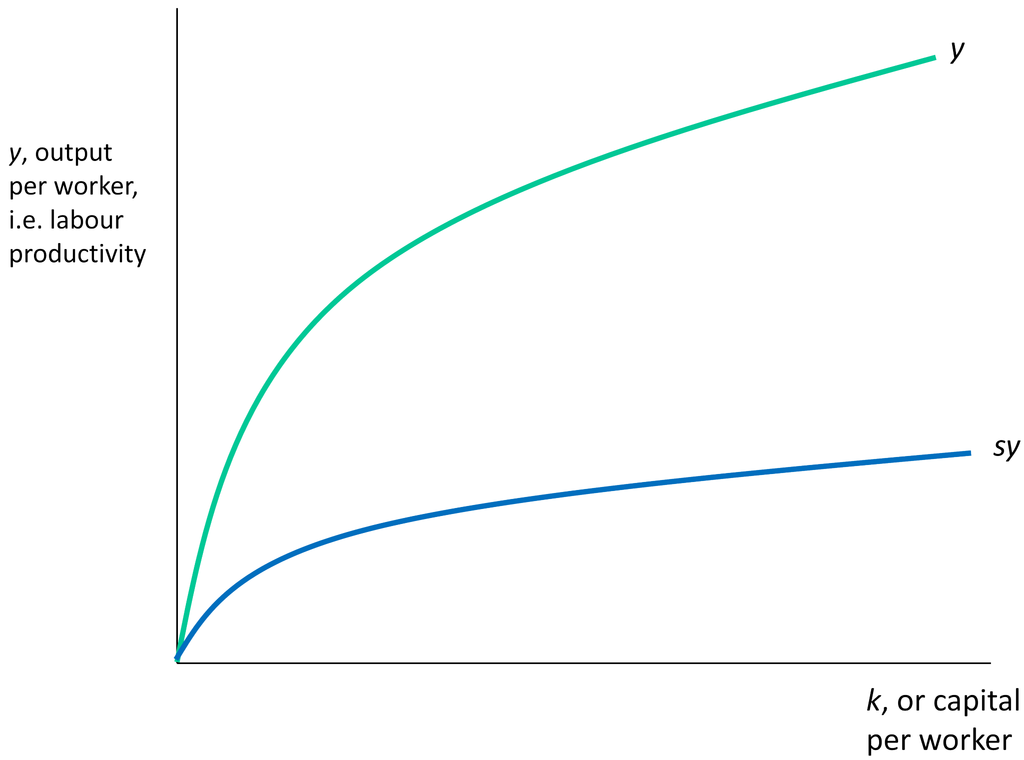


Figure 18-1 shows output-per-worker as a function of the capital:labour ratio. This function demonstrates diminishing marginal returns to k.

Figure 18-2 shows the same function multiplied by fraction s. s is the savings rate.

Figure 18-2. Savings Per Worker as a Function of Capital Per Worker



In the Solow model, we produce y, which represents output per worker or output per person (since all people work). Fraction (1-s) of this is consumed, and fraction s is saved/invested into the stock of physical capital, K. Every year, K increases by sY. It can be shown (if interested, see the end of this chapter) that the amount of savings needed to keep the capital:labour ratio steady must satisfy Equation 18-1.

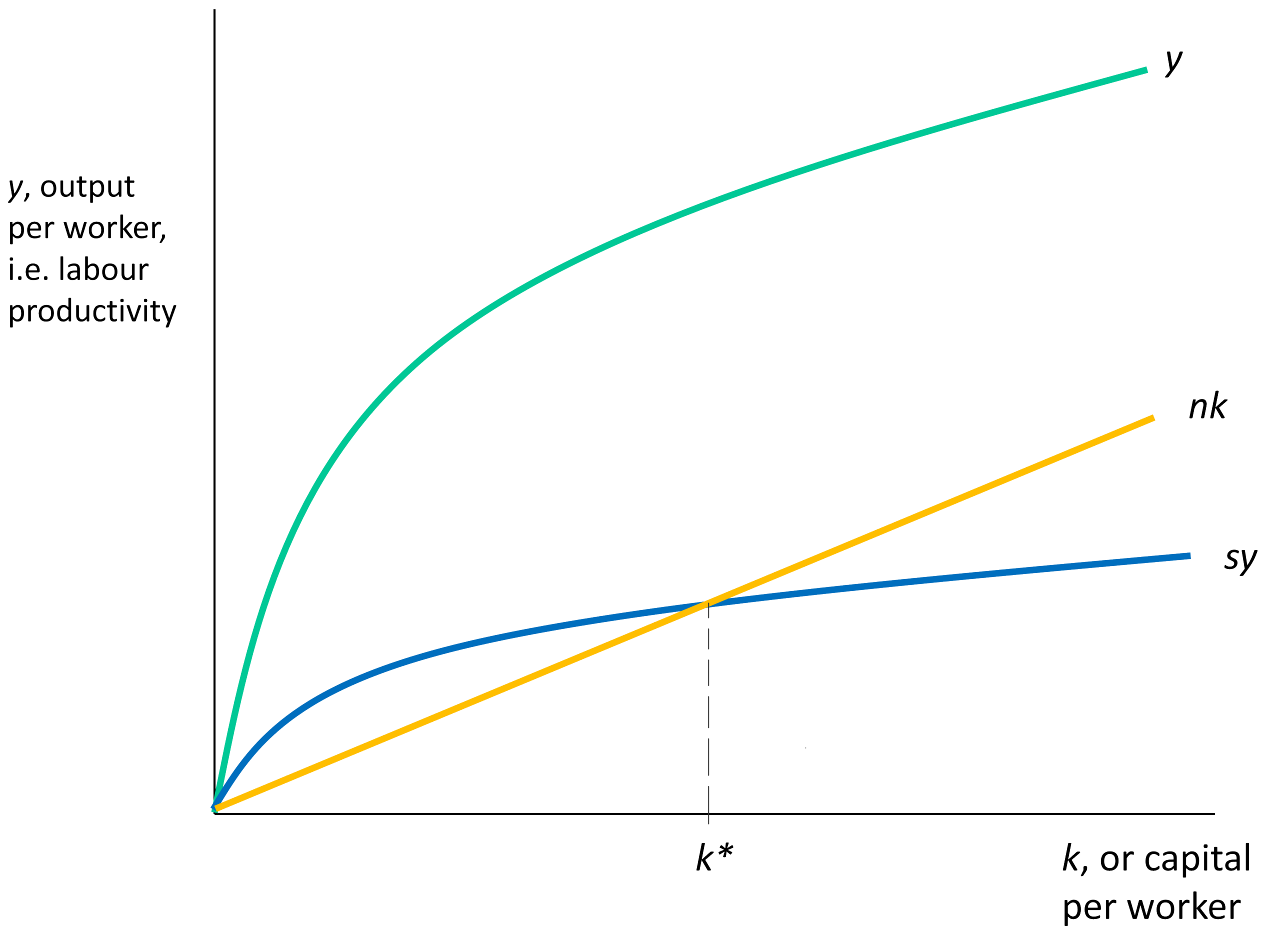
Equation 18-1. $sy = nk$ (n is the rate of growth of population)

The amount saved per worker must equal the population growth rate/labour force growth rate multiplied by the capital:labour ratio.

The original Solow model also included another term, called d. d is the rate at which physical capital depreciates, by rusting away or becoming obsolete. If you include d in the model, Equation 18-1 becomes $sy=(n+d)k$. We show that at the end of this chapter.

According to Equation 18-1, sustainability requires that a population must save enough to offset something, something to do with population growth. Let's have a look at Figure 18-3 to learn more.

Figure 18-3. The Solow Condition



The blue line above, sy, represents the left-hand side of the Solow condition (Equation 18-1), while the yellow line, nk, represents the right-hand side. Where these lines intersect is the level of k, where the Solow condition is satisfied.

The lines intersect at a particular level of k, called the **steady state capital:labour ratio, or k*.**

Wherever the blue savings line is higher than the yellow population line, *sy* > *nk,* and the capital:labour ratio rises. As it rises, we move rightward along the horizontal axis until we get to k*.

Wherever the blue savings line is lower than the yellow population line, *sy* < *nk,* and the capital:labour ratio falls. We call this "**capital shallowing**". As k falls, we move leftward along the horizontal axis until we get to k*.

So whatever capital:labour ratio k we start out with, we tend to reach k*. k* is an equilibrium.

If we start out with a k that is higher than k*, k falls. That's because k is so high that diminishing returns are kicking in, and the extra output we get from our investment is not enough to prevent capital shallowing. If we start off with a low k, we will find that our savings and investments are so productive that capital accumulates faster than population.

This is exciting! Whatever savings rate we choose, we can achieve:

> equilibrium level of capital:worker → equilibrium level of output:worker → equilibrium level of consumption:worker for any savings rate *s*

Even though the labour force in the Solow model is constantly growing at rate n, the amount each worker/person consumes will never fall. Consumption per person never falls = that's what theoretical macroeconomists call sustainability**.** Like a lot in economics, the conception of sustainability is very anthropocentric.

Population growth will cause capital shallowing, but we can save and reverse that capital shallowing. By means of saving, the capital stock can grow as quickly as the population.

If the population growth rate were to rise for some reason, our yellow population line would become steeper. It would intersect the blue savings line at a lower k*. This would means lower output per worker and lower consumption per worker. However, the output and consumption per worker are still constant every year. They are still sustainable. Consumption may be reduced because population growth has accelerated, but it is still sustainable, unless it falls below the critical threshold needed to support human life.

If the efficiency level A were to rise for some reason, again our blue savings line would pivot up and intersect the yellow population line at a higher steady state k*. Output per worker would rise, and so would consumption per worker, since output has increased and the savings rate has not changed.

If the savings rate were to increase for some reason, our blue savings line would pivot up and intersect the yellow population line at a higher steady state k*. This would result in a higher steady state level of output per person; however, because a higher fraction of that output is being saved, it's not clear whether consumption per person would actually increase.

We can solve mathematically for the savings rate that would result in the highest level of consumption per person. That savings rate is the one that achieves the "golden rule" k*. The golden rule k* is found where the slope of the per-worker production function (y=Y/L=Af(k*)) is equal to n.[1]

In the real world...

1. The intuition is that we keep raising k* until the net benefit of doing so is zero. The net benefit of raising k* is the resulting increase in output per worker minus the extra n units of output required to prevent capital shallowing. (Van Gaasbeck (2022)).

The Solow model tells us that, if we save, we can achieve sustainability of consumption despite population growth, unless the rate of population growth is so very high that k* and the resulting consumption (=(1-s)y) are too low to support life. In the real world, things are more complicated. The Solow model ignores the natural environment. It ignores the fact that not everyone works. And it assumes that the rate of population growth doesn't affect how much people save. In the real world there is environmental degradation, there is dependency, and there is the likelihood that dependency reduces workers' savings.

Photo by Payton Chung, 2010, flickr.com, CC BY 2.0 DEED

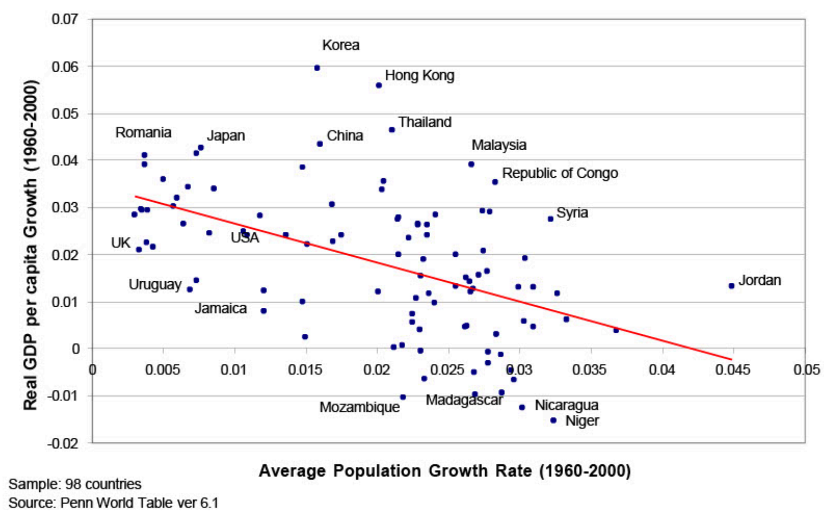
When the rate of population growth is increasing, it is likely that the young dependency ratio (YDR) and total dependency ratio (TDR) are increasing. It is likely that savings will fall as parents devote resources to caring for the young. Kelley (1998) calls this the **youth dependency effect**. It is also likely that governments will spend on education and health care for the young, diverting money away from investment in various forms of physical and knowledge capital. Most of the spending on children will not improve the productivity of the current working generation. Kelley calls this the **investment-diversion effect**.

A. C. Kelley (1998) reviewed the many journal articles on population and economic growth available at that time. He concluded that,***ceteris paribus***, the rate of population growth likely reduces the standard of living through the youth dependency effect, the investment-diversion effect, and capital shallowing. However, there is no clear empirical relationship between the population growth rate and per capita output. Many other important factors also influence per capita output, factors like the economy's overall size, its civil and political institutions, its educational achievement, and its openness to trade (Bloom 2003).

If we observe an apparent negative correlation between income growth and population growth, we have to remember that causation can flow both ways in a negative feedback loop. Low economic growth could mean lower rates of female education, low rates of female employment, higher rates of infant mortality, and a smaller social safety net, all of which tend to increase fertility.

The graph below shows GDP per capita growth, adjusted for inflation, between 1960 and 2000, for 98 different countries, as a function of the average population growth rate for each country between 1960 and 2000. A simple best fit line has been generated. Variation in population growth rates "explains" 25% of the variation in GDP per capita growth, or vice versa. 75% of the variation remains unexplained.

Figure18-4. Per Capita GDP Growth vs. Population Growth



Source: Figure 2 of Boldrin, Jones and Kahn (2005)

Natural and Environmental Capital

The Solow model paints a scenario where saving prevents consumption per worker from falling as the population grows. Could that work if there are natural resources needed for production?

The Solow model will continue to generate sustainable output and consumption per worker when the production function includes a **renewable** resource. The renewable resource must be harvested sustainably. No more of the resource each year can be harvested than can grow back in one year. In fact, we should harvest less than that, because the stock must continue to grow as long as population grows.

When we add a **non-renewable** resource, such as oil, coal, or lithium to the production function, the Solow model can no longer generate sustainable output or sustainable consumption in the presence of population growth, at least not as long as population growth is geometric or exponential.

In the Solow model, savings can compensate for capital shallowing and capital depreciation, or savings can compensate for non-renewable resource depletion, but not both.

If there were no population growth (i.e. n=0) and no depreciation of capital (i.e. d=0), then consumption could be sustained despite the depletion of non-renewables like oil. Solow (1974) and Hartwick (1977) showed that IF physical capital can substitute to some degree for non-renewables like oil, and IF enough physical capital were accumulated to make up for the diminishing stock, then consumption could be sustained indefinitely.

Hartwick derived the formula for the precise amount of savings needed to make up for declining non-renewable resource stocks. The amount needed is equal to the amount of non-renewable resource extracted multiplied by **rent** (price minus marginal cost) on the marginal ton. This amount is known as **Total Hotelling Rent**.

Hartwick's Rule tells us to invest non-renewable resource rents in other forms of capital. This will keep our output and consumption steady, so long as the savings rate is not affected and dependency is not an issue. If there is geometric or exponential population growth, sustainability is not achievable; however, if there is arithmetic or quasi-arithmetic population growth[2], sustainability can be achieved by investing even more than Total Hotelling Rent.

In real life, our population *has* grown and our capital stock *has* more than kept up, because of technological improvements, other efficiency improvements, and the colonization of new lands and peoples. Neither Malthus nor Solow nor Hartwick include technological change in their models. That is because the introduction of technical change into a mathematical model will too easily generate sustainability.

Criticisms of Hartwick's Rule

Hartwick's Rule depends on the production function being the kind where the inputs are multiplied together to yield the output. This means that it is always possible to make up for a shrinking amount of one input by using more of another input. In Hartwick's model, an expanding stock of K makes up for a diminishing stock of non-renewable resource. R. Herman Daly (1990), one of the founders of Ecological Economics, has pointed out that there may be critical thresholds below which all the physical capital in the world cannot make up for the loss of natural or environmental capital.

Ecological Economics was established as a discipline in 1990 by economists who were concerned that traditional economics does not adequately consider the economy's size and the population's size relative to the carrying capacity of the environment. We will discuss population size in our next Chapter.

A compromise

We can take Hartwick's Rule as suggestive rather than definitive. It recommends something that common sense immediately recognizes: do not allow the stock of your capital to diminish. Invest the profits you earn from nonrenewable resources. Save for the day when your resources run out.

Many nations have created **sovereign wealth funds** to invest the tax revenue that their governments collect from the oil and gas industry. Alaska, Kuwait, and Norway have such sovereign wealth funds. Alberta

2. In quasi-arithmetic growth, $N(t) = a + b(t)$

contributed to its Sovereign Heritage Savings Trust Fund between 1976-1988, and 2005-8, but otherwise the revenue has been used by the government or distributed among Alberta's residents. Chile and Venezuela use resource tax revenues to help with government spending needs.

Genuine Savings

Genuine Savings, also known as Adjusted Net Savings, is an estimate of whether a nation's capital stock (including physical, human, natural, and environmental capital) is really growing or not. If genuine savings is positive, then the nation is wisely building up its capital stock. If genuine savings is negative, then the nation is dissipating its capital.

Here is the calculation:

$$\textbf{Genuine savings} = \text{investment in physical capital} + \underbrace{\text{current spending on education}}_{\text{(i.e. investment in human capital)}} - \underbrace{\text{depreciation of physical capital}}_{\text{(due to wear \& tear)}} - \underbrace{\text{Total Hotelling Rent}}_{\text{(representing depreciation of exhaustible resources)}} - \text{a charge for over-harvesting renewable resources} - \text{estimated damages from pollution}$$

If the rate of genuine savings is positive, the nation is accumulating capital. The question then is whether the rate of capital accumulation is high enough to match population growth.

In Table 18-1 we see estimates of Genuine Savings (as a rate) for several countries, computed by the World Bank.

Table18-1. Genuine Savings Rate and Population Growth for Selected Nations, 2018-2019

Selected Countries	Genuine savings (Adjusted Net Savings) as a % of Gross National Income (GNI) [2018-19]	Population Growth [2019]
Macao SAR, China	49.4	1.4
Bermuda	34.2	-0.0
Kuwait	30	1.7
Qatar	30	1.8
Singapore	28.8	1.1
China	27	0.4
Saudi Arabia	23.4	1.7
Dominican Republic	19.1	1.0
Denmark	14.6	0.4
Norway	14.4	0.7
Ireland	14.2	1.4
Mexico	6.4	1.1
Australia	5	1.5
Romania	4.5	-0.5
Canada	3.4	1.4
Bolivia	3.2	1.4
USA	2.4	0.5
Kenya	-7.5	2.3
Zimbabwe	-11.4	1.4
Lebanon	-23.2	-0.1
Liberia	-69.4	2.4

[58] Compiled by Pauline Galoustian. Sources: World Bank (data.worldbank.org) /United Nations Population Division/Eurostat: Demographic Statistics/United Nations Statistical Division/Secretariat of the Pacific Community (CC BY 4.0)

How can we tell whether the Genuine Savings of a country is enough to keep its consumption sustainable? If the population is not growing, any genuine savings above zero indicates an increase in the productive capacity of the economy and an improvement in its ability to provide consumption sustainably into the future. If the population is growing geometrically or exponentially (as is usually the case), then Genuine Savings needs to be impossibly high unless technical change and efficiency improvements are occurring (as is usually the case). In the situation of population growth with technical change, we don't have a simple equation to calculate how high a nation's Genuine Savings needs to be.

The World Bank (2011), in its Appendix E, tried to estimate that anyway. Their calculations for the year 2005 purported to show that Canada's genuine savings that year had been sufficient to cover its population growth. They also estimated that the United States had needed to save an additional 2% of gross national income in 2005 to keep its capital-per-person (they did not calculate it per worker) intact.

In our next chapter, we'll study the effects on the economy of the absolute size of the population.

The end-of-chapter questions follow the Appendix below.

Appendix: Solow model math

Let *K(t)* be the capital stock at time *t*. *s* is the savings rate. *d* is the rate at which capital breaks down or becomes obsolete: the depreciation rate. We will set $d = 0$ for simplicity. *L(t)*, the labour force at time *t*, is growing every year at rate *n*.

The production function is:

$$Y(t) = A(t)\, F(\, K(t), L(t)\,)$$

$A(t)$ is efficiency or technology at time t and we just hold it constant, meaning:

$$Y(t) = A\, F(\, K(t), L(t)\,)$$

Dividing by $L(t)$, we write $y(t) = A\, f\,(1, k(t))$ where y is output per worker and k is capital per worker.

We can ignore the 1 and write:

$$y(t) = A\, f(\, k(t)\,)$$

The following equation shows how the capital stock grows from year to year:

$$K(t+1) = K(t) + s\, Y(t)$$

Translation: capital next year = capital this year + amount saved minus capital lost to decay and obsolescence. Rearranging:

$$K(t+1) - K(t) = s\,Y(t) = s\,A\,F(K(t), L(t))$$

What we're going to do now is divide everything by $K(t)$.

$$\frac{K(t+1) - K(t)}{K(t)} = \frac{s\,A\,F(K(t), L(t))}{K(t)}$$

Using the fact that,

$$\frac{F(K(t), L(t))}{K(t)} = \frac{\left(\frac{F(K(t), L(t))}{L(t)}\right)}{\left(\frac{K(t)}{L(t)}\right)} = \frac{f(k)}{k}$$

the equation becomes:

$$\frac{K(t+1) - K(t)}{K(t)} = \frac{sAf(k)}{k}$$

The left-hand side is "percentage change in K". Now the percentage change in little k is equal (by definition) to the percentage change in K minus the percentage change in L. The percentage change in L is the population growth rate, since in this model, everyone is in the labour force. So let's replace the left-hand side of our Solow equation with the percentage change in k plus n, the population growth rate.

$$\frac{k(t+1) - k(t)}{k(t)} + n = \frac{sAf(k)}{k}$$

$$\frac{k(t+1) - k(t)}{k(t)} = \frac{sAf(k)}{k} - n$$

Now multiply both sides by $k(t)$ and we have our final version:

$$k(t+1) - k(t) = sAf(k(t)) - nk(t)$$

This is Equation 18.1 It tells us that, for capital-per-worker to be constant over time – i.e. for the left hand side of this equation to be equal to zero, – savings per worker must equal the population growth rate multiplied by capital per worker.

Exercises: Chapter 18

1. What assumptions about the economy does the Solow model make?
2. In the Solow model, what are three ways that n, the rate of growth of population, can affect the steady-state capital:labour ratio, k*?
3. What is Hartwick's Rule and how has it been criticized?
4. If in 2008, Country X sells 100,000,000 barrels of oil, and if the marginal cost of this oil is $92 per barrel, and if the price of this oil is $100 per barrel, what is Total Hotelling Rent for Country X in 2008?
5. Country Y in 2008 has:

- investment in physical capital=15.9 percent of GNI (gross national income)
- current spending on education = 5 percent of GNI
- depreciation of physical capital = 11.5 percent of GNI
- Total Hotelling Rent of 0
- over-harvesting renewable resources valued at 0.1 percent of GNI
- estimated damages from pollution valued at 0.3 percent of GNI

a) What is genuine savings for Country Y?

b) What can you tell me about Country Y?

Chapter 19: Size and Sustainability

We've examined the economic strains associated with population growth. Population growth results in a larger population – something that can bring economic benefits as well as economic challenges.

Now that we have considered the economic impact of the rate of population growth, let's consider the economic impact of the population's current size.

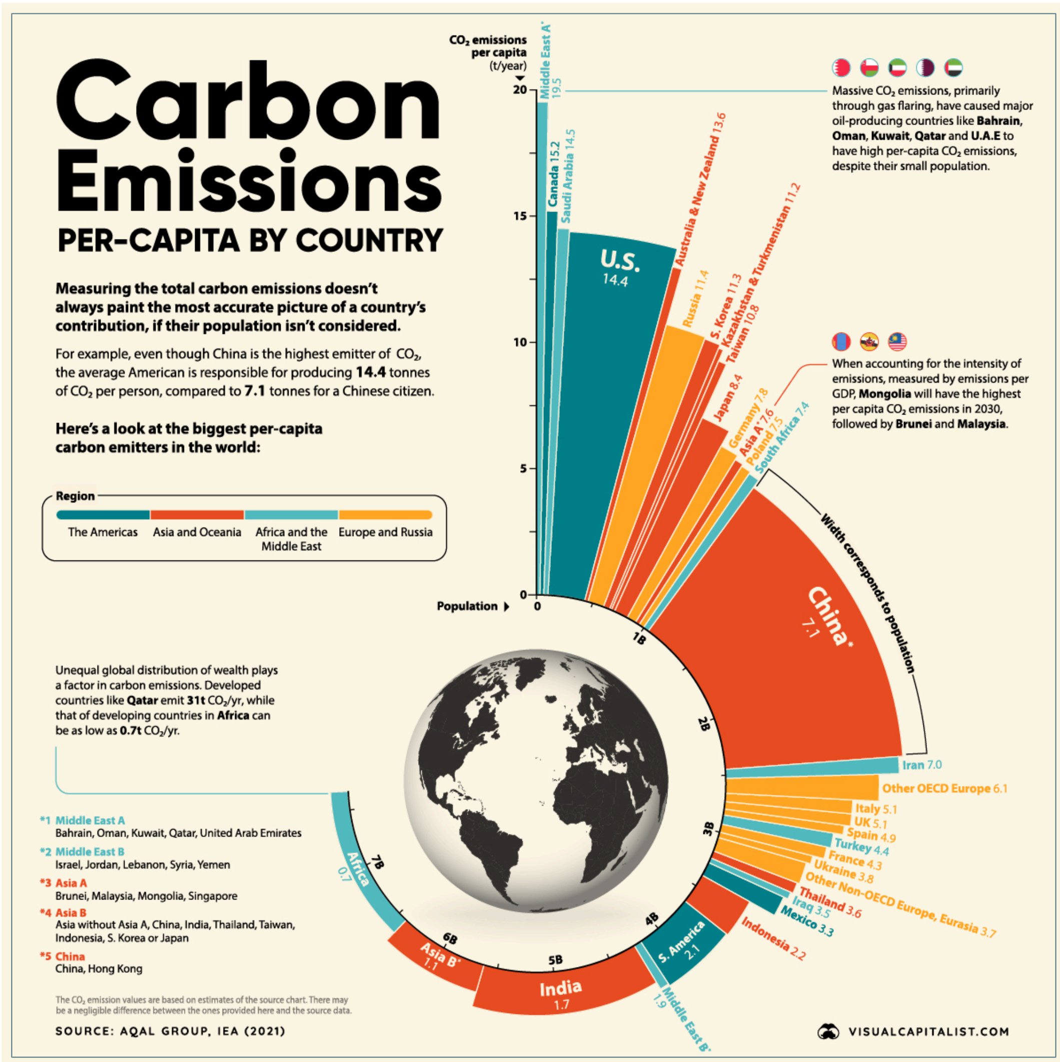
Even if the population is no longer growing, the population may be so large that just maintaining the population as its current size and standard of living requires the overexploitation of sensitive natural and environmental capital. We see this possibility today as we face global warming due to human activity. The level of carbon emissions rises with the number of people, other things being equal. But other things may not be equal. The level of carbon emissions also depends on production and consumption per person and the carbon intensity of that production and consumption.

carbon emissions = # people x carbon emissions per person

carbon emissions per person = goods consumed/produced per person x carbon intensity per good consumed/produced

That is why wealthier nations tend to have larger carbon footprints than poorer nations. Canada in 2020 was the eleventh largest emitter of CO2 in the world, right after various Middle Eastern countries, and approximately thirty-ninth by population.

Figure 19-0. Carbon Emissions circa 2021



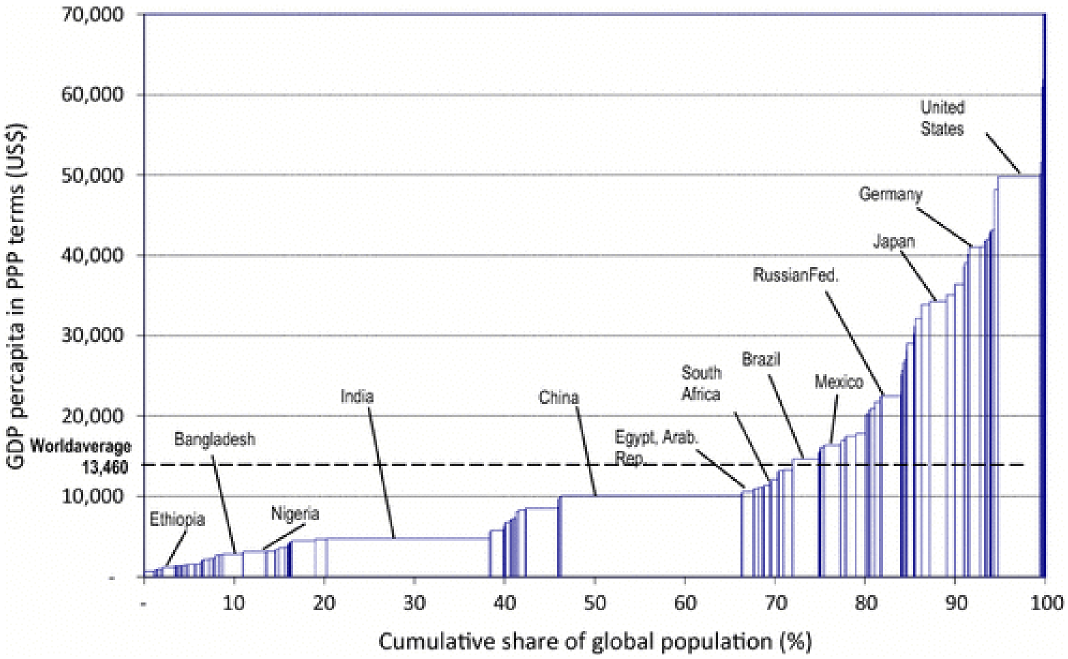
Source: Anshool Deshmukh and Amanda Smith, 2021, Visual Capitalist at visualcapitalist.com, some rights reserved.

In Figure 19-0 above, the width of a country's bar shows the number of people, and the height of the bar shows the carbon emissions per person.

We see that a population's size is not tightly correlated to its carbon emissions per person.

Figure 19-1 shows us data from 2011. The width of the each bar indicates the size of the nation's population as a fraction of the world population, while the height of the bar indicates its GDP per person, measured in US dollars and adjusted for differences in the cost of living. Some of the largest countries are the poorest, but there are many exceptions. The nation with the highest material standard of living, the United States, is not one of the smaller ones.

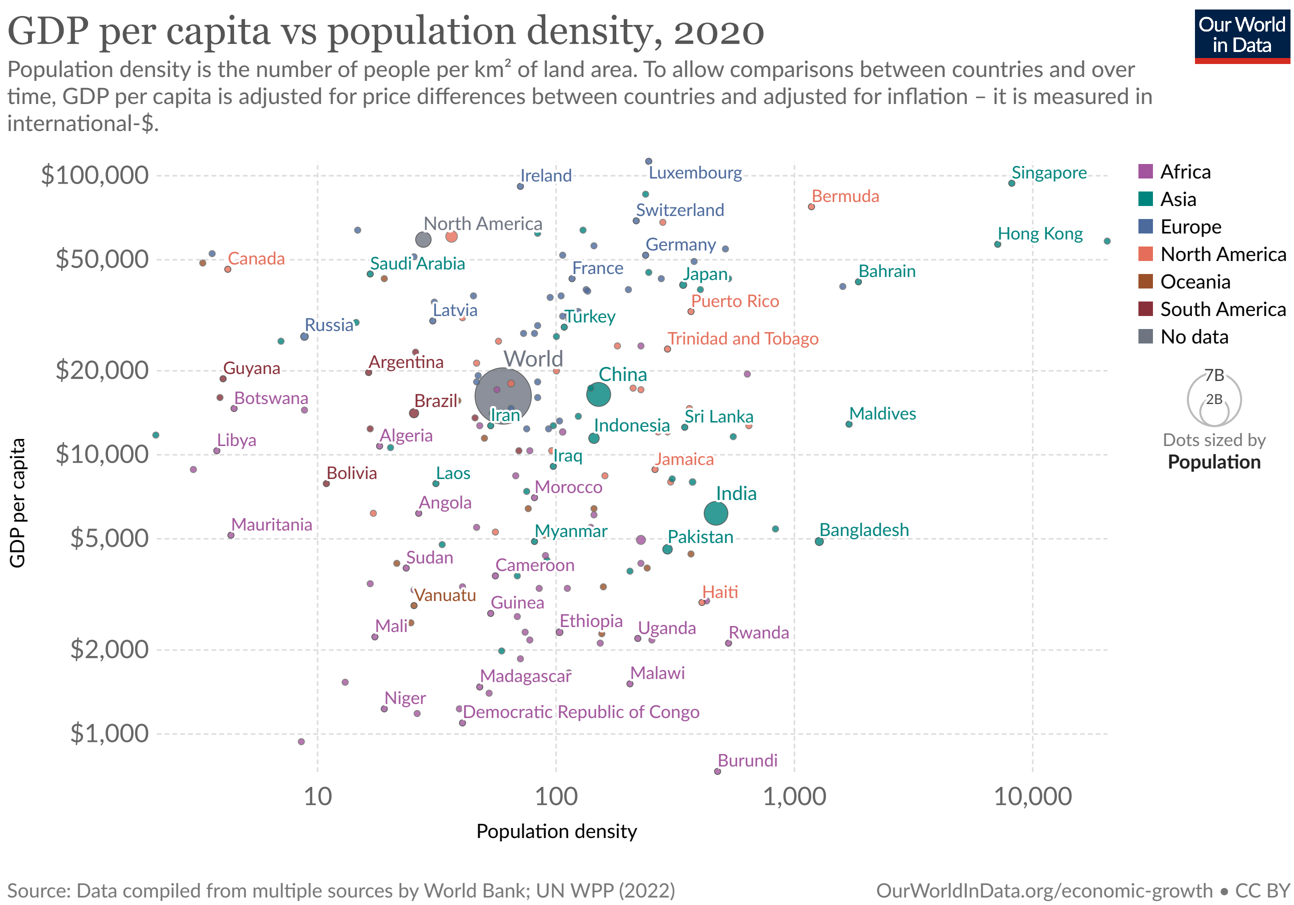
Figure19-1. Nations by GDP per capita and share of the global population, 2011



Source: World Bank (2014).

The next Figure compares per-capita income to population density for countries in 2020. Both axes are in logarithmic scale because the differences measured linearly would be too great to fit all countries on the same graph.

Figure 19-2



Population density may be relevant to the standard of living inasmuch as capital – physical, environmental, social – may be strained within a particular region. However, within a country, densely populated regions such as cities often feature more capital per worker than less densely populated regions.

Discussion Idea

What kinds of capital may be critically low in a crowded city? How would that affect GDP and well-being?

Figure 19-2 shows us that, while many low-GDP-per-capita nations were densely populated in 2020, so too were the Netherlands, Singapore, and Hong Kong.

Consider that there are several ways in which population size and density can benefit a nation economically. A large and densely populated nation potentially can enjoy more specialists, a thicker market, internal economies of scale, external economies of scale, and improved innovation. Not that a small or sparsely populated country couldn't enjoy some of these features. If a small or sparsely populated country had extensive free trade relationships, a similar language and culture as its trading partners, excellent telecommunications and transportation networks, similar regulations, and few tariffs, national borders would be irrelevant and its small size would not matter.

Would you prefer to live in a larger city? Would you prefer to attend a larger university? Scale brings some advantages.

Specialization

A larger population provides a greater variety of individuals, organizations, businesses, and educational institutions which, given opportunities, are able to make available specialized services and unique points of view. To reap this reward, everyone should have equal access to supports and opportunities, and it should be easy to start new businesses.

When people are able to specialize, there are gains from trade as each person operates according to their comparative advantage.

> *Example from the world of music*: In a very large city, as opposed to a small town, there is likely an expert who can teach you to play an unusual musical instrument such as the harp.

Thicker markets

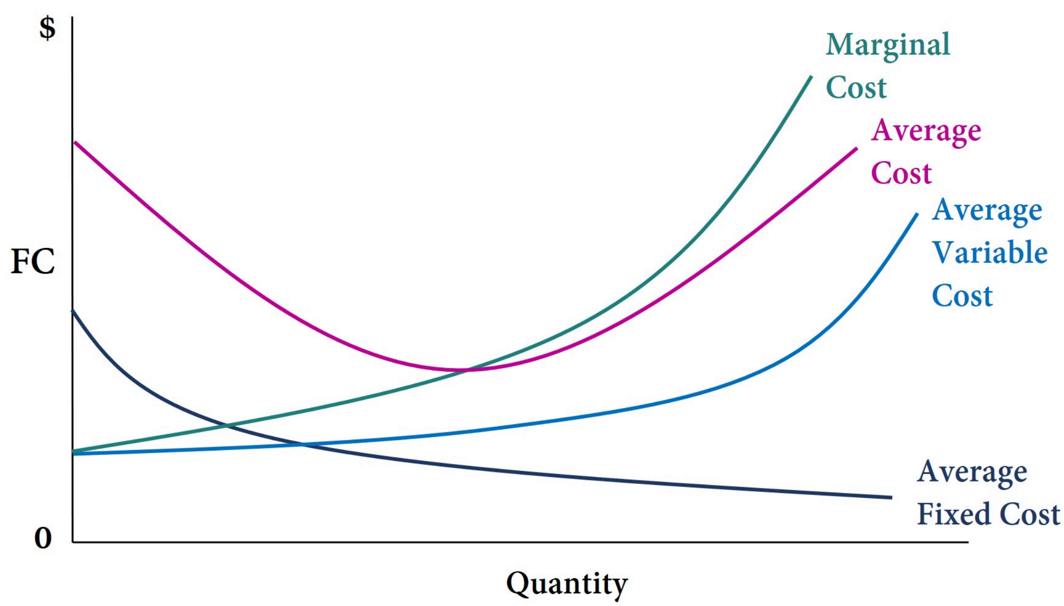
In a dense population it is easier for buyers and sellers to find one another. There is likely always something available in any product class.

Example from the world of music: In a very large city, there is likely some kind of concert offered every weekend. There will at least occasionally be less popular kinds of concerts, such as operas.

Internal Economies of Scale

Businesses and governments spread fixed costs like buildings, advertising, and administration over the number of customers/citizens they serve. The point at which average costs (the red line in Figure 19-3) are lowest is called an entity's **minimum efficient scale**.

Figure 19-3. Typical Cost Curves



A business that has not yet reached its minimum efficient scale can achieve **internal economies of scale** by growing and increasing its output. If the domestic market is very small, a firm might be able to achieve economies of scale by exporting; however, exporting entails complications like exchange rates, tariffs, and transportation across borders.

Example from the world of music: A voice instructor may be willing to drive to another town for four students but not for one student.

External Economies of Scale

A business can also achieve lower costs by being near other, similar businesses. For example, like a mini-Silicon Valley and a mini-Hollywood, Burnaby, British Columbia has attracted many film studios and tech companies. For this reason, other film and tech firms are likely to locate nearby. Together they will attract the talent, the attention, and the service industries they all require. They may also become more productive by sparking off each other or by competing. The profit a firm can earn by being part of a local industry is called **external economies of scale**.

Example from the world of music: A large population is more likely to have enough singers and musicians to support one or more shops supplying sheet music and musical instruments, as well as an orchestra, a youth orchestra, and concert halls.

Improved innovation

Larger countries may have an innovation advantage. For one thing, the research sector is likely larger. This will support more specialists, and more internal and external economies of scale in research.

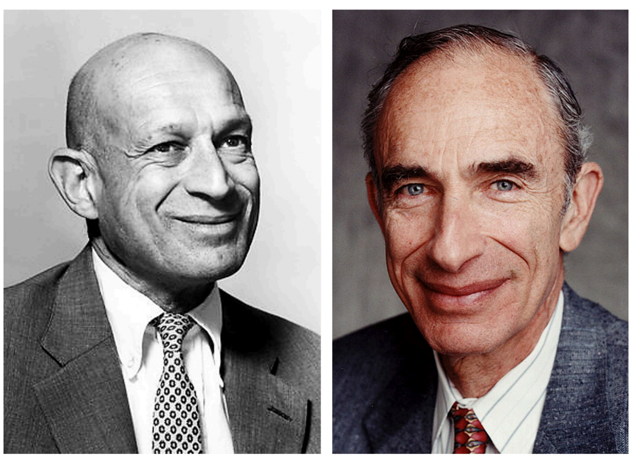
Another reason is that there is more economic activity in a larger country. Some innovation develops spontaneously in a process of learning-by-doing.

Example from the world of music: Western musical notation developed during the Middle Ages in the Church's vast network of choirs, all of which used the same prayers chanted or sung in the Latin language.

In addition to all the advantages listed above, there may be other material benefits of having a large population. For example, sheer size of population may be important, though not conclusive, militarily. Some groups desire population growth to ensure physical safety. Some groups desire a large population in order to preserve their unique culture, language, or beliefs.

A famous debate

Two prominent thinkers had very different ideas of whether population size would eventually overwhelm the natural world. Julian Simon, an economist (pictured at left) and author of ***The Ultimate Resource* (1981)**, argued that human ingenuity is the ultimate resource. Human ingenuity will respond to scarcity with new ideas that permit more substitution for natural resources. Prices will signal scarcity and reward innovators. The standard of living can be sustained and improved with the help of new technology and new systems.



Left: Julian Simon (1932-1998), Photo courtesy University of Maryland. Right: Paul Ralph Ehrlich (1932-present), credits to: Stanford University.

Paul R. Ehrlich (at right), a biologist and co-author of ***The Population Bomb* (1968),** argued that innovations buy only temporary respite from scarcity and mask the fact that we will not survive once natural capital is driven below a critical threshold. Our standard of living cannot be sustained, and it is jeopardized more and more by population growth.

In 1980, these two scholars made a bet about how high mineral prices would be in 1990. Simon was so sure that natural resources would not rise in price over the next decade that he allowed Ehrlich to choose any five resources that Ehrlich thought would become more expensive in real terms (i.e. excluding inflation). Ehrlich chose five different metals. Each fell in price between 1980 and 1990, despite the world's population having grown by 869 million people.

Not to be outdone, Ehrlich proposed a second bet. This time he wanted to wager that in 2004 compared to 1994 there would be less agricultural soil per person, less rice and wheat grown per person, lower sperm cell counts in human males, fewer plant and animal species in existence, a greater gap between the richest and poorest people, and so forth. This time Ehrlich was focusing on physical counts rather than dollar values.

Simon declined this new bet, saying it measured changes to human welfare only indirectly.

Discussion Idea

Is the second bet as meaningful as the first? In what ways is it more or less meaningful?

While we're all hoping that world history will continue to back Simon's point of view, there have been times when the sustainability of human culture and economic activity has been compromised by environmental degradation.

The case of Easter Island is the most famous example of environmental collapse. But this case has recently been re-interpreted, as discussed in Box 19-1.

Box 19-1. The Case of Easter Island

Easter Island or Rapa Nui is a 71-square km island in the Pacific Ocean which was settled by people of Polynesian ancestry. Initial radiocarbon dating indicated that it was first settled between AD 400-800.

Photo credit: Ken Wiseman, flick.com, CC BY 2.0

In 1722, Roggeveen became the first European to encounter the island. He reported the island as being treeless, and the islanders, as starving. Later he revised his account and promoted the island as having great agricultural potential. Scholars such as Diamond (2004) concluded that the islanders, who grew to about 15,000 people, deforested Rapa Nui. Their failure to protect the trees, restrict wasteful activities, and solve social problems resulted in poverty.

More recently, Hunt and Lipo (2006) proposed that the population of Rapa Nui was never as large as 15,000 because it was not colonized as early as previously thought. Their carbon dating of sites suggests first settlement at AD 1200 or later.

Hunt and Lippo believe that rats from the boats of the Polynesian settlers ate too many of the nuts of the slow-growing palm trees, and in this way destroyed the forest. They also think that the settlers managed well despite the deforestation, until European contact brought disease. European slavers took at least 1,000 people from Rapa Nui in the early 1860s.

We will revisit the themes of sustainability and collapse in Chapter 25, as we summarize what we have learned in this course. For now, we turn to study that third driver of population change, Migration. Migration has the ability to change population size, density, and age structure in the blink of an eye.

Exercises: Chapter 19

1. Describe, as best you can, an actual place whose economy might benefit from a larger size population. Explain why a larger size population could be advantageous.

2. Give an example from real life where the internet is helping make markets

a) bigger

b) thicker

c) more friendly to innovation

3. Replace this chapter's "examples from the world of music" with examples from the world of football or soccer.

MIGRATION

Chapter 20: Voluntary Migration - Theory

Migration is defined as any permanent change in residence from one region to another. In-migration (immigration) and out-migration (emigration) are the fastest ways in which a population can change its size and composition. Such rapid change can pose many challenges, including the challenge of socially integrating people from different backgrounds.

So far we have not studied migration. Everything we have learned can apply to an isolated population. But very few societies are isolated any longer. Immigration and emigration pressures can greatly influence a nation's standard of living and economic potential.

Usually when we speak of immigration, we mean legal migration across national borders. But the motives and consequences of migration are similar whether the movement is legal, illegal, across national borders, or just across the neighbourhood.

Governments tightly regulate immigration, but there are always some people who manage to enter illegally. Governments typically do not keep track of emigration. In this way both immigration and emigration pose measurement challenges.

$$\text{The Net Migration rate (NMR)} = 1000 \times \frac{(\text{immigrants} - \text{emigrants})}{\text{mid-year population}}$$

If migration data are lacking, you can estimate the NMR using the demographic equation from Chapter 3. If you know the change in population, and births and deaths during the year, you can infer the rate of increase due to net migration. If further you know the immigration rate, you can infer the emigration rate.

$$\text{The migration ratio} = \frac{(\text{net immigration})}{(\text{natural increase})}$$

Migration factors

People migrate because they are PUSHed out of their old place of residence and/or PULLed into their new place of residence. We'll discuss the special push and pull factors associated with human trafficking and slavery in our next chapter. For people who are choosing to migrate,

Push factors include:

- imminent personal danger
- environmental degradation
- threat of destruction or confiscation of property
- discrimination: oppression against one's religious, political, ethnic group etc.
- economic hardship
- military draft
- forced marriage
- indebtedness
- misinformation

Pull factors include:

- higher wages, lower land prices, greater economic opportunity
- better amenities
- educational opportunities
- greater safety and freedom
- adventure

International Organization for Migration staff member registers Chadian migrants seeking to return home after hostilities broke out in the Central African Republic in 2014. Photo by Sandra Black for IOM, flickr.com. CC BY-NC-ND 2.0 DEED.

Depending on the push or pull factors, those who migrate may share certain characteristics.

E.S. Lee (1966) emphasized that "migrants are not a random selection of the population at origin." For one thing, migration is more likely at certain stages of life, such as graduation from an educational program, entering the labor force, leaving the parental home, widowhood or divorce, and retirement.

Abramitsky, Boustan, and Erikkson (2012) studied men who migrated from Norway to the United States in the late nineteenth century, men who had non-emigrating brothers. They found that households with poorer economic prospects were more likely to send migrants to the US, and that within households, men with poorer prospects were more likely to migrate. Men who migrated from rural areas ended up doing 93% better financially than their brothers who remained at home, whereas men from urban areas did 42% better financially after migrating.

Simone Wegge (2009) has studied data from more than 1000 villages in the German principality of Hesse-Cassel during 1852-1857. Her data suggest that, up to a certain point of wealth, people with more money were more likely to immigrate than those without. After all, the trip to New York from Hamburg cost twice the yearly wage of a labourer. But at the highest levels of wealth, there was not the incentive to emigrate. This suggests that regions with more polarization of income will experience less emigration.[1]. Wegge found that the villages which experienced the most emigration were those

- that practiced unigeniture: the eldest son would inherit the entire farm, leaving little for other sons.
- those which had higher emigration flows in the past
- those with fewer factories
- those with more religious minorities

When migration is voluntary, the people most likely to migrate are possibly:

- ☑ The most entrepreneurial. (The check mark indicates this is a good thing for the recipient country)
- ☑ The most willing to change
- ☑ People with marketable education and skills
- ☑ People with existing connections to the new place
- ☑ People not desperately poor
- ? Young adults and retirees versus working age people
- ? Those who were minorities in their own nation
- ? Newly-weds versus longer married
- ☒ Those not wealthy

It is important to anticipate how an immigration policy and a global situation will *select* for a particular kind of immigrant.

1. Arends-Kuenning, Baylis, and Garduño-Rivera (2019) find this in Mexico, before and especially after implementation of the North American Free Trade Agreement.

Brain Teaser

Lee (1966) noted that the characteristics (such as education, health, desired family size) of migrants who are pulled rather than pushed towards a new residence tend to be intermediate between the characteristics of the average citizen in their home country and the average citizen in their destination country. What does this do to the characteristics of the average citizen in each place?

The Expected Real Wage

The most important PULL factor tends to be the expected **real wage** in the destination country. It is not enough to know that the average wage is higher in the destination country than in the home country. A would-be migrant must divide the average after-tax wage in the destination country by the cost-of-living to find the after-tax real wage in the destination country, and that after-tax real wage must be multiplied by the probability (less than one) that he or she will succeed in finding a job.

The savvy migrant calculates the **expected real wage**, formed by multiplying each possible real wage (after income tax) by the probability of achieving it, and summing the total. The migrant then compares that expected real wage to what they are earning in the home country.

The same math works for migrants considering moving within a country between one region and another. This model, known as the Harris-Todaro model, was developed to explain rural-to-urban migration. It does not consider a region's amenities, safety, or other factors, just the real wage that people can be expected to earn.

Consider a hypothetical city in which there are two sectors, a **formal sector** where wages are recorded and taxes are paid, and an **informal sector** where taxes are not paid**.** Let e_1 be the probability that the migrant can find work in the formal sector. Similarly, let e_2 be the probability the migrant can find work in only the informal sector, which is not recorded or taxed, presumed to be their second choice. The unemployment rate is $1-e_1-e_2$.

As expressed in Equation 20-1, workers going to the city can expect to earn the formal sector after-tax real wage multiplied by e_1, plus the informal sector real wage multiplied by e_2, plus nothing at all or some welfare payment multiplied by the probability of not finding a job in either sector ($1-e_1-e_2$).

Equation 20-1. expected real wage in city = e_1 x formal sector after-tax real wage + e_2 x informal sector real wage +($1-e_1-e_2$) x income available if unemployed

As workers stream into the city looking for work, the unemployment rate in each sector is likely to rise, and wages are likely to fall, at least in the short run, because more people are competing to work there. Thus the expected urban wage will fall until it is equal to the rural wage. At that point, moving to the city to earn a better wage is likely to be disappointing.

Equation 20-2. expected real wage in destination location = actual real wage in current location

Equation 20-2 tells us that in equilibrium, one city cannot offer higher expected real wages than another city. Migration to the city with the higher expected real wage would continue until its wages came down or its unemployment rate went up.

If the formal sector city wage cannot fall as low as the rural wage, perhaps because of legislation or unionization, people will migrate to the city until the unemployment rate there rises to the point that Equation 20-2 is satisfied.

If two cities have the same unemployment rate and the same real wage, but one of the cities has a much larger economy than the other, then the larger city is more attractive. This is because the presence of a new arrival does not change the unemployment rate as much in a larger city as in a smaller city. If the large city is ten times the size of the small city, ten times as many people will migrate to the larger city to keep the expected real wage the same. The unemployment rate in each city will then be the same.

Consequences of rural-urban migration

The consequences of rural-urban migration are the same as those for international migration, but there are some special considerations:

- The geographic concentration/ population density implied by urbanization may overwhelm the infrastructure.
- The population density makes unemployment or underemployment more visible.
- There may be no legal way to prevent the migration. It is more difficult to keep people out of a city than out of a nation.

How could one stem a tide of rural migrants? Force is sometimes used. Since 1958 China has had a system of residency permits called "hukou". The permits specify in which region you are allowed to enjoy schooling, housing, medical, and other subsidies. Permits for major cities are highly sought after, but usually only temporary residence permits can be obtained, with which it is not possible to have one's children schooled or to have the same quality of life as permanent residents. In 2009, when per capita income in China was about $2,000 USD, the black market price of a Beijing hukou was $5,900 USD.[2]

Using instead a market approach to discourage rural:urban migration would require the city to be made less

2. "China's outdated residence permit system", UPI Asia.com, Feb 20, 2009, downloaded March 3, 2011.

attractive to migrants, or the rural area more attractive. Rural areas could be made more attractive by lowering taxes, improving infrastructure, improving access to loans, and improving government services.

The government of Canada effectively subsidizes citizens to live "up north". The Northern Residents Deduction (see Canada Revenue Agency Form T2222) is an income tax rebate for people living in qualifying areas. The federal government also provides home heating subsidies to older adults and others in northern communities.

Tying Treaty benefits such as income-tax exemptions to residence on a reserve in Canada incentivizes members of First Nations to stay on those reserves.

Consequences of urbanization

What is "urban"? John Weeks (1989) defined an urban area as a spatial concentration of people whose lives are organized around non-agricultural activities.

Urban areas grow by natural increase, international immigration, and domestic migration, as well as by amalgamation with smaller cities nearby, which is more of an administrative matter.

In our chapter on population size and scale we described some of the labour-productivity benefits of cities. Indeed, urbanization is correlated with economic development and prosperity. Which comes first? Economic development or urbanization? The traditional view is that, at a certain level of development and population growth, settling down and specializing tasks becomes possible. But Jane Jacobs (1969) argued eloquently that only in cities, where people are brought together, will economic development occur. The traditional view says that when agriculture is productive and yields output greater than what is needed for survival, then urbanization can begin. Jacobs was convinced that innovations in agriculture began in the marketplaces of towns.

[60] Photo of the outskirts of Kolkata by Abhijit Kar Gupta, 2018, flickr.com. CC BY 2.0

Urbanization is not all good. Cities are crowded. Contagion and conflict are likely. Only in cities can pandemic disease agents survive and evolve. Sanitation problems are likely, as are other forms of pollution. It is believed that during the early years of the Industrial Revolution, population growth was less than it otherwise could have been because the concurrent urbanization compromised health and safety.

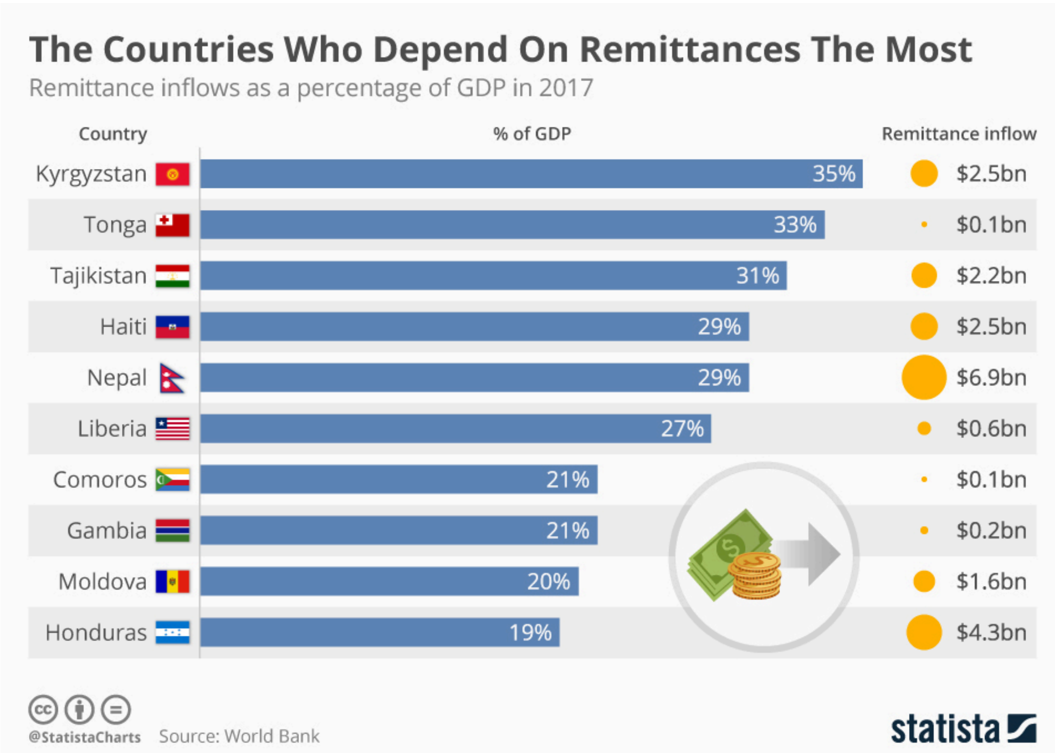
Population growth may give greater impetus to city growth. City growth may lead to innovation and improvements in the standard of living, but it also adds mortality risk factors such as disease and crime. Fertility rates tend to be lower in cities.

Consequences of emigration

Those who voluntarily emigrate or who migrate from rural regions to urban regions must be doing so because they perceive that their lives will be improved by doing so. Unless they have been misinformed or have made wrong assumptions, they will benefit from leaving. The population left behind may also benefit from the migration if its economy is characterized by a low capital:labor ratio. In that case, emigration will cause wages to rise compared to what they would have been otherwise, and land and capital prices may fall.

The population left behind may benefit from **remittances** of cash which the emigrants send back home, or money which they can earn as temporary foreign workers. Figure 20-0 shows that, for many countries, remittances are a significant source of income when compared to Gross Domestic Product (GDP). In 2018, remittances to low and middle income countries amounted to 526 billion US dollars[3], more than *three times as high* as official donations of foreign aid (149.3 billion dollars).[4].

Figure 20-0.



Measured in US dollars.

The economy left behind may be hurt by emigration if the emigrants were better educated than average. This phenomenon is referred to as **brain-drain**. Canada is considered to suffer from brain-drain to the United States. Rural and remote communities suffer brain-drain to urban centres. The economy of the place of origin can also be hurt if it loses citizens who were harder-working, wealthier, or more politically active than average. Family and friends of emigrants will miss them.

Consequences of immigration

If immigrants' dreams come true, they will benefit from their move. However, many are disappointed by the limited opportunity to use their skills in the new country. Countries like Canada impose serious re-

3. Ratha et al (2019)
4. OECD (April 2019)

training requirements on teachers, doctors, and other professionals. Sometimes lack of language proficiency or discrimination are barriers to employment. Many immigrants pin their hopes for financial success on their children.

We shall see below that the citizens of the host country can materially benefit from immigration over the long term if immigrants bring skills, entrepreneurship, ideas and new technologies, and if it is easy to finance and organize new businesses.

Immigration Sign. Credits to: BriansBlog. CC BY-SA 2.0

A casual glance around the world shows that some of the most economically vital nations are nations which welcome immigrants and enjoy a great deal of cultural diversity.

Immigrants may be welcomed for their help supporting an aging population. The idea is that immigrants decrease the Aged Dependency Ratio and pay taxes that support social programs. Whether this is true depends on immigrants not having large numbers of dependents, and on immigrants providing a net fiscal benefit i.e. paying more in taxes than they consume in services.

In Canada, immigrants are immediately eligible for free language training, free health care, and public education. They use the existing infrastructure. After one year of residence they may apply for welfare and subsidized housing. Constantine Kapsalis (2021) estimated the net **fiscal** cost per recent[5] immigrant to be between $900 and $2,000 in 2015. While refugees and immigrants sponsored by family members were net recipients of government spending, Economic Class immigrants (representing the majority of immigrants) actually paid more in taxes than they used.

5. recent immigrants are here described as having arrived between 1995 and 2014.

The host country may have concerns about immigrants' ability and willingness to integrate. Zrill (2007) has a useful model of this.

Consequences of Immigration for Social Cohesion

In Zrill's model, immigrants choose how closely to adopt the characteristics of native-born residents, whom we shall call "locals". The more closely the immigrants conform to local customs, the more pleasant their interactions with locals will be, but the less pleasant will be their interactions with immigrants who have not conformed.

The more that residents, both immigrants and locals, resemble one another overall, the greater the community spirit or "social cohesion". More social cohesion leads to more willingness to contribute to public goods[6], such as neighbourhood-watch programs, clean-up programs, community gardens, and local school programs.

Each immigrant chooses how much to conform to local customs, for example by choice of language, dress, and children's names. This choice is modeled as maximizing a utility function which depends on the level of a public good as well as on the pleasure derived from the average encounter with another person. For each person encountered, the pleasure of the encounter depends on how similar the background characteristics of both people are, and on how similar the chosen characteristics of both people are. There is a tradeoff: the more an immigrant resembles local residents, the less awkward that immigrant feels meeting local residents but the more awkward they feel meeting immigrants who have not conformed.

Each immigrant and each local chooses how much to voluntarily contribute to a public good. In doing so they consider the utility the public good will bring to themselves and others. The utility of others is weighted: the higher the level of social cohesion, the more you care about other people's utility. Thus, the higher the coefficient of social cohesion, the higher the supply of the public good will be.

Zrill works out a simple mathematical example where immigrants can only choose either to not conform at all or to conform completely. He solves for the tipping point between those two extreme choices. The tipping point is found at a particular ratio of immigrants to locals. If the number of immigrants becomes sufficiently high, no integration will take place. This is because encounters with other immigrants are relatively more frequent than encounters with locals, so conforming to other immigrants is more important than conforming to locals.

In Zrill's model, the more ghettoized a group is, the more likely we are to get the non-integration, low public good case. While Zrill's model intriguingly links customs, social cohesion, and public goods, it omits any benefits from cultural diversity.

6. A public good is a good which an entire community shares, and which does not diminish much with each use. Public radio programs, sewage plants, and public parks are examples of public goods.

Suggested Activity:

Apply this model to the case of a university town where students arrive from elsewhere.

Class Discussion

As noted by Doug Saunders (2020), anti-immigration political parties do best in regions where there are few immigrants or racial minority families. Does Zrill's model explain this phenomenon?

Consequences of immigration for the standard of living

Setting aside consideration of social cohesion and public goods, we can use some simple math to uncover the direct material consequences of immigration for the standard of living.

As we saw in chapter 16, the standard of living, defined only in the simplest, most material way, can be broken down into three components:

Equation 16-1. $Y/N = Y/H * H/L * L/N$

Now we'll condense the expression:

Equation 20-3. $Y/N = Y/L * L/N$

Where Y/N is output per person, Y/L is labour productivity multiplied by hours worked per worker i.e. labour productivity measured per worker instead of per hour, and L/N is the number of workers divided by the population. L/N is inversely correlated with the total dependency ratio, TDR.

When the population increases, either by natural increase or by immigration, the consequence for the standard of living depends on the impact of the population increase on labour productivity and on dependency.

To the degree that immigrants have few dependents and can find work, they will increase L/N.

If new immigrants receive more government services than they pay for, the distribution of GDP will be affected, but not necessarily GDP per person, unless the taxes used to pay for immigrants' needs are negatively impacting labour productivity. From the native-born population's point of view, however, net transfers of tax revenue to newcomers is a cost.

In this chapter we will call all people who are not newcomers "native-born", for simplicity.

What about labour productivity? Does immigrant labour improve it? Labour productivity depends on efficiency and on the capital:labour ratio. Most people agree that a lot of immigrants are hard-working and that immigration improves efficiency. Immigrants arriving without money, skill, or new ideas, however, will drive down the capital:labour ratio K^+/L, at least temporarily.

Consequences of immigration for the real wage

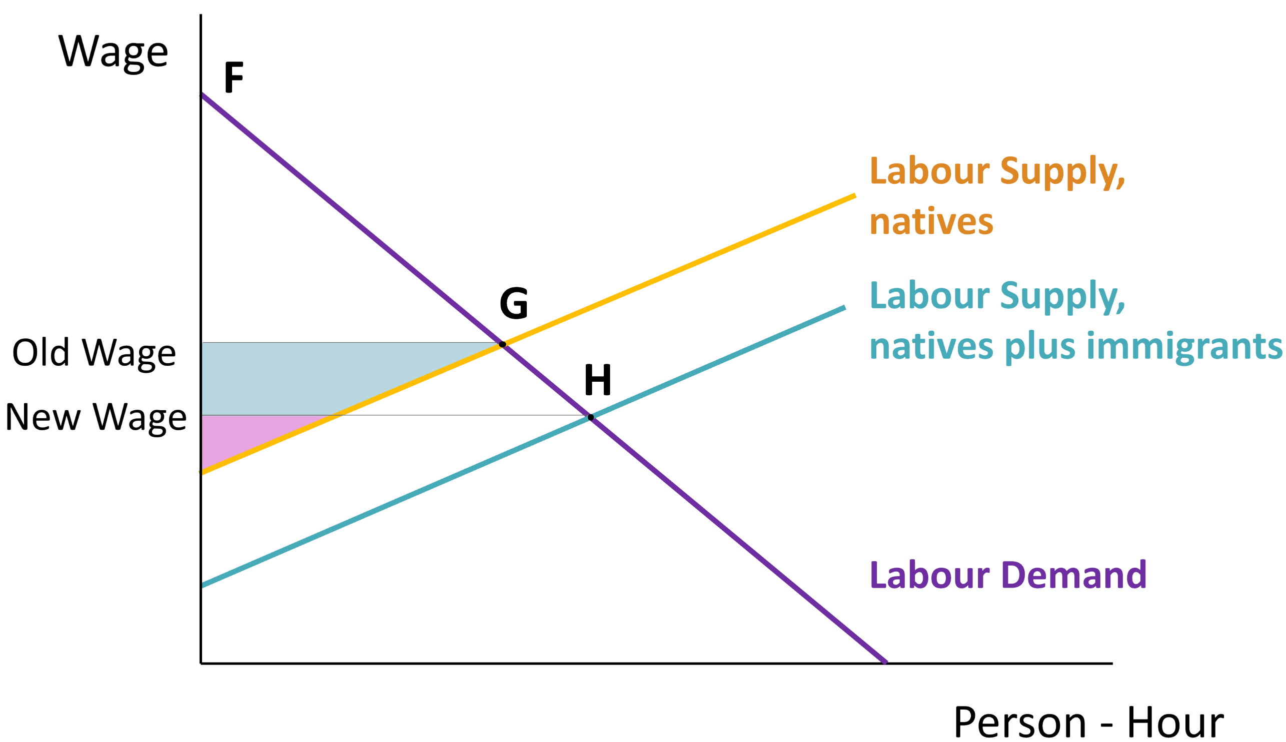
We noted in Chapter 18 that a growing population experiences a falling capital:labour ratio unless the savings rate is sufficiently high. We employed a constant-returns-to-scale aggregate production function, one example of which would be $Y = A\,K^{+1/3}L^{\,2/3}$, where A is efficiency, otherwise known as "multifactor productivity"; L is raw labour, measured in person hours; and K^{+} is any kind of capital, including human capital like education, that workers can use. In this very macro model, there is only one good produced, so we can take the price of it as being equal to $1.

Dividing Y by L we see that labour productivity measured per worker is equal to $Y/L = A\,(K^{+}/L)^{1/3}$.

The expression for the wage is very similar. The wage is equal to the derivative of Y with respect to L, multiplied by the price of the output. Taking the price of output Y to be $1, the wage is equal to the derivative of Y with respect to L, which is $2/3\,A(K^{+}/L)^{\,1/3}$.

Since this wage, reflecting what employers are willing to pay, is inversely related to L, we can draw the labour demand curve – the horizontal summation of individual employers' demands for labour – as a downward sloping line in wage/person-hours space. A and K^{+} are held constant. It is graphed in Figure 20-1 below.

Figure 20-1. Labour Market with Immigration



Since Labour Demand is a function of efficiency (A) and the capital:labour ratio (K^{+}/L), any improvements in A or K^{+} will shift the Labour Demand curve to the right, resulting in higher employment.

This diagram is for a nation's labour market as a whole. But it would be better to study labour

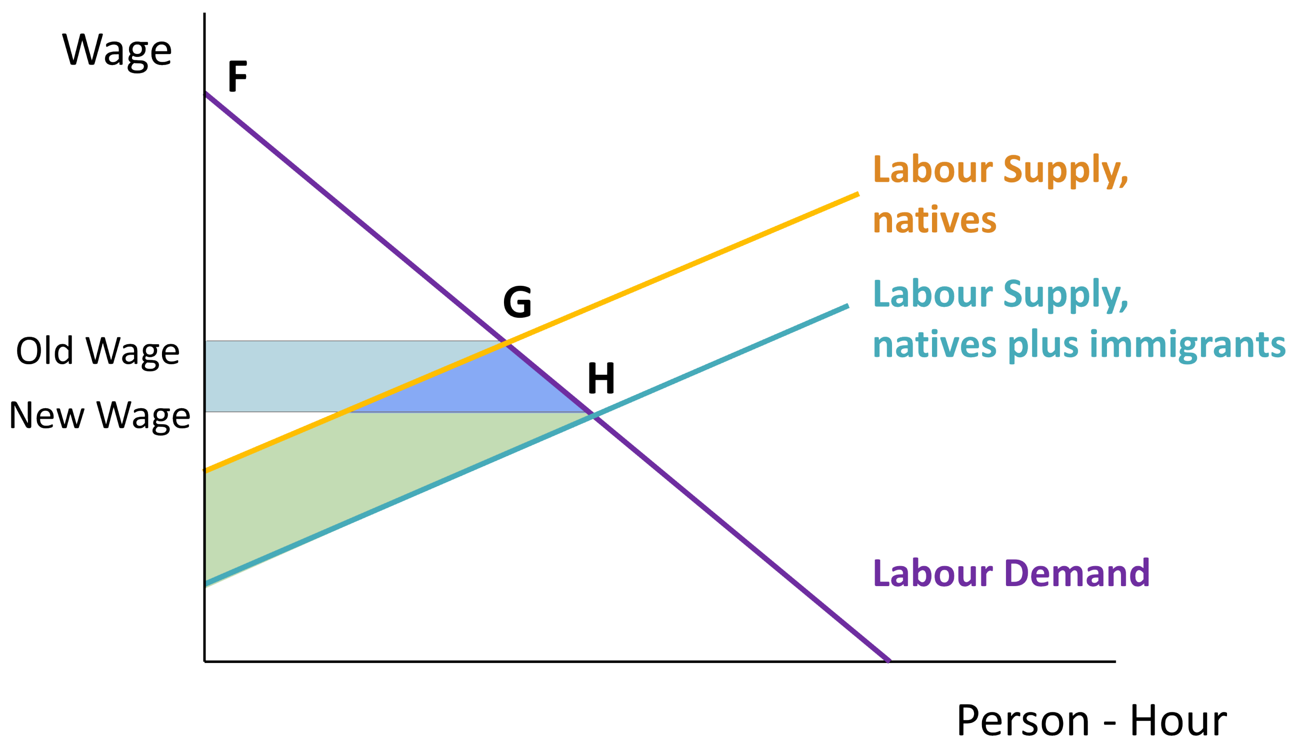
supply and labour demand for particular occupations in particular regions. Not all occupations and regions will be equally affected by immigration.

Let's examine Figure 20-1. Before immigration took place, the native-born workers earned the "old wage" and earned **producer surplus** equal to the light blue shape PLUS the purple triangle. This shows what native-born workers gain that is over-and-above their minimum requirements for compensation.

Once immigrants join the labour market, the wage falls to "new wage". This is all about the capital:labour ratio dropping. The new wage line meets the native-born labour supply curve at a lower level of employment, indicating that some native-born workers are not willing to work at the new wage. Those who are willing earn a lower wage, and their producer surplus shrinks to just the purple triangle. So the light blue area is lost the native-born workers.

Figure 20-2 shows us who gains from an expanded labour market. **Consumer surplus**, which shows the difference between what employers would have paid (as shown by the demand curve) and what they had to pay (the going wage), has expanded. It has increased from triangle F-G-Old Wage to become F-H-New Wage. The increase is represented by the light blue shape (at native-born workers' expense) and the bright blue triangle (pure gain). The immigrants earn the green area (pure gain), which is the area between the two supply curves and under the new wage.

Figure 20-2. Changes due to Labour Supply Expansion



Comparing the total surplus (producer surplus plus consumer surplus) before and after immigration, there is a net gain of surplus equal to the green area plus the bright blue triangle. The bright blue triangle is the net gain to the host country's population, and it accrues to employers, whereas the green area accrues to immigrants.

GDP has increased, but GDP per person may not have increased (yet)

GDP has increased because there is more of one of the inputs (labour); however, as we learned in chapter 16, GDP **per person** does not increase unless labour productivity improves or dependency falls. The material well-being of the average native-born person likely falls in the short run because their wage and labour force participation is reduced. They may also experience a redistribution of tax revenues from themselves to the immigrants.

Discussion Idea

In Economics theory, people are both workers and employers, buyers and sellers. As workers they are treated as mere inputs, but as human beings they are the raison d'être, the *sine qua non* of Economics. Discuss the tension this creates.

Hope for native workers

Although an increase in the supply of raw labour depresses the wage, it is possible that the new workers bring with them some capital K^+ or some new ideas A. If so, labour demand will rise and shift to the right, raising the wage.

Even if the new workers do not have any K^+ or A with them, K^+ can be accumulated over time through education or investment. The following factors will help speed the wage's recovery:

- access to affordable education
- subsidies for research and innovation
- ease of starting new businesses: few regulations and fees.
- access to affordable loans
- ease of hiring and firing

In real life there is more than one production process and more than one labour market, and the price level is not equal to 1. The price level will be falling as lower wages in industries affected by immigration make for lower prices of goods and services produced in those industries. Workers may experience rising real wages if the cost of living is falling faster than the nominal wage pertaining to their occupation.

Table 20-1 summarizes what we have learned so far about the short-run effects of immigration on the standard of living.

Table 20-1. Short Run Economic Consequences of Immigration

	Short Run Effects of Immigration in affected labour markets
Native workers	Some workers quit. Remaining workers earn a lower nominal wage. Will be affected by the net redistribution of tax revenues to or from newcomers.
Immigrants	Earn the new, lower nominal wage.
Employers	Benefit from the new, lower nominal wage.
Everyone	Benefits from falling prices for goods and services.
GDP	Rises because there is more labour input.
GDP per worker	Likely falls initially due to capital shallowing; can recover as capital is accumulated or efficiency improves.
GDP per person	Depends on the change in labour productivity and the change in dependency.

Another short-run, likely persistent effect of immigration is that the population has grown larger. This can have both beneficial and harmful effects on the standard of living, as discussed in our previous chapter, Chapter 19.

In this Chapter we have learned that migration, both international and rural-to-urban, is very responsive to the expected real wage. Immigration into an area depresses the nominal wage of native-born workers until capital accumulation can catch up or until efficiency increases can give productivity a boost. Immigration increases the population's size and diversity. It is likely to reduce the dependency ratio.

Having thoroughly explored the causes and consequences of voluntary migration, let's see what Canada and the US have done and are doing with immigration. That will be the subject of Chapter 21.

Exercises: Chapter 20

1. Complete the clear cells in the following table:

	July 1, 2009	July 1, 2010	July 1, '09-July 1, '10
Canadian population	33,739,900	34,108,800	
Change in population			
Mid-year population			
Births			381,382
Deaths			247,556
Natural Increase			
Net Migration			
Net Migration Rate			
Migration Ratio			

2. If 40% of a nation's population growth comes from net migration, what is its migration ratio?

3. In the life table for a nation, females have a 95 % chance of surviving until age 15, and males have a 94 % chance of surviving until age 15. 15 years ago there were 20,000 females born and 21,100 males. Today there are 19, 100 15 year-old females and 19,000 15 year-old males. Assuming no foul play, what is a rough estimation of the net migration of this cohort so far?

4. In the mid 1990s, universities and boards of education in Ontario offered generous early retirement packages. Who was most likely to take up such a package and "emigrate" out of the education system?

5. Wegge found that the villages that experienced the most emigration were those with that practised unigeniture (first son gets entire farm), and those that had higher emigration flows in the past, fewer factories, and more religious minorities. What is the relevance of each of these four factors to migration?

6. Describe an immigrant who poses least economic threat to a nation's automobile assembly workers.

7. A large group of unskilled, poor, illiterate refugees arrives in your city. What can the city do to make sure that all residents benefit economically?

8. If a nation has a shortage of doctors, what are some ways of increasing the number of doctors?

9. Hanson (2007) estimated that for the United States, the bright blue triangle of lost labour market surplus

for Americans was less than 0.07% of GDP, while the cost of patrolling the border was 0.1 % of GDP. Can he use these numbers to conclude that it does not make economic sense to patrol the border?

Chapter 21: Voluntary Migration – Canada's Experience and Policy

In this Chapter we examine some of the immigration history and policy in Canada and the United States. Instructors and readers in other countries may wish to compare these descriptions and statistics to those of their own country

Having studied the economic consequences of immigration, let's consider the decisions Canada has made regarding who can immigrate, and how many.

Migration policy

The ability of a nation to control its borders depends on its financial resources, the level of corruption within government and law enforcement, the length and nature of its border, and the desperation of people to cross it. The Canadian government has it pretty easy with the Arctic to the north, oceans on each side, and the United States to the south. Canada is an attractive destination country for people from Central and South America and the Caribbean, but the United States is even more attractive, and it lies between. The US actively monitors the border crossing between itself and Canada. Americans themselves are not very interested in moving to Canada.

The *Canada-United States Safe Third Country Agreement* (2004), which states that people cannot seek refuge in Canada if they have been in the United States, has been used by Canada to dismiss requests for asylum from many refugees passing into Canada from the United States. The *Agreement* is predicated on the United States giving refugees safe treatment and a fair hearing.

Many people enter Canada first, then attempt to enter the United States. For example, in March 2023 a family of four from India on a tourist visa, together with a family of four from Romania who had been living in Canada, were found drowned in the St. Lawrence River in the vicinity of the Mohawk Nation of Akwesasne. A local man, presumed to have been transporting them to the United States illegally, was missing.

Illegal migration to the United States

The Pew Research Center has estimated that there were about 10.5 million unauthorized immigrants in the United States in 2021, representing just over three percent of the American population[1]. For Canada, the high estimate in 2023 was 600,000 unauthorized workers, about 1.5 percent of the population, as reported by *The Globe and Mail* (December 14, 2023).

In 2008, migrants entering the US illegally made up 25% of farm workers, 19% of cleaners, and 17% of construction workers in the United States(Hanson, 2009). Many politicians would like to extend privileges to those migrants, to help with health care and education needs, but that would encourage more illegal immigration and be unpopular with voters.

Migrant Farmworkers pick strawberries at Lewis Taylor Farms, Fort Valley, GA, 2019. Photo and text credits to: US Department of Agriculture (Public Domain)

The USA also offers H1B, H2A, H2B, and H4 visas for workers and their families to temporarily enter the country for up to three years at the request of an employer. Over 980,000 such visas were issued in 2022[2].

In a 2007 paper, Gordon Hanson suggested that migrants entering illegally [or legally but temporarily] to work in low-skilled jobs may be meeting a need: between 1960 and the date of his study, the share of native-

1. Passel and Krogstad (2023)
2. Klobucista and Roy (2023)

born workers with less than a high-school diploma fell from 50% to 12%. A counterargument is that, if less-skilled labor is scarce, wages for less-skilled work should rise, attracting more native-born Americans to those jobs. The rebuttal is that there is a stigma to those jobs. The counter-rebuttal is that high-paying jobs may lose their stigma.

Hanson argued that migrants entering illegally are more likely than legal immigrants to be financially beneficial to American citizens. His arguments also apply to temporary workers entering legally:

- they improve the dependency ratio. Most are of working age and do not bring their families
- a significant portion of these migrants come and go according to the demand for their services
- their wages tend to be low, so their share of what they produce is not high
- they are ineligible for many public programs
- they end up paying some taxes such as payroll, sales, and property taxes

Hanson estimated that, in 2002, the net gain to native-born Americans from illegal immigration in terms of GDP, the bright blue triangle from the previous chapter, was about 0.03 percent of GDP. That was offset by net transfer of tax revenue to migrants of 0.10 percent of GDP. (Migrants were using more government services than they paid for.) So, illegal migration overall cost 0.07 percent of GDP to native-born Americans. This was less than proposed measures to keep migrants out, which were about 0.10% of GDP. Hanson did not estimate the efficiency benefits of immigrants or the costs that might occur if the border were not patrolled and many more migrants entered.

Class Discussion

Notice that the welfare of illegal immigrants is missing from this analysis.
Is Economics inherently nationalistic?

By calculating the triangle of lost surplus, Hanson is assuming that it doesn't matter if employers gain at the expense of native-born workers. In Economics we only accept this if the "winners" (employers) compensate the "losers" (native-born workers). The **Pareto criterion** says that, for an economic outcome to be preferred, someone must be made better off and *no one* can be made worse off.

Though the pareto criterion is not being satisfied, and native-born workers feel the brunt of migrants entering illegally migrants, the United States as a whole appears willing to tolerate illegal migration to some degree to keep the wages in construction and agriculture competitive.

It's not just the American economy that benefits from the labour of "second-class citizens"; Canada does too.

Temporary Foreign Workers in Canada

Most non-citizens living in Canada Have come to Canada legally using the **Temporary Foreign Worker Program**. This program allows employers to bring temporary foreign workers (TFWs) to Canada for up to four years. The employer must first advertise the job vacancy for a set period of time. The TFWs are to be paid at least the minimum wage, or the union wage if applicable. They must be paid at least 85% of what Canadians are paid for the same work.

TFWs cannot bring children to Canada. They can't apply for social assistance or collect pensions. They do receive health care, and they may apply for permanent residency after their contracted work period ends.

In 2019, 6% of professional, scientific, and technical service workers, and 5% of information and cultural sector workers in Canada were TFWs.[3]Most TFWs, however, worked in less prestigious occupations.

According to a study by Yuqian Lu (2020), in 2017 TFWs represented about 3% of Canada's workforce. They made up over one quarter of all crop production workers, and about 10% of nannies and caregivers working in private households. They also accounted for about 7% of workers in the accommodation and food services sector. Until 2012 there had even been an "exotic dancer" category, but we now realize how easily exotic dancing can tie in to human trafficking.

Because they are tied to one employer, who can cancel their work arrangement if displeased, lower-earning, less well-connected TFWs may be coerced into accepting abusive working conditions. Sometimes employers take advantage of the TFWs' ignorance of Canadian law and their limited knowledge of English. For example, some employers have taken away a TFW's passport. Some TFWs may be forced to give up most or all their wages for excessively-priced room and board. Employers are supposed to pay for the workers' transportation to Canada, but some rely on recruiters who exploit the TFWs by demanding a share of their wages. In our next chapter we will learn more about slavery and the exploitation of labour.

Foreign students are not temporary foreign workers, but they are temporary residents who could be said to be exploited. Some are channeled into mass preparatory courses offered by private companies. Foreign students in colleges and universities were paying six times the domestic tuition rate in 2022/2023.[4] Many may be coming only for a chance at permanent residency in Canada. Incidentally, about half of foreign students earned taxable earnings in 2019. [5]

According to breaking news in the fall of 2023, there were 2.2 million temporary residents living in Canada including 807,26 foreign students,[6]. This amounted to a million more temporary residents than the federal government had been reporting. The government does not record who is leaving the country[7], and it was

3. Statistics Canada (June 22, 2022)
4. Statistics Canada (Sept 7, 2022)
5. Statistics Canada, June 22, 2022)
6. "Time to address the immigration number that matters now", Globe and Mail, November 2, 2023.
7. "Ottawa to refine way it counts non-permanent residents," Globe and Mail, September 15, 2023.

assuming that temporary residents left within 30 days of their visas or permits expiring. In reality, many of the foreign students and TFWs were overstaying their visas while they applied to stay longer or become permanent residents.

According to Statistics Canada (June 22, 2022), about 25% of TFWs and about 33% of foreign students do end up becoming Canadian citizens: in fact, these temporary programs are serving as the first step in a two-step immigration process that is yielding better labour market outcomes for new Canadians.

Class Discussion

Would you be willing to pay more for a coffee or a sandwich to have a Canadian citizen employed?

Canada's approach to immigration

Canada will always have a high land:labour ratio compared to other countries; that is one reason why, since colonization, the settler government has invited newcomers to work the land. Today the capital:labour ratio is more relevant to international trade than the land:labour ratio. Although Canada has a lower capital:labour ratio than the United States, we are still rich in human, natural, environmental, physical, and social capital compared to many countries. Labour is relatively expensive in Canada, and that is a major reason why Canada continues to encourage temporary foreign workers, other temporary visitors such as students, and permanent residents to come to Canada. Canada's net migration rate, 5.2 per 1000 in 2020[8], is similar to Australia's and higher than most western nations including the USA (2020 net migration rate of 2.0 per 1000).

Class Discussion

What are the arguments for and against simply accepting Canada's status as a country which does not have a comparative advantage in labour-intensive goods?

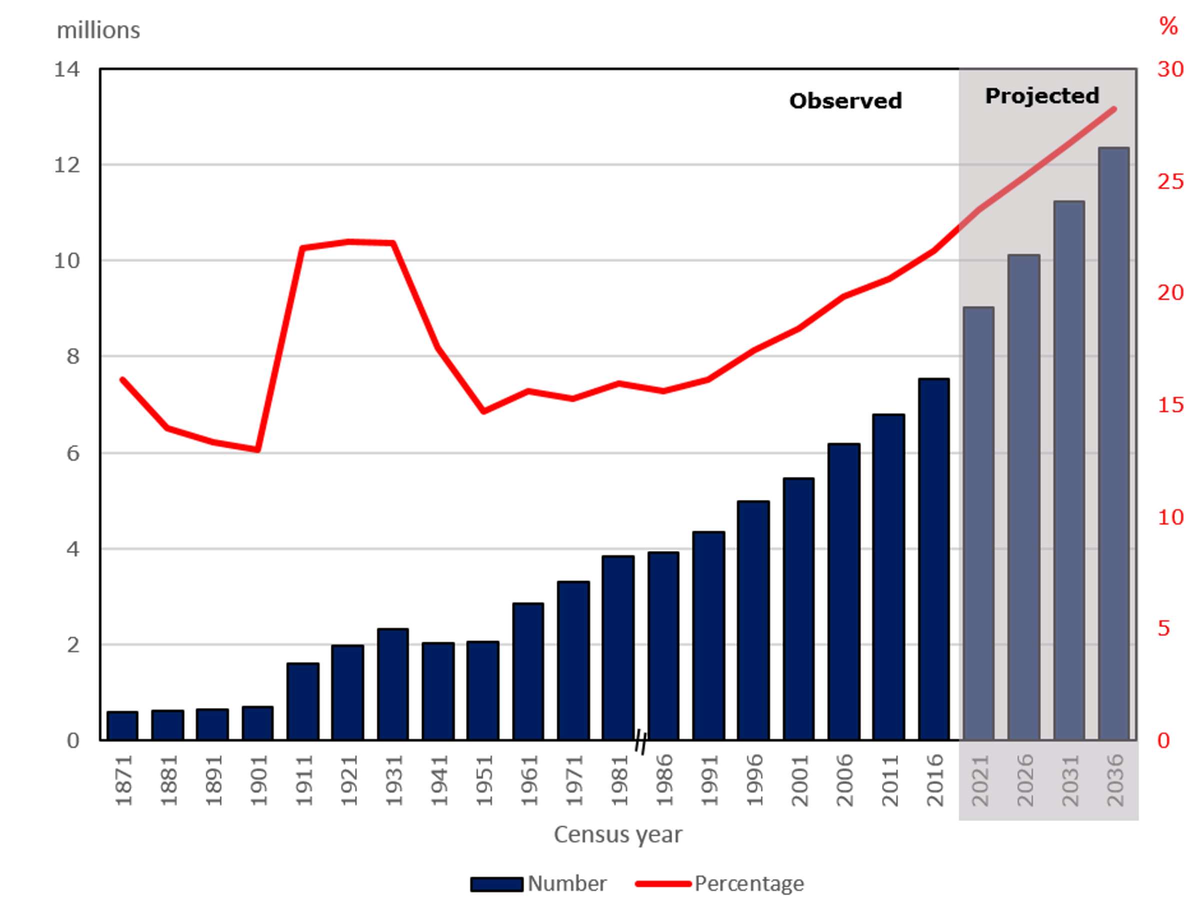
Doug Saunders, author of *Maximum Canada: why 35 million Canadians is not enough* (2017), has been a leading spokesperson in favour of immigration. In his book and his many newspaper columns, he has argued

8. undata.org

that Canada needs a much larger population to capture the scale economies and other advantages we described in Chapter 19. He also makes the case for urbanization and densification, noting the environmental benefits.

Figure 21-1 shows the number of immigrants living in Canada, people who came to Canada from various places in various years. The fraction of the population which represents immigrants has been trending up since 1951 and has now surpassed the high of 1911-1931. Figure 21-1's projection for 2021 has been exceeded: in 2021, 23% of Canadian residents were foreign-born.

Figure 21-1. Number and Proportion of Foreign-Born Population in Canada, 1871-2036

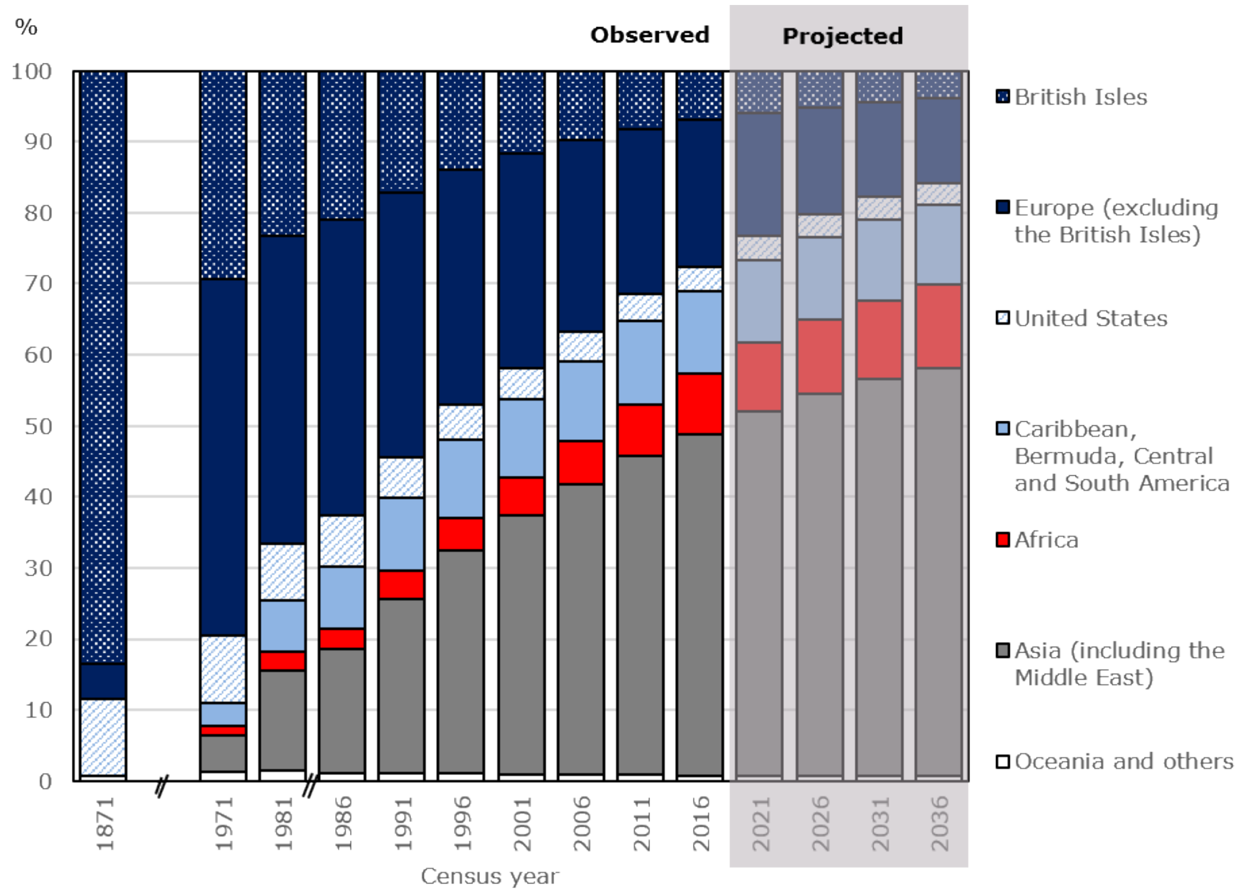


Note: // represents a break in the historical series.
Sources: Statistics Canada, Census of Population, 1871 to 2006, 2016; National Household Survey, 2011; Immigration and Diversity: Population Projections for Canada and its Regions, 2011 to 2036 (reference scenario).

Figure 1 of Statistics Canada (Oct. 25, 2017)

Immigration today is inclusive of many different ethnicities. Figure 21-2 shows that, shortly after Confederation, Canada's foreign-born population was largely British-born, with some Americans and some continental Europeans. That changed decisively in the late 1960s. Today, most Canadians who were not born in Canada were born in Asia or the Middle East. In 2016, the country contributing the most immigrants to Canada was the Philippines, at 15.6% of recent immigrants.

Figure 21-2. Foreign-Born Population by Place of Birth, 1871-2036



Note: // refers to a break in the time series.
Sources: Statistics Canada, Census of Population, 1871 to 2006, 2016; National Household Survey, 2011; Immigration and Diversity: Population Projections for Canada and its Regions, 2011 to 2036 (reference scenario).

Source: Figure 4 of Statistics Canada (Oct. 25, 2017)

In the late nineteenth century, visible minorities were not welcome, just tolerated if needed to perform work others would not do. For example, Chinese men were permitted to enter

Canada to work on railway construction, but had to pay a $500 head tax from 1885 to 1923, after which time only special categories of Chinese people, such as business people and students, were allowed to immigrate. During the Great Depression, Canada passed a law such that only Americans, Britons, and agriculturalists with money could immigrate.(Canadian Council for Refugees, 2000). Clearly, the racism so prevalent at the time shaped this policy.

> Did you know?
>
> Between 1924 and 1965, the US restricted immigration from Eastern and Southern Europe (ESE). Using Canada as a control, Moser and San (2020) show that these restrictions reduced the number of ESE-born scientists living in the USA by 1,165 persons, reduced the number of American scientists working in ESE-specialty fields by 40%, and reduced the number of patents in these fields per American scientist by 33%.

After World War II, immigration rules were relaxed. In 1967, discrimination on the basis of race was forbidden. For more detail, see the Canadian Council for Refugees (2000) excellent summary article, "*A hundred years of immigration to Canada 1900-1999.*"

Canada's immigration criteria

Canada today admits roughly three categories of immigrants on a permanent basis: economic immigrants, family members of Canadians, and refugees.

The 2019 target was about 331,000 immigrants, of which 58% were economic immigrants, 27% were extended family members, and 15% were refugees, protected persons and other humanitarian categories.

The COVID 19 pandemic in 2020 and 2021 disrupted immigration flow for fear of spreading the virus. To make up for lost immigration during the pandemic, in 2021 the government of Canada created the "Temporary Resident to Permanent Resident Pathway" to make citizens out of non-citizens already living in Canada. International students graduating in Canada could apply for one of 40,000 spots; foreigners working in Canada's health care sector could apply for one of 20,000 spots; and other foreign workers could apply for one of the remaining 30,000 spots. This sums to potentially 90,000 new Canadians plus their spouses and children.

In 2023 the government was on track to admit 485,000 immigrants in 2024 and 500,000 in 2025, but was facing a public increasingly concerned about the lack of affordable housing and family doctors in most Canadian cities.

Economic Immigrants

There are a variety of tracks for economic immigrants. Applicants are usually given points for English and French proficiency, education, work experience, Canadian work experience, age, "adaptability", and pre-arranged employment in Canada. They are admitted or not on the basis of their score.

There are no longer any investor and entrepreneur pathways to immigration, at least officially. In 2011 there were three categories of business immigrants: investors who made an $800,000 interest-free loan to

Citizenship and Immigration Canada, to be repaid after five years; entrepreneurs, who had business experience and $300,000 to back it up; and self-employed people with experience in culture, recreation, or agriculture.

In contrast to Gordon Hanson's recommendations, Canada has made it more difficult for lower skilled people to immigrate to Canada. Concerned about rising poverty rates for immigrants in the 1980s and 1990s, Canada selected higher educated and higher skilled immigrants beginning in 1993. Unfortunately, this made things worse.[9] Whereas in 1992, immigrants in Canada ten years or less had been twice as likely to have low income than native-born Canadians, in 2004 they were about 2.5 times more likely to have low income. In fact, by 2000 the skilled worker class of immigrant was more likely to experience low income and chronic low income than was the family class of immigrant! University-educated immigrants were earning no more than the high school-educated. Clearly, skilled workers were have difficulty translating their skills into employment.

University degrees earned in Asian universities are discounted by Canadian employers and professional associations. Economic immigrants also often lack the social support that immigrants in the family class enjoy.

Others have suggested that the way the ethnicity of immigrants has changed -fewer European and more Asian – accounts for some of the difficulty finding employment. Language acquisition or social adaptation may be more difficult. Racism may also be a factor.

In 2021, the poverty rate among all immigrants was 9.1% compared to 6.1% for native-born Canadians of the same age, but as high as 16.1% among immigrants in Canada five years or less.[10]. The poverty rate among immigrants in Canada ten years or less was not reported, suggesting that there has not been much improvement since the 1990s.

To sum up, immigrants to Canada have significantly higher poverty rates than native-born Canadians.

The picture is rosier for child immigrants. A 2022 study found that Canadians aged 20 or 25 years old in 2019 who had immigrated to Canada before the age of fifteen were more likely to be pursuing postsecondary education than other Canadians their age.[11]. Canadians who had immigrated as children and were thirty years of age in 2019 had median wages 29% higher than average than the average thirty-year-old Canadian, if their parents had come as economic class immigrants. This reflects, in part, the socioeconomic background of their parents; however, even thirty-year-olds who had come with their parents to Canada as refugees were making slightly more than the average thirty-year-old Canadian. If a thirty-year-old had come to Canada with their parents as family class immigrants, they were earning slightly less. Overall, Canadians who were once immigrant children earned higher median wages.[Ibid.]

To sum up, 2019 data showed that child immigrants had fared better educationally than the average Canadian. If they came as economic immigrants or refugees, they were also earning more.

9. Picot et al. (2007)
10. Statistics Canada, November 9, 2022
11. Statistics Canada (February 2022)

Citizenship Ceremony, 2015. Photo by Province of British Columbia, flickr.com. CC BY-NC-ND 2.0 DEED

The native-born children of immigrants have typically fared better economically than the children of Canadian-born parents. 2001 Census data indicate that children born 25 to 37 years previously in Canada to immigrant parents, were on average more highly educated and earning more income than other 25-37 year-olds.[12]

2016 Census data agree that most Canadian-born children of immigrants, both men and women, achieve significantly more higher education than their parents and the average Canadian their age, even after adjusting for province, location, age, and language spoken at home (Hou and Chen (Feb. 2019)).

To sum up, 2001 and 2016 data showed that Canadian-born children of immigrants had done better educationally than the average Canadian.

However, the same study shows that some Canadian-born children of immigrants are not taking great educational strides, and many are not able to translate their education into higher earnings. How the i**ncome** of the children of immigrants compares to the Canadian average depends on the racial and cultural background of their parents who immigrated. As a whole, second-generation men earn more than men whose parents were not immigrants, but that's partly because they are more likely to live in cities, for example. Once you adjust for province, location, age, language spoken at home, education completed, school attendance, and marital status, they earn less. Second-generation women earn the same superficially but once you make the adjustments, they are earning less. As Canadian immigration becomes more diverse, it becomes more complicated to predict the educational and income attainment of immigrants and their children.

12. M. Corak (2008)

To sum up, 2016 data shows that Canadian-born children of immigrants from many, but not all, cultural backgrounds were earning less than the average Canadian.

Having studied international immigration in detail, let's now consider the flow of people within Canada.

Interprovincial migration

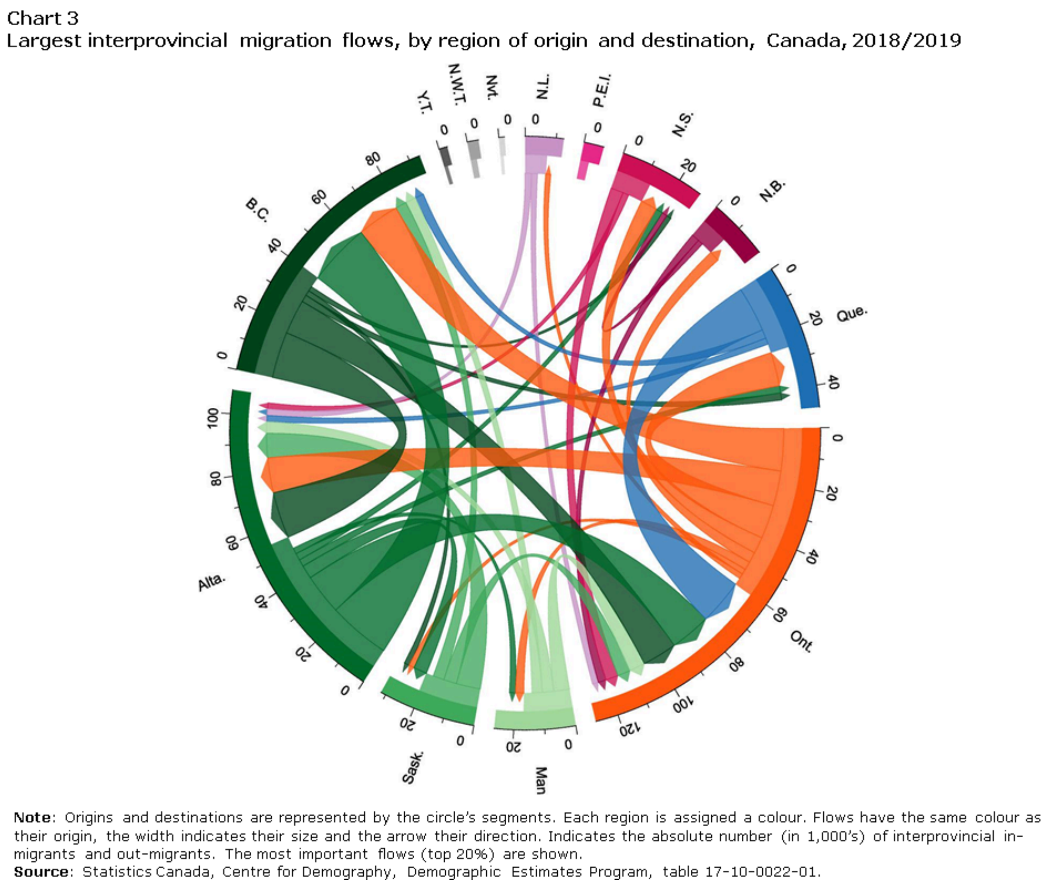
Canadian citizens may live anywhere in Canada they wish; the only restriction may be found in Indigenous-governed communities, where family or ancestral ties to the community may be required.

For many years, the most-discussed feature of Canadian internal migration has been the flow of people from the East, especially the Maritime provinces, to Alberta, where work in the oil fields has been plentiful. Figure 21-3 below shows that in 2018/9, the flow to Ontario was even larger, at 70,000 people. Generally, the higher expected real wage in Ontario and other prosperous provinces has motivated in-migration.

While the Figure makes the flows look massive, the total number of Canadians (not all of whom were workers) moving to Ontario that year was only about one-tenth of one percent the number of people employed in Ontario that year.

In Figure 21-3, each place of origin has its own colour. For example, Quebec is blue. We see that many people moved from Quebec to Ontario in 2018/2019, likely because of economic opportunity. People from Ontario (orange), Alberta (medium green) and British Columbia (dark green) arrived in Quebec, as shown by the corresponding arrows arriving at Quebec's blue arc. Some inflows are small and not shown, hence the empty space at the arc. There was about equal inflow and outflow for Quebec, the second-largest provincial economy in Canada.

Figure 21-3. Major internal migration flows, Canada, 2018/2019



Source: Chart 3 of Chastko (2021).

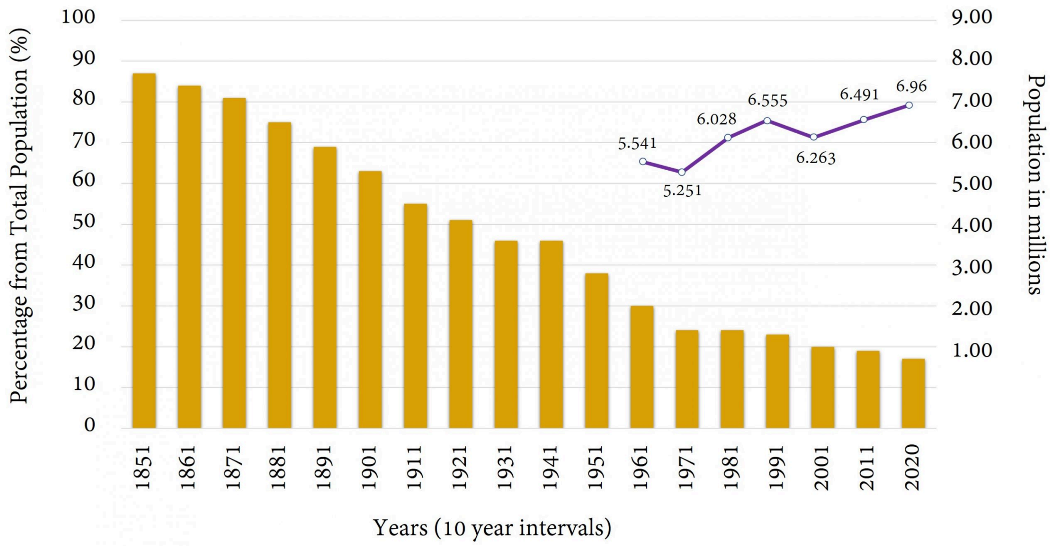
Figure 21-3 shows the most migration occurring between the three largest anglophone economies. About as many people left as entered each one in 2018/9, suggestive of a mobile group of people optimizing their employment prospects in particular occupations and competencies.

Rural-urban migration

Urbanization is happening all around the world. In 1900, about 10% of the world's population lived in cities, compared to 46% in 2014. The UN expects the urban population share to be 66% by 2050.

Canada has followed the same trend, as shown in Figure 21-4.

Figure 21-4. Proportion of Canadians living in rural areas, 1851-2020



The data presented for the censuses from 1851 to 1951 are based on the definition of rural areas in use at that time. Source: Statistics Canada, censuses of population, 1851 to 2011. Data presented for 2020 was sourced from the World Bank/ TradingEconomics.com Credits to: Statistics Canada/ World Bank/ TradingEconomics.Com/MacroTrends. Compiled by: Pauline Galoustian

According to Moazzami (2014), Ontario's urban population grew 15% between 2001 and 2011, but its rural population shrank at least 7%, for an overall population increase in Ontario of almost 13%. In 2011, 97% of Ontario's immigrants headed to the city, where the average earnings were 51% higher than elsewhere.

Economic opportunity remains the strongest motive for people to voluntarily migrate. In our next chapter, we'll look at the economic push and pull factors behind involuntary migration.

Abandoned farm, Nassagaweya Township, Halton Region, Ontario. Photo by edk7, 2021, flickr.com. CC BY-SA 2.0

Exercises: Chapter 21

1. Which are likely to have a greater net positive effect on GDP per worker: legal immigrants or migrants entering illegally, and why?

2. How did Canada's immigration policy change in the 1990s? Using one of our policy pointers from chapter 10, explain why this policy failed to alleviate poverty among immigrants.

3. A city wishes to grow via migration. How might it do so?

Chapter 22: Involuntary Relocation

> We must not neglect to study the dark side of migration: forced migration or forced confinement. Throughout history various groups have had their movements controlled, with economic and demographic consequences for them and other groups.

Just as migration has its push and pull factors, so does slavery. To describe the conditions ripe for slavery we begin with **Domar's Hypothesis**.

Domar's Hypothesis

Evsey Domar (1970) examined the history of Russian serfdom and hypothesized that the following three things cannot co-exist: free land, free **peasants**, and an upper class that does not work. ***Where there is free land and an upper class that wants to make its living without working the land, there will be slavery.*** Free land means that holding land is not profitable; profit is found in the relatively scarce workers, who become the objects of the upper classes' profit motive.

Portrait photo of Russian-American Economist Evsey David Domar. Photo credits to: Massachusetts Institute of Technology. CC BY 2.0

As Domar describes it, in the late 1400s, the Russian government was at war and facing a shortage of soldiers and arms. It hoped to get financial support and new recruits from the upper class by rewarding donors with land for agriculture. Land for agriculture, however, was already abundant; it did not offer much potential income, whether rental income or earnings from agricultural sales.

The upper class landlords squeezed the peasants who were renting and farming the land. The landlords charged more for rent than the peasants could reasonably afford based on what the land produced. The government helped landlords by gradually restricting the freedom of the debt-ridden peasants. By the mid-1600s, the peasants had become **serfs**. They were tied to the land to provide landlords with a dedicated workforce. Officially, serfs could not be sold, but they were tied to property which could be sold, and their rights were often violated.

A 1907 painting by Boris Kustodiev depicting Russian serfs listening to the proclamation of the Emancipation Manifesto in 1861. Credits to: Art-Catalogue.ru. Public Domain

Domar's Hypothesis predicts that, in a land-abundant economy, those who do not want to work the land will enslave others to do so. In contrast to this hypothesis, when deaths from the Bubonic Plague made land very much more abundant than workers in Europe, European peasants gained labour rights. Domar believes that political developments in Europe were sufficient to counter the forces explained by his hypothesis. Another factor protecting European peasants is that they were less geographically isolated than Russian peasants, thus better able to organize, publicize their plight, and assert their wishes.

The case of the Egba in Nigeria

Fenske (2009) describes the case of the Egba of south-western Nigeria and finds that it fits with Domar's hypothesis. **Indenture** and slavery were present in this land-abundant economy. Fenske also makes a connection between land-abundance and lack of credit.

The Egba are Yoruba-speaking Nigerians who first settled their current territory in 1830. Their military success expanded their base so much that, by 1911, population density was still only 142 people per square mile.

Between 1830 and 1914 the Egba followed a system of extensive agriculture which involved clearing forest, farming the land for five or six years without fertilizer, and then moving on to new land. Land, especially land far from settlement and without many palm, kola, or cocoa trees, could be acquired for very little if any payment. Property rights over cleared land were loosely defined and rarely permanent. In 1914, the British were renting over 26,000 acres from the Egba at less than one shilling per acre.

Since every Egba man could have all the land he required, no Egba man was willing to work for another farmer and earn less than his total product. Since the technology was very simple, and there were no large fixed costs to farming, there were no economies of scale to make a farm with many workers more productive than a farm with one worker. Consequently, wage labor was rare. Wage labour became stigmatized.

The second consequence of land abundance was that land was not very valuable and did not serve well as collateral. It was difficult for the Egba to get loans. The record shows that people pawned themselves and their children in exchange for loans, and that people took draconian measures to achieve payback from their borrowers.

In a society without credit and without a social safety net, when all you have is yourself and your family, slavery is a way to escape starvation. It is a way to pay debt, including debt to a community because of crime. When someone saves your life, you may have no means to repay this person other than by paying this "life debt" with a life of service. In a way, a life of service is one inalienable thing each human being has to offer in trade. Perhaps this is one reason why slavery was tolerated for thousands of years.

At Abeokuta's Egba Oba palace. Credits to: Carsten ten Brink. CC BY-NC-ND 2.0

In their situation of land abundance, labour scarcity, and credit scarcity, the Egba accepted slavery and pawning. They also practiced **polygyny** and **bride price**. Polygyny is the practice of having multiple wives. When land is cheap, and when women work the land, there is little cost to having more wives. In fact, wives are a net material benefit as agricultural workers, and command a bride price, a payment from the groom's family to the bride's family upon marriage.

Slaves may have made up as much as one fifth of the population. They were generally strangers who were captured in war, people who sold themselves or who were sold by their relatives to pay debt, or criminals being punished. Slaves provided scarce labor, reduced the uncertainty around labour availability at harvest time, and also served as productive "assets" in an economy where there were few opportunities to save or invest.

> Land abundance → low land prices → land not useful for collateral → pawning of labour for loans
>
> Land abundance → low land prices → workers have their own farms → labour scarcity → no comparative advantage in labor-intensive goods and services, no advantage from owning land without working → increased likelihood of slavery, polygyny, and brideprice.

Fenske writes, "Understanding the existence of forced labor is of particular relevance to Africa, given the large-scale export of human beings from an under-populated region – a trade which had the effect of keeping the continent's population stagnant over the course of several centuries." Usually, an economy exports goods which make intensive use of whatever resource the country has in abundance. In the case of Africa, heat-loving crops, gold, or ivory would be obvious choices. But the very fact that Africa was under-populated meant that humans were the most valuable thing around and vulnerable to disenfranchisement and commoditization by one another. Another, more important factor was the demand by Europeans for crops grown in plantation style, which required gang labour. We discuss this more in the next section.

Box 22-1. Polygyny in Canada

A polygamous community in southeastern British Columbia came into the spotlight in 2007, when a senior leader was charged with being an accomplice to rape of a minor but was later discharged for lack of evidence. It seemed that the two groups which comprise this community would continue their illegal marital practices - underage marriage, polygyny, and the probable coercion of brides - in their remote location. Now, however, changes to property rights are developing that could change the incentives faced by powerful men in this community. The land used by this branch of the Fundamentalist Church of Jesus Christ of Latter-Day Saints (FLDS) is owned in trust by FLDS leadership in Utah, but the Canadians want to hold their land in their own names. So, the State of Utah has appointed a trustee to privatize the land. This would involve putting names on leases and property titles. The trustee is looking for names of all wives, and finding it difficult to collect the information, but he intends to make all spouses equally owners of any land a husband has claim to. If there is a chance that the women might actually make use of these ownership rights, men's incentive to have multiple wives will be reduced. ("Wives to be named on leases", Robert Matas, Globe and Mail, July 11, 2009)

The family of Joseph F. Smith, the fifth president of the Church of Jesus Christ of Latter-day Saints and the nephew of founder Joseph Smith. The photo shows six of his wives and 48 of his children. Public Domain

African slaves in the Americas

We have seen that slavery is likely to arise when labour is scarce relative to other factors. Slavery is also associated with a particular kind of work, namely, work that is intense and demeaning.

Work that is particularly intense and demeaning is work that no one wants to do. The wage offered may be higher than the average wage, but the non-pecuniary factors cause individuals to feel better off without that kind of employment. Plantation-style agricultural work, manufacturing under sweatshop conditions, mining in hazardous conditions, and prostitution come to mind as examples of work that many people will not do unless coerced.

When this kind of work is profitable, there is an incentive for humans to be trafficked to provide the labour. Slavery can increase the enslaved person's material output, but too little of that output will accrue to the enslaved person.

Fogel and Engleman, in their book "Time on the Cross" (1974), make a detailed study of the economics of the transatlantic slave trade between 1500-1870. During this time, about 9.5 million Africans were enslaved and brought to the Americas, 60% to Latin America, 40% to the Caribbean, and 6% to the United States. Most of the slaves were employed on sugar plantations, except in the United States, where sugarcane was not grown.

By 1825 the United States had become the major holder of slaves in the Americas, owning 36% of slaves in the West. This was not because it had imported most of the slaves, but because of a high rate of natural increase in the American slave population (25% per decade). This high rate of natural increase was likely due to a more balanced sex ratio, lower incidence of infectious disease, and absence of sugarcane plantations. Work on sugarcane plantations was brutal.

Indentured Europeans were brought to the West Indies to work on sugarcane plantations shortly after Columbus arrived. However, indentured Europeans defected in response to the difficult work, hot weather, and tropical disease, and new recruits could not be persuaded to come in great numbers.

Enslaved people cutting sugarcane on the Caribbean island of Antigua, aquatint from Ten Views of the Island of Antigua by William Clark, 1832. Credits to: The British Library. Public Domain

Fogel and Engerman conclude that slavery in the Americas was associated not with agriculture in general, but with plantation agriculture -large scale and labour-intensive- in particular. They claim that plantation-style agriculture was about 50% more productive than other methods of growing sugar and cotton. However, nowhere could free men be induced to work on plantations, not even for 50% higher wages. "For it was only by force that it was possible to get blacks to accept gang labor without having to pay a premium that was in excess of the gains from economies of scale… After the slaves were freed, many planters attempted to reconstruct their work gangs on the basis of wage payments. But such attempts generally foundered, despite the fact that the wages offered to freedmen exceeded the incomes they had received as slaves by more than 100 percent."

Fogel and Engerman argue that, while force was necessary to get gang-style labour, the use of force had its costs, and there were diminishing returns to using force. They provide some evidence suggesting that the nutrition and health of American slaves was at least as good as that of the average white person in the American south. Slaves may have "shared" in the gains from the economies of scale; some with specialized skills, such as musicians and blacksmiths, earned money. What the slaves were paid was, of course, not enough to compensate them for their loss of freedom, the unpleasantness of their labour, and the risks to their health and life. Fogel and Engerman write: "For every dollar gained by a typical consumer of cotton cloth [in lower cotton prices], there was a slave laboring somewhere under the hot southern sun who would lose at least $400 [in non-pecuniary costs]."

When slaves are freed, they are able to choose work more amenable to them… if they are not prevented by racism. Immediately after emancipation, many former slaves were worse off economically. After emancipation, African American nutrition, health, and life expectancy declined (Fogel and Engerman (1974) p. 261). Whereas some slaveowners had put Black people in jobs where they were most productive, after emancipation Whites pushed Blacks out of skilled trades, and Black wages declined relative to White wages.

back to Domar's Hypothesis

Adding the insight of Fogel and Engerman (1974) that slaves are used to do particular kinds of work, we can write Domar's Hypothesis this way:

When there exists universal economic opportunity, people of ordinary skill who refuse to do ordinary work may seek extraordinary profit by forcing others to do extraordinarily unpleasant work.

British "Home Children" in Canada

As described by Joy Parr (1980), in the late nineteenth century about 30% of the British population lived in poverty. In city slums the infant mortality rate was 25%, and life expectancy at birth was about 36. In the event of a financial crisis, children were sometimes brought to the local authorities, then placed in apprenticeships, rural factories (restricted after 1830), industrial schools, or workhouses.[1] The workhouses became increasingly crowded after the Irish Potato Famine (late 1840s) and the recession of the late 1860s.

In response to lobbying efforts, the government agreed to allow children to be sent to Canada. Most were sent by municipalities, about 20% by evangelical church groups who had spearheaded the lobbying, and the rest by other religious denominations or charities. Sometimes children were sent abroad against the wishes of their parents. The first two distributional homes were at Niagara-on-the-Lake and Belleville, Ontario. Other major centres were Toronto, Peterborough, Brockville, Ottawa, Montreal, Sherbrooke, and Halifax. There is a reference to a "Barnardo boy", Barnardo being one of the founders of this child emigration movement, in the classic novel *Anne of Green Gables*. A total of 80,000 British children were compelled to come to Canada between 1868-1925.

1. Workhouses were not usually places of hard work but were places where the poor could be housed. They were usually crowded and provided minimal food. There were attempts to find employment for residents of workhouses, and sometimes the working-age residents were forced to do work at the workhouse itself.

Group of boys working in a field at the Philanthropic Society Farm School, Red Hill Valley, Hamilton, Ontario (1898-1910). Credits to: Library and Archives Canada [MIKAN 4456336, 4447441]. Access 90 Open

What motivated the forced migration of these children? Besides a desire to help them, there must have been a belief that land-rich Canada, with a scarcity of labour, would welcome these children for the labour that they could provide. Indeed, for children over eight years old, that seemed all that Canada was willing to do. Joy Parr argues that, for these children, a formal work obligation helped protect them.

Very young children were placed in trial adoptions, but the placement agencies found that children over the age of eight were usually not accepted as part of the family. Because of this, indenture seemed preferable to an attempted adoptive relationship, because indenture defined the rights of the child and spared them fantasies of achieving birth child status in the family. Parr writes, "Formal apprenticeship indentures did more to define the rights of British immigrant children than to extinguish their liberties."

What transpired is that children six to ten years of age were housed with families in exchange for a fee paid by the agencies. Between age eleven and age fourteen children usually boarded for free in return for their chores, and between the ages of fifteen and eighteen they were indentured to work for pay that the agency collected. After they turned eighteen they were free to earn their own wages and manage their own lives.

Younger children were more popular in isolated areas where there was little off-farm opportunity for the farmwife, and where it was more difficult to market farm produce for cash. “Home children” would help earn cash and could be fed on farm produce. As children grew in skill and stature, they were relocated to more prosperous areas which could offer more pay. In one sample, boys were moved an average of 3 times, girls even more frequently. This must have been disruptive to their development.

Human trafficking today

We have seen that slavery and forced migration are more likely when labor and credit are scarce. Human trafficking is likely in industries where workers’ conditions are intense and dangerous. Slaves welcome liberty, but sometimes their material standard of living deteriorates once they are freed.

In the world today, women, men, and children are being trafficked. Statista.com reports 115,324 identified cases of trafficking in 2022, but there are likely many more. Victims are used for sex or made to work long, hard shifts as nannies, agricultural workers, construction workers, food service workers, and more. Some victims are conned by people offering to sneak them into a better country.

According to the Trafficking in Persons Report issued by the United States State Department each year, there are countries which do not fully meet the recommendations of the United States *Trafficking Victims Protection Act* (2000) and are not making significant progress towards doing so. In 2023 they were, by region:

Burma*, Cambodia, China*, Macau, North Korea*

Afghanistan*, Iran*, Syria*, Yemen

Algeria, Chad, Djibouti, Equatorial Guinea, Eritrea*, Guinea-Bissau, Libya, Somalia, South Sudan*

Belarus, Russia*, Turkmenistan*

Cuba*, Curacao, Nicaragua, Sint Maarten, Venezuela

Papua New Guinea

In these countries, sometimes because of war and government dysfunction, modern standards of prevention and care are not being met. The starred (*) countries are said to display an entrenched pattern of human trafficking. This may include recruitment of child soldiers, use of slaves in government-funded projects, and slave labour at government detention centres.

Not only these, but all countries have progress to make in uprooting human trafficking.

According to a publication of the Canadian Centre for Justice and Community Safety Statistics (Conroy and Sutton (2022)), almost three thousand cases of human trafficking were reported by Canadian police between 2010 and 2020. In these incidents, 25% of victims were under the age of eighteen and 96% of all victims were female. Seventy-seven percent of accused perpetrators were under the age of 35. Ninety-one percent of victims knew their trafficker – most often a former or current intimate partner (31% of victims).

The same report noted that, of 342 incidents in 2020, about half had to do with immigrants, refugees, or temporary foreign workers. Throughout the previous decade, 2010-2020, most reported victims were

Canadian; the number of those with Indigenous identity was not given, but can be assumed to be disproportionately large.

A dear friend of the author (Hageman) came all by herself from Hong Kong to Vancouver in the 1980s to attend high school.[2] Her contact was a former piano teacher, with whom she stayed. The piano teacher soon had my friend doing household chores. She then began to bring men around the house and make suggestions. Before anything worse happened, my friend, penniless and in tears, boarded a bus and blurted out one of the few English words she knew: "YMCA". I'm happy to say that things took a turn for the better at that point.

This story illustrates the sad reality that often, when a group is exploited, one of its own members is collaborating.

To combat human trafficking we need to uncover and prosecute it. It is also important to understand the push and pull factors.

Push factors:

- Being alone
- unemployment and poverty
- lack of credit and opportunities to improve one's life
- abuse in the home or the home community
- ignorance and credulity

Pull factors :

- deceit and predation
- profits for the trafficker due to demand for gang-style labour
- lack of concern, lack of detection in the host community
- low likelihood of apprehension and punishment
- lack of solidarity between people of different races, socioeconomic classes, ages

To fight human trafficking we need to educate potential victims and potential host communities. We must ensure that people have a fair chance to develop their potential, and to safely move to areas where they have more economic opportunity. We must also spend resources finding human traffickers. Traffickers must then be given a significant penalty.

2. A report based on 2003 data found that East Asian homestay students in British Columbia were at greater risk for abuse and self-harm than immigrants and Canadian-born students of East Asian heritage. See S. T. Wong et al. (2010)

Source: www.canadianhumantraffickinghotline.ca, downloaded March 2023

Some practical tips to combat forced labour from the 2023 Trafficking in Persons report include:[3]

- Targeted public awareness campaigns
- Frequent, unannounced audits of employers as to worker recruitment, working, and living conditions

3. United States Department of State (2023)

- Interviewing workers in a safe space away from management
- Giving workers access to anonymous complaints channels
- Educating workers on their rights

and to combat sexual exploitation:[4]

- Targeted public awareness campaigns
- Training for first responders, medical staff, and criminal justice workers to understand the needs of female and also male victims
- Safe housing for victims, particularly male victims
- Medical care including trauma-informed and culturally appropriate mental health and psycho-social support
- Help with education, skills training, and employment

Criminalization

Criminalization of an activity raises the costs of that activity. Costs include the fines and jail time that are incurred with various probabilities, and the cost of avoiding detection. The two main results of these higher costs are that:

1) the activity is discouraged; and

2) the activity is driven underground.

There is no question that criminalizing an activity will reduce its incidence. When costs rise, the supply curve rises or "shifts left to the origin". Higher prices are charged to cover the higher costs, and this discourages use. If suppliers fight among themselves for control of the market, and one succeeds in monopolizing the market, prices will rise even more, and output will fall even more. Monopolists always restrict output to keep prices above the free market price.

So far so good. But we have not addressed the consequences of the activity being driven underground. This gives rise to all kinds of negative external costs. As previously mentioned, the suppliers are able to conduct turf wars underground, and violent crime is likely to escalate, at least among the criminal class. The criminals who succeed may use their monopoly profits to branch into other criminal activities or to bribe politicians.

Another consequence of an activity being driven underground is that the activity can change. Sellers may contaminate the product, which is now unregulated, endangering buyers. And workers will suffer if they are forced into more isolated and less safe working environments.

4. Ibid.

Prostitution is an especially tough case. Legalizing brothels will lead to more prostitution. And brothels are places where confinement and violence can occur unseen. On the other hand, criminalizing brothels forces prostitutes into the cars and hotel rooms of strangers.

Human trafficking is something so simply exploitative that we cannot legalize it without tearing the heart out of our society. However we must recognize that as long as the push:pull factors are there, human trafficking will be hiding somewhere.

We have now treated the three drivers of population change: mortality, fertility, and migration. In our next chapters, we zoom in on Family Structure and Son Preference.

Exercises: Chapter 22

1. Fill in the blanks based on what you learned in this chapter:

	Temporary Foreign Workers in Canada today	Indenture	Serfdom	Slavery
Migrate freely?				
Family life, choice of employer?				
Unpleasant work?				
Permanent condition?				

2. Usually, nations or colonial masters of a nation export a commodity which they have in abundance. Why were humans exported from Africa in recent centuries when the population density of Africa was low?

3. Why is polygyny less likely in an urban environment?

4. Consider a village that routinely looks the other way when “employers” from the city come to bargain with poor parents for preteen girls. Your parents still live in that village, and you return from time to time with gifts. What can you do to change the situation for the better for preteen girls?

ZOOMING IN

Chapter 23: Family Structure

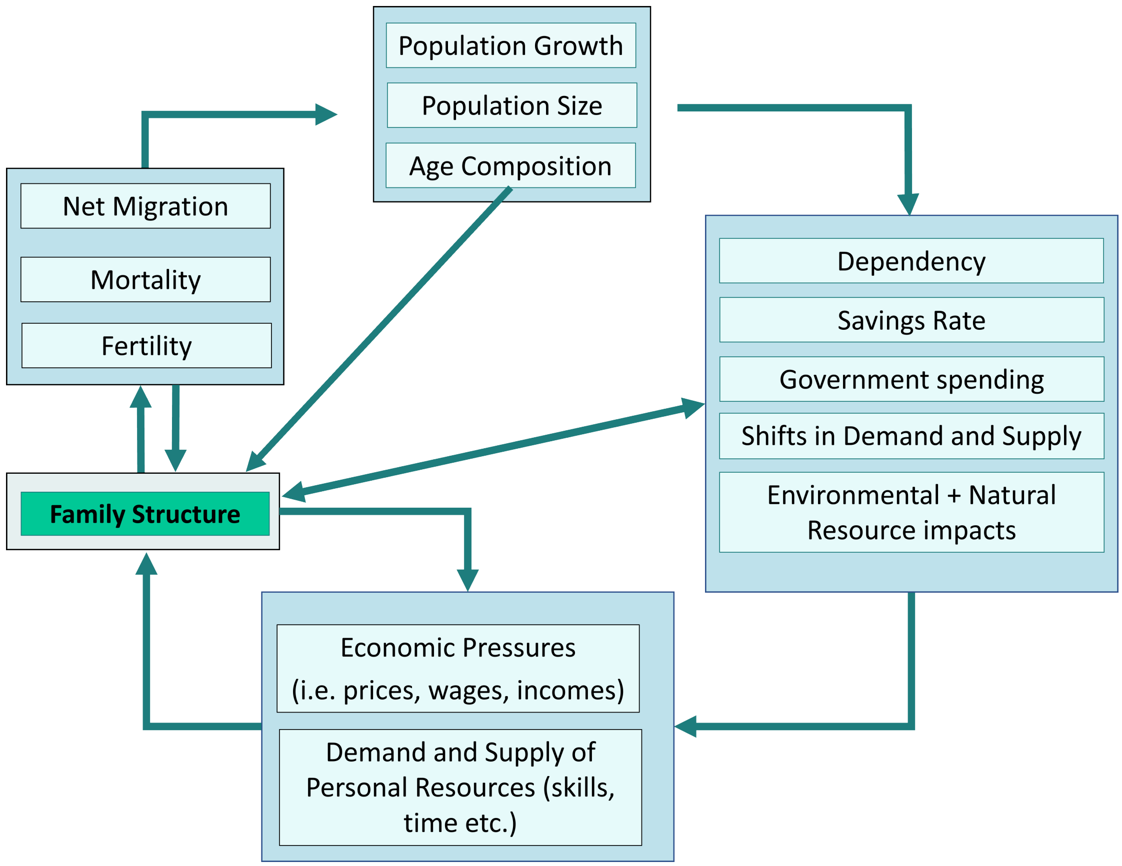
The composition of a population in terms of family structure is of interest to demographers and economists. But where does it fit in to economic demography? It fits right at the heart of the micro-economic responses to demography and the micro-demographic responses to the economy.

Photo by OakleyOriginals, 2016, flickr.com. CC BY 2.0 DEED.

The family is the tiniest multi-person population of interest, the tiniest economy. As illustrated in Figure 23-1, family structure influences and responds to fertility, mortality, and migration. It influences and responds to economic pressures. An integral part of our culture, family structure is a matrix in which economic and demographic pressures play out.

Family structure is affected by many things, including the three population processes (fertility, mortality, and migration), the sex ratio, and economic pressures. In turn, family structure affects the economy. For example, the rate of divorce affects the demand for housing. The rate of divorce also affects savings and labour force participation. It can also affect the completed fertility rate, the migration rate, health, and mortality, thereby affecting the economy indirectly.

Figure 23-1. Economics, Demography and Family



Examples of changes in family structure

Since roughly the 1970s, western societies have increasingly accepted and adopted new family structures. The number of single parent families, step-parent families, blended families, **cohabiting** adults, and LGBTQ2S+ unions has greatly increased.

This change can be attributed to secularization as well as to activism, publicity, and discussion. There has also been an economic connection: a rising standard of living makes people less dependent on family members' support and opinion, and a strong social safety net gives them courage to try unconventional things.

The economy can affect family structure more directly. A poor economy may force people to migrate in search of work, which may separate family members or prevent people from getting together. A high cost of living may give couples the incentive to stay together during low moments in their relationship, but it can also be a strain that drives people apart.

As families form or break apart, there may be economic consequences as well as emotional ones. Some innovative family structures provide a strong framework for health and prosperity. Others are weaker and may place family members at greater economic risk. When family structure works well, love, skills and ideas are shared, as well as expenses, care of dependents, and economic risk.

Women in the workforce

In the West, many more women work outside the home than was the case in the first half of the twentieth century, when gender was always perceived as binary, when gender roles were more rigid than they are today, and when more couples worked together on a family farm. Feminist activism, as well as affirmative action, legislation, literature, media, and urbanization have expanded women's opportunities. The greater participation of women in postsecondary education prepares them to work outside the home, and most expect to do so.

As we learned in Chapter 20, the influx of a large number of new workers into a labour market can depress the wage unless and until improvements in efficiency or capital accumulation expand labour demand.

We have already discussed how an increase in education and in the variety of opportunities available to women tends to decrease fertility. Generally, higher education, and work outside the home, are correlated with fewer children in the family. Women's work affects not only fertility but also, of course, the economy directly. If time worked in the marketplace is more materially productive than time worked at home or in volunteer positions, there is a net material benefit to society (excluding consideration of fertility and other impacts). Can we assume that time worked outside the home is more productive? Perhaps yes, because women now have the ability to specialize in what they are best at.

Regardless of the material benefit, people identified as female of course appreciate having more choices in life; however, if they are still expected to assume traditional responsibilities in addition to their work outside the home, their lives may become more stressful. More and more, people identified as men are sharing in childcare and housekeeping, but in 2015 for example, Canadian men ages 25-54 spent 1.9 hours per day on unpaid work, while women the same age spent 3.9 hours.[1]

Gary Becker (*A Treatise on the Family*, 1981) theorized that the material benefits of specialization (wife to childcare, husband to marketplace) helped keep couples together. The blurring of the expected duties of each partner may stress the relationship. Expectations may have to change and traditions be adapted for marriages to thrive.

Increased similarity of couples

With the expanded opportunities, women are likely to have experiences, education, and workplace achievements which are similar to those of their partners. Romantic love and compatibility have become the top criterion for marriage in the West. Couples are taking longer to get to know one another.

1. https://www150.statcan.gc.ca/n1/pub/89-503-x/2015001/article/54931-eng.htm

Goldin and Katz (2002) believe that the contraceptive pill, which makes it less likely that pre-marital sex will lead to pregnancy, has made longer courtships (with sex) less costly and made it more likely that people who marry are compatible. They demonstrated a statistical relationship between access to the pill and lower marriage rates, higher age at first marriage, and lower divorce. They also demonstrate similar, but weaker, effects from the legalization of abortion.

On the other hand, because of the pill and the availability of abortion, women unwilling to use the pill or have an abortion are facing increased pressure for sex while no longer being able to count on "shot-gun marriages"[2]in the case of a pregnancy. This may explain an increase in out of-wedlock births following the pill and following the legalization of abortion

Couple similarity has consequences for the distribution of income. When only a husband works, and his income is twice as much as his brother's, the first brother's household is twice as rich as the second's. If each brother has a spouse earning an amount similar to his own, then the first household is still twice as rich as the second, but the difference between their incomes is doubled.

Declining prevalence of marriage

A smaller percentage of marriage-aged westerners is married these days, because of people waiting longer to marry, people choosing not to marry, and people divorcing.

1) Age at first marriage has risen. In 1973 the average Canadian bride and groom getting married for the first time were 22.8 and 25.2 years old respectively,[3] but in 2011 they were 29.6 and 31.0 years old.[4] This statistic appears to no longer be tracked. Instead, age of the average person getting married (either for the first time or for a second, third, of greater number of times) is tracked. That rate has risen from a low of 25.6 in 1968 to 35.3 in 2019.[5]. It decreased slightly in 2020, mostly because during the pandemic older people's marriage rate fell more than did younger people's.

Economic explanations for a higher age at *first* marriage include the increased availability of education for women and men, and increased economic opportunities for women. Demographic consequences include delayed fertility and a lower total fertility rate. The rising age of parents may have positive consequence for the viability of marriage and the parents' ability to take care of the children.

2) Marriage rates have declined. In 1950, eighty percent of Americans ages 21-54 were married. That began to decline in the mid 1960s, and even more steeply during the 70s and 80s. In 1990, sixty-seven percent adults

2. "shot-gun marriages" are marriages arranged in haste when a woman becomes pregnant. The metaphor refers to a woman's father holding a shotgun to the woman's boyfriend to compel him to marry her.
3. https://www150.statcan.gc.ca/n1/pub/91-209-x/2013001/article/11788-eng.htm
4. https://www.cardus.ca/research/family/reports/the-canadian-marriage-map/
5. Statistics Canada (November 2022)

ages 25-54 (now excluding 21-24 year olds) were married, and in 2019, fifty-three percent of that age group were married[6].

We have some Canadian statistics for younger people. In 1996, 50.5 percent of Canadians ages 20-34 were not married or living common-law. 14.3 percent were living common-law and 35.2 percent were married. By 2021, the number of non-married, non-common-law Canadians ages 20-34 was had fallen to 60.3 percent, with the remaining forty percent split almost equally between married and common-law.[7].

Economic factors which have contributed to declining marriage rates include an increase in the standard of living which makes single living more affordable, and increased earnings opportunities for women outside the home, which also makes single living more affordable.

3) Divorce has become common. We discuss divorce in detail below.

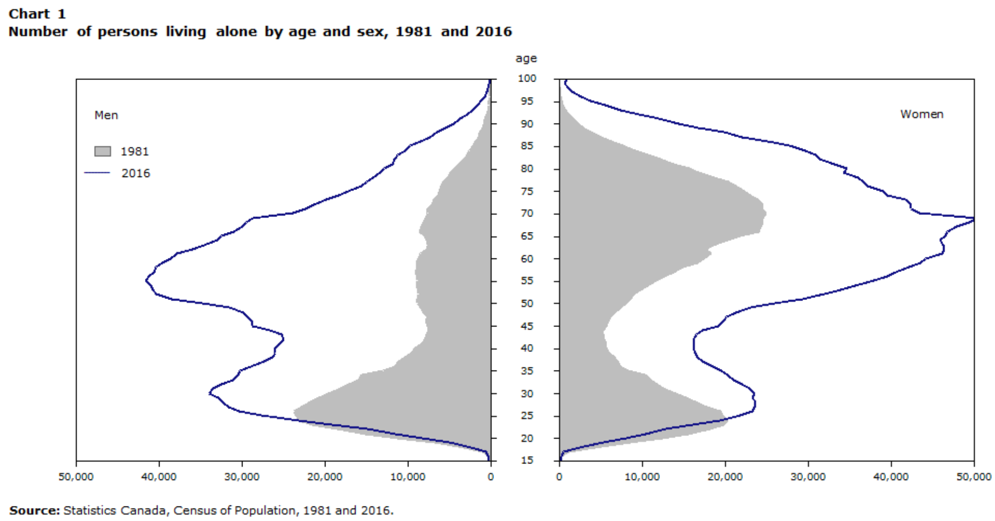
More singles

A greater fraction of people ages 20-34 and older are not marrying or cohabiting but remaining single. They may choose to live with roommates, friends, or family members, or they may choose to live alone. The chart below illustrates an increase in the number of people living alone at the time of the 2016 census compared to the time of the 1981 census, and the change in the age and sex composition of those people. The increase is large, but the chart exaggerates it by not accounting for the fact that the overall population grew about forty percent between 1981 and 2016.

Whereas in 1981 a large fraction of people living alone were widowed women in their 60s and 70s, in 2016 there were many people, both men and women, living alone in their 50s and 60s due to separation or divorce.

6. Pew Research Center (2021)
7. Cardus Associated Authors (2022)

Figure 23-3. Single Canadians, 1981-2016



Source: Tang, Galbraith and Truong (2019).

The single life can be satisfying and productive. It is not as likely to produce children, however, so expect a drop in fertility when the rate of singlehood increases.

There are health consequences for single people, who typically must be economically self-sufficient and responsible for their own health. Married men live longer than unmarried men (for example see Lillard and Panis, 1996). This is likely because of protection conferred by not living alone, and because men who get married have characteristics that make them more likely to live healthy lives. Is it also because men who get married are healthier than men who do not? Lillard and Panis (1996) found that that is not the case: unhealthy American men marry earlier than their peers, are less likely to divorce, and are more likely to remarry after being widowed or divorced.

Married women are also healthier than single, divorced, or widowed women – but only if they report a happy marriage. (Gallo et al. 2003).

In terms of GDP per capita, single people look good for the economy. They work and can save without the diversion of childcare. They are available as community volunteers and activists, as well as supportive relatives. On the other hand, having children may motivate greater work effort. The support of a spouse often contributes to a person's career.

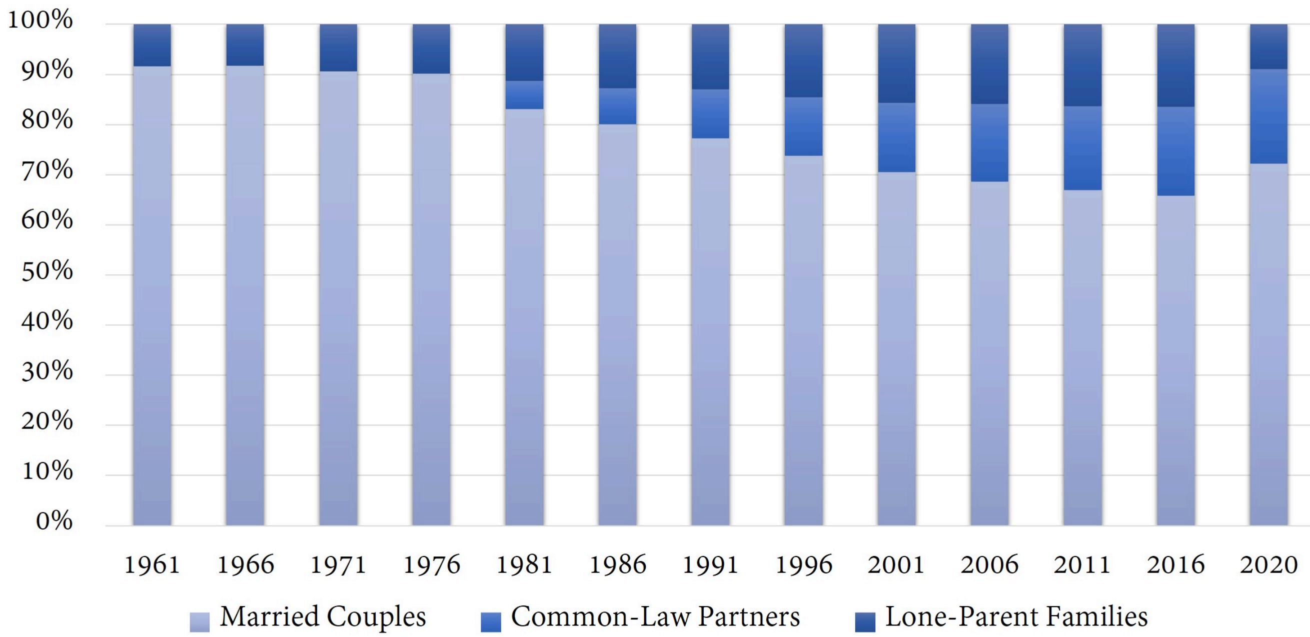
Class Discussion

Consider the historical roles and social status of single people, whether celibate by choice, unsuccessful in marriage, or remaining single for other reasons.

Cohabitation

The phenomenon of men and women living together without being married was relatively rare in the West before 1970, but **cohabitation** has grown in popularity steadily since then, as you can see in Figure 23-4 below. This Figure does not include single people.

Figure 23-4. Family Structure, 1961-2020



Data source: Figure 1 of Statistics Canada (2018). Adapted by: Pauline Galoustian. Note: For 2016 the data was sources from 2016 Census Data (from Statistics Canada, 2016 Census of Canada); For 2020, the percentages were based on preliminary estimates (from Estimates of population as of July 1st, by marital status or legal marital status, age and sex, Statistics Canada. CC BY 2.0)

In some times and places, cohabitation offers financial advantages over marriage, for example being able to file income taxes independently, or being able to receive more in welfare payments. In contrast, cohabitation may mean less entitlement to pension benefits (if a partner dies) or financial settlement (if the relationship breaks up.)

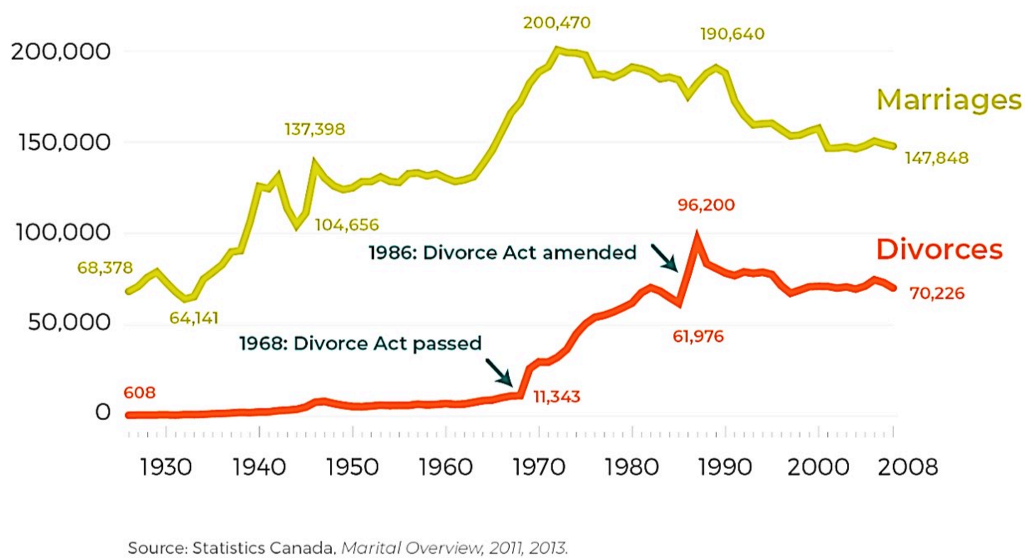
Cohabitating or "common-law" couples are more likely to break up than married couples. It has also been noted that couples who cohabit prior to marriage have a higher rate of divorce. See for example Rosenfeld and Roesler (2018). This conflicts with the findings of Goldin and Katz (2002) noted above. We will discuss the economic consequences of divorce below.

Economic factors which contribute to cohabitation include the emotional and financial cost of divorce, which have become well-known and which discourage people from marrying.

Divorce has become common

In the United States, the divorce rate's overall trend since the late nineteenth century has been upward. The divorce rate increased rapidly 1960-1981, but has fallen somewhat since then. Canada's divorce laws were liberalized in the late 1960s (no-fault divorce) and then again in the mid 1980s (only one year, not three years of separation required), and Figure 23-5 shows the surges in divorce that followed. Figure 23-5 shows only numbers, not rates, however. The refined divorce rate (to be explained later) has been falling since 1991. This is attributed not only to the rising age of married persons but also to a decreasing likelihood of younger people to divorce.[8].

Figure 23-5. Number of Marriages and Divorces, Canada (1926-2008)



Source: Cardus Associated Authors (2020). CC BY 2.0

Up-to-date marriage and divorce data have proven difficult to obtain since Statistics Canada stopped processing provincial marriage and divorce data in 2008, citing costs and the tangled web of cohabitation and remarriage.

The median length of marriage for Canadian marriages eventually ending in divorce was roughly 11 years between 1986 and 1996[9], about 12 years in 2010, and over 15 years in 2020[10]. It would be interesting to learn if immigrants divorce at lower rates, and if so, how much that has affected divorce statistics.

Non-economic factors contributing to divorce include secularization, more liberal divorce laws, higher expectations for couple-compatibility, unclear expectations about gender roles, and higher expectations for self-fulfillment. Economic factors contributing to divorce include an increase in the average woman's post-divorce standard of living and the declining cost of arranging a divorce. Economic consequences of divorce include increased demand for housing, a reduced standard of living for spouses and children, stresses on

8. Statistics Canada (March 2022)
9. Statistics Canada, Number of Divorces and Divorce Indicators, Table 39-10-0051-01 released November 14, 2022.
10. Statistics Canada (March 2022)

children, and stresses on parents. Separation of children from one of the parents when that parent does not have custody can be painful for parent and child.

In 2021, the Canadian Health Survey on Children and Youth estimated that just under twenty percent of Canadians who were born after 2001 had experienced experienced parental separation or divorce before reaching the age of eighteen[11].

Many studies have demonstrated adverse effects of divorce on children' education, health, and behaviour, but more work is being done to distinguish between low-distress and high-distress marriage and differing divorce experiences. Adverse effects may be due to unobserved differences, such as mental health of parents, which affect both the likelihood of divorce and outcomes for children. Unfortunately, any adverse effects of divorce on children may compound existing disadvantages when divorce is more likely for parents with lower levels of parental educational achievement, as it seems to be in the United States (e.g. Cohen (2019)).

Measuring marriage and divorce rates

Like the crude birth rate and crude death rate, the **crude marriage rate** is the number of marriages per year, divided by the midyear population, and expressed as a number per 1000. The **crude divorce rate** could be computed the same way.

These rates, however, do not tell us much. The mid-year population includes people who are already married, people who are divorced or widowed, and children too young to marry. Depending on the age structure of the population, the marriage or divorce rate may be very high when it appears to be low.

A better marriage measure would be a **refined marriage rate,** which is the number of marriages that year per 1,000 single, widowed, or divorced women (or men) at mid-year. The **refined divorce rate** is the number of divorces that year per 1,000 married women (or men) at mid-year, as documented in Figure 23-6 below.

11. Statistics Canada (Sept. 2021)

Figure 23-6. Refined Divorce Rate, Canada, 1991-2020

Source: Chart 1 of Statistics Canada (March 9, 2022).

Another useful rate is the **first marriage rate of 21-25 year olds,** that is, the number of marriages of 21-25 year olds who are getting married for the first time, divided by the number of 21-25 year olds at mid-year. We can compute other age-specific first marriage rates as well.

We can do age-specific divorce rates as well, but it makes more sense to use the age (i.e. length) of the marriage rather than the age of the people involved.

The age-of-marriage specific divorce rates are called **duration-specific divorce rates, DSDR.**

$$DSRD = 1000 \times \frac{\text{people divorcing this year after n years of marriage}}{\text{midyear population of people who married n years ago}}$$

The mid-year population of people married *n* years ago depends on the number of people who married n years ago, and also on how many of them are still alive.

Summing up DSRD for marriages of all different durations, we get the Total Divorce Rate (TDR), not to be confused with the Total Dependency Ratio. Like Life Expectancy and the Total Fertility Rate, the Total Divorce Rate is hypothetical.

$$TDR = \frac{\Sigma DSRD}{1000}$$

where the summation is usually over marriages lasting between 1 and 30 years.

The total divorce rate is the percentage of marriages that would end in divorce if today's duration-specific divorce rates remained the same throughout a couple's life. It is technically possible for the TDR to be greater than 1, so interpret the TDR with caution.

In 2019, before the pandemic, the TDR over marriages lasting between 1 and 50 years was 369.4 per 1000 marriages, down from 421.5 in 2000.[12]

So far we have focused on adults and the rates at which they get together and stay together. There is definitely more to be said about the economic and demographic consequences of family structure, but we cannot cover it all in this textbook. In our next chapter, we'll look at the preference for sons that sometimes exists in families.

Exercises: Chapter 23

1. In Country A, the marriage rate is 10 per 1000, while the divorce rate is 5 per 1000. Can we conclude that 50% of marriages end in divorce? Why or why not?
2. In Canada today, fewer households include grandparents. What are some possible economic reasons for this, and what are the possible economic repercussions?

12. Table 39-10-0051-01 in "Number of divorces and divorce indicators in Canada," Statistics Canada, November 14, 2022.

Chapter 24: Son Preference and Dowry

We have learned that family structure is influenced by and influences the standard of living. In particular, economic pressures partially explain the value traditionally placed on sons and the payments traditionally made upon marriage.

In this chapter we will combine what we have learned about calculating the number of missing females, about fertility, family structure, and even human trafficking. We will focus on son preference and marriage payments. Both of these are heavily influenced by culture and tradition, but economic pressures help explain the origin and continuation of these practices. Both of these practices can result in hardship, even mortality for people identified as girls and women. People identified as boys and men may also be adversely affected.

Son preference

In earlier chapters we mentioned that girl infants and children may experience unnaturally high mortality rates due to preference for boy children. Figure 24-1 below shows some unusually low and some unusually high sex ratios at birth. If the data can be believed, in 2019 Sichuan province in China had a sex ratio of 97 boys per 100 girls, in contrast to the biological sex ratio of 105-6, while Tianjin had a sex ratio of 123. In 2018, one Indian province had a sex ratio of 92 while another had a sex ratio of 132.

Figure 24-1. Selected Sex Ratios, China, India, and South Korea, various years

Sex Ratios: (at birth)	1953	1964	1982	1990	2000	2001	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China (Total)	107.6	105.5	106.3	106.6	106.7	—	105.2	105.2	105.1	105.2	105.0	105.0	104.9	104.8	104.6	104.5	105.1
Sichuan, Province	—	—	—	—	—	—	—	104.4	109.9	104.0	98.23	100.9	99.7	101.9	98.7	96.73	—
Tianjin, Province	—	—	—	—	—	—	—	98.83	98.61	98.87	100.3	120.4	114.4	111.1	115.7	123.2	—
India (Total)	105.8	107.0	107.6	107.9	108.3	108.3	108.5	108.4	108.4	108.4	108.4	108.3	108.3	108.3	108.2	108.2	108.2
Kerala	—	—	—	—	—	94.5	—	92.2	—	—	—	—	—	—	103.8	—	—
Puducherry	—	—	—	—	—	99.9	—	96.4	—	—	—	—	—	—	106.3	—	—
Arunachal Pradesh	—	—	—	—	—	111.9	—	123.0	—	—	—	—	—	—	92.2	—	—
Haryana	—	—	—	—	—	116.1	—	113.8	—	—	—	—	—	—	109.4	—	—
Daman & Diu	—	—	—	—	—	140.8	—	161.8	—	—	—	—	—	—	114.0	—	—
Manipur	—	—	—	—	—	102.7	—	101.5	—	—	—	—	—	—	132.1	—	—
South Korea (First Child)	—	106.0	108.5	113.0	106.3	105.5	105.8	105.0	105.3	105.4	105.6	105.4	105.2	106.1	106.5	—	100.2

Sex Ratios at birth for provinces/states displaying extreme sex ratios for China, India, and South Korea. Graphic compiled by: Pauline Galoustian; Sources: Statista/Government of India/Census of China/Oxford University Press

Whatever these data say, it is common knowledge that sex ratios at birth, especially for "higher order" children (the 2nd, 3rd, 4th child) tend to be higher in South Asia and East Asia. In contrast to the datum in the Table above, the CIA World Factbook reported the sex ratio at birth for China to have been 111 in 2020, not 105.1.

A 2016 study in the *Canadian Medical Association Journal* [1] discovered that the sex ratio at birth did not vary much among ethnic groups in Canada, except in the case of Canadian women born in India whose first and second children were female. For that group of women, the sex ratio at birth for the third child was 196:100, more than 80% higher than normal. The greater the number of induced abortions between the second birth (female) and the third birth, the more likely the third child was to be male, indicating that female fetuses were being aborted. An abortion at 15 weeks of pregnancy or later was associated with an almost four times greater ratio of baby boys to baby girls than normal.

M. Das Gupta (2009) explains that Korea, China, and northwestern India, places where son preference has manifested itself especially strongly, have traditional political systems which are very much organized around male ancestry. In East Asia, ancestor worship helps reinforce notions of loyalty, order, and political hierarchy, and requires ceremonies carried out by men. Property is typically inherited by men only.

In rural areas of East and Southeast Asia, a rural man's identity, social status, and access to resources may

1. Marcelo L. Urquia et al. (2016)

be determined by his position in a clan, with the oldest son of an oldest son at the top. A woman's identity is determined by her husband. Women born into the clan are required to leave and marry men of other clans. They leave their land and forego any inheritance other than what is given to them as part of the marriage settlement.

Since women live with their in-laws once married, it is their brothers who look after their aging parents.

Ding and Zhang (2014) find evidence that, in rural China, having a son has been perceived as a good investment. Using 2003 data on three thousand rural Chinese households, Ding and Zhang found that households having at least one son received more gifts and cash transfers from family and friends, gave and lent more to family and friends, and invested more in their agricultural enterprises and family businesses.

Rural Asian parents have looked mostly to their sons for labour, old age support, continuation of family influence, and ceremonial obligations. This has been true in most societies through human history. Most societies have been patrilineal, with surnames, titles, privileges and property passing from father to son.

Consequences of son preference

The importance of sons financially and culturally has led, in various times and places, to a sex ratio at birth that is higher than normal, and to higher-than-normal mortality for girls and women. We saw that when we observed the high number of girls and women calculated to be missing from China during the twentieth century, back in Chapter 7.

Son preference leads to higher-than-normal sex ratios at all ages. According to the CIA World Factbook, in 2020 the sex ratio of the Canadian population was 0.98, but it was 1.06 in China. The sex ratio for 15-24 year-olds was 1.17 in China compared to 1.07 in Canada, meaning ten extra males 15-24 for every 100 girls compared to the situation in Canada.

What are the consequences of a shortage of females? We might think that there would be a lower rate of family formation, ceteris paribus, with consequences for fertility. Men would have to look abroad to find wives, with consequences for immigration and human trafficking. We might expense violence against women to rise. Research indicates that the story is not so simple.

Trent et al. (2013) found that, in India during 2005-6, a shortage of females was associated with a small increase in the likelihood that women would marry before age 16 and/or be coerced into having sex. Yet overall, the shortage of women seemed to result in women being treated better, not worse. A 2014 review of twenty studies on the subject by Schacht, Rauch and Mulder found no clear correlation between a shortage of women and violence. In a 2016 article, Schacht, Tharp and Smith, having studied over three thousand American counties in 2010, found that a shortage of women was correlated with lower rates of murders and sexual assaults.

Schacht et al. found evidence that a shortage of females leads more domestic violence but also to higher rates of marriage, increased practice of monogamy, less inter-male conflict over women, and less rape.

In a more recent article, Pabst, Walfield, and Schacht (2022) correlate violence against women in the United

States with a skewed sex ratio, but not necessarily one skewed in favour of men. In fact, a shortage of men seems to be a higher risk situation for American women than a surplus of men.

A surplus of men may ease pressures on brides' families to pay high dowries to grooms' families.

Dowry/Groomprice

There has been in many societies – including those of Europe – a tradition of **groom price**. It is based in patriarchy and income inequality, resulting in the situation where social status and income depend mostly on the husband's social connections and wealth. To secure the best match for one's daughter in terms of privilege and wealth, a dowry must be offered. **Dowry** and groom price are synonymous.

The five Bennet sisters, whose mother seeks to marry them to wealthy men despite not having money for their dowries, are the subject of Jane Austen's classic 1813 novel, "Pride and Prejudice". Source: Public domain.

Without the backdrop of social safety nets and institutions to protect human rights, marrying into financial and social security is even more attractive. Parents may greatly influence or completely control who marries whom.

In countries where groom price is paid, groom price provides a disincentive to raise girl children, because girls will eventually require a dowry and an expensive wedding. As one advertisement for a fetal-gender test kit put it, "Spend 500 rupees now to save 500,000 rupees later."[2]

2. As reported in "Land of the rising son", Globe and Mail, Sept. 12, 2009.

Class Discussion

What remnants of the dowry tradition can you find in the wedding practices of North America today?

Instead of groom price, in some countries there is a tradition of "bride price." Bride price is the norm in most of China, and used to be the norm in southern India. Where land is plentiful and low-cost, and women are expected to do manual work, bride price is often found. It can reflect compensation to the bride's family for the expenses of raising her and for the emotional cost of letting her go live with another family. It can reflect her future value as a worker. Bride price can be considered a form of inheritance, some of which the bride herself may be able to keep or control.

Both groom price and bride price involve gifts of jewelry, cash, land, or an annuity, some of which may remain in the possession of the woman. This can serve as a safety net for the woman. For example, in Iran a bride traditionally receives a gift from the groom called "mahr". Should divorce occur, she can take the mahr with her.

Both groom price and bride price help a couple build their new home and life together.

Bride price helps counter son-preference, giving families an incentive to care for girl children who will eventually leave the family home and work for another family. The bride price received for a daughter can be used to pay the bride price needed when finding one's son a wife[3].

When a woman lives with her in-laws, she may be dependent on them for protection, sustenance, and approval, but may have the lowest status in the family. The husband's parents are likely to influence her and her husband's fertility decisions. Entering into the husband's family often affects women's development, education and employment. Commonly, daughters-in-law work for the family business and/or take care of the household while the men are employed elsewhere.

3. Ding and Zhang (2014)

Manjula Durgaiah (l) and Suarupa (r), daughters-in-law to farmer M. Durgaiah, help harvest his sorghum crop. Date unknown. Credits to: International Livestock Research Institute. CC BY-NC-ND 2.0

Analyzing Groom Price

Baht and Halli (1999) studied groom price in India, which rose faster than the rate of inflation during the twentieth century. As a cultural practice it spread from northern India and upper-caste families to eventually include most of the population. Baht and Halli correlate groom price in Indian between 1911 and 1971 with the sex ratio among people of marriageable age.

As the population of India began to grow rapidly, younger cohorts became larger in size than older cohorts, and the availability of marriageable men, who are typically older than the women they marry, declined. Because of that declining availability, the age gap between marriage partners narrowed.

As India experienced mortality transition, fewer women died in childbirth. That meant fewer widowers (men who have lost their wives) available for re-marriage, another reason for the declining availability of men. The overall declining availability of men helps explain the increase in groom price during that period.

Class Discussion

Which is more stigmatized in your cultural tradition – ignoring passion and marrying for money, or ignoring money and marrying for passion?

Siwan Anderson (2003) used a Gale-Shapley matching model to pair off hypothetical men and women of different social classes and different incomes and study the implications for groom price.

The Gale-Shapley matching model is an incredible tool used to match students and universities, doctors and hospitals, and transplant donors and recipients. Just like Gale's proof that the average number of sexual partners of men and women must be the same if the numbers of men and women are the same (see Chapter 11), his matching model is elegant and simple.

The matching model requires members of one of the parties, say the women, to line up. The members of the other party, which in the case of heterosexual marriage would be the men, then take action. Each man lines up in front of the woman he is most interested in. At that point, each woman chooses the man she is most interested in, *out of the men who have lined up in front of her. She cannot choose a man who has lined up in front of someone else.* The first iteration is now complete. In the second iteration, the men who have been rejected now line up in front of their second-favourite woman. After they have done so, each woman either retains her previously-chosen man or chooses one of the new men lined up in front of her. The second iteration is now complete, and the rejected men try again.

This algorithm continues until each man, starting with his top choice but working down his list as necessary, has found a woman for whom he is her top choice. It can be shown that this outcome is an equilibrium – no man can do better, since the women he prefers rejected him, and no woman can do any better, since if there is a man she prefers to the one she has, it is a man who doesn't want to be with her since he never lined up in front of her. Thus each person can do no better than what they have done. The matches are stable.

Class Discussion

In the matching game, would you rather be lined up like the women in the example, or be lining up in front of your top choice, like the men? Will the eventual matches be the same? Experiment using a deck of cards.

Does the matching model shed light on why, in most cultures, men take the active role in courtship?

Anderson assumed that brides' families offer dowry to grooms for two reasons: income and class. Lower class families want their daughters to marry into the upper classes. Anderson used the Gale-Shapley algorithm to show that, when income becomes more variable within each social class, the richer lower-class families begin to compete with the poorer upper-class families for grooms. The upper-class families have to raise their bids on the poorest upper-class grooms, and of course the richer upper-class grooms "cost" even more. In this way, groom prices inflate as income becomes more variable. Groom prices have to inflate if people are to continue marrying within their class.

Reena Kukreja, in her 2020 book "Why Would I be Married Here?", describes the migration of poor, darker-skinned Dalit and Muslim girls to rural northern India. They are going there to meet and live with the husbands selected for them, poor men of their own social background. The parents of these girls do not have the money to secure local Dalit and Muslim husbands for them. The local men are upwardly mobile and are demanding high dowries to help them get ahead. For whatever reason or insanity, they are willing to accept a lower dowry for a lighter-skinned wife.

If incomes become equalized between upper and lower classes, the poorer upper class families can no longer outbid the richer lower class families, and lower and upper classes will intermarry. Because class is less significant, there is less reason to offer groom price.

In Europe, groom price disappeared as the economy modernized and income inequality lessened. Sons were becoming less likely to work in a family business, or use their family's land. Women were eventually allowed to inherit property. Their prospects depended less on their family background than previously. Educating children became an important way to transfer privilege to sons and to daughters.

We've come a long way in analyzing demographic phenomena with economics, and explaining the impact on the economy of demographic phenomena. Let's sum up in the next chapter.

Exercises: Chapter 24

1. Explain how the following might affect son preference and groom price or bride price.

a) mechanization of agriculture

b) reductions in infant mortality

c) mandatory schooling for all children ages 5-14

ZOOMING OUT

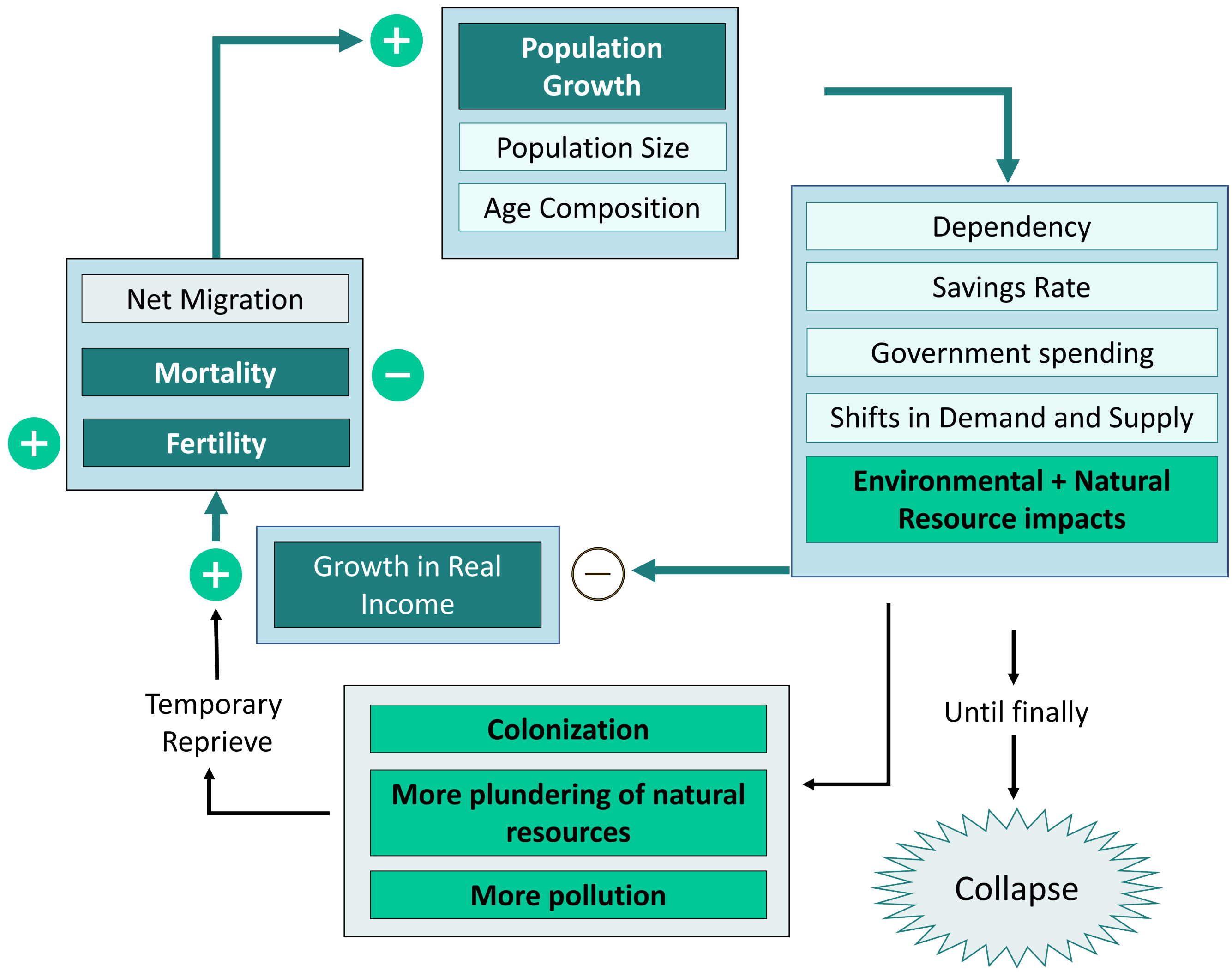
Chapter 25: Models of Economic and Demographic Change

While the Industrial Revolution was disproving the Malthusian assumption that food production could grow only arithmetically, the Demographic Transition was disproving the Malthusian assumption that the birth rate would always rise when the standard of living improved.
Since 1750, most of the world has defied the Malthusian model's predictions and experienced both a rising standard of living and a growing population. What new model can explain Economics and Population Change?

The Malthusian model seems no longer relevant in a world experiencing ongoing technological development, a rising standard of living, and a slowing rate of population growth.

Paul Ehrlich (author of The Population Bomb, 1968) warned us not to disregard the Malthusian model. Food production has been able to keep up with population growth, but only because we have been exploiting natural resources, environmental capital, and other societies in an unsustainable way, Ehrlich said. At some point we will not be able to do this any longer; confronted by a wasted environment or social upheaval, our civilization will collapse.

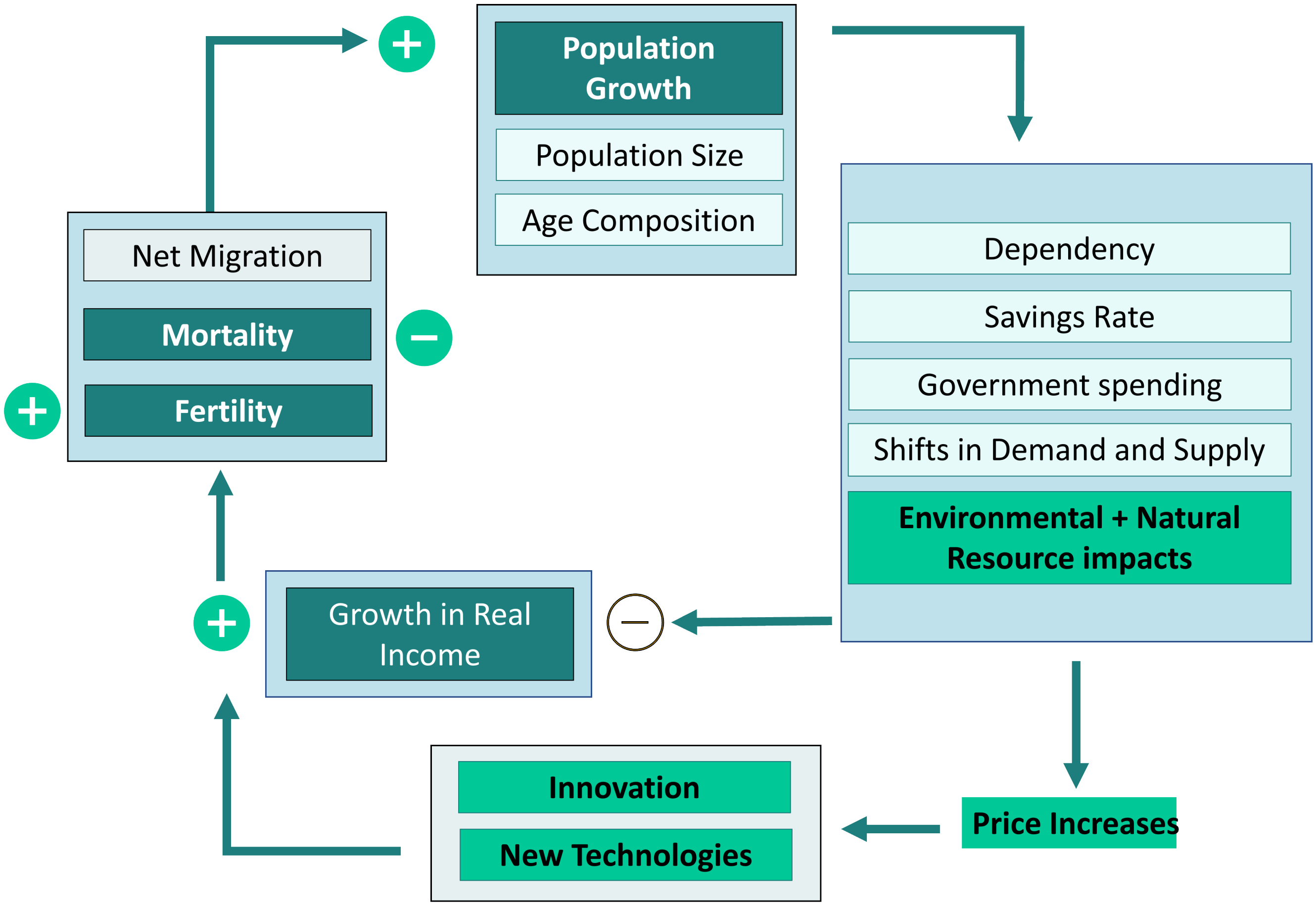
Ehrlich Model



Cycle spins until collapse

Esther Boserup (1965) and ***Julian Simon*** (1981) had a rosier view. They noted that, as population grows and resources become relatively scarce, prices rise. They believed that rising prices will motivate people to innovate and develop new technologies, and that these innovations will be successful.

Boserup-Simon Model



Virtuous Cycle

In this model, the standard of living is rescued again and again by technological change. For that to happen, there must be a political and intellectual climate conducive to innovation. Governments help by pursuing peace, upholding civil and commercial law, protecting personal and intellectual property, and funding education and research. A well-functioning market is needed to provide innovators with investment funds and inputs, and to help them find customers for their inventions.

New technology disrupts old technology, and existing companies may want to stamp it out, fearing their own obsolescence. The market must be open to new ideas, and free from artificial barriers.

In some countries these preconditions for innovation are not well established, so the economy must acquire new technologies from other countries.

Modern societies are more and more dependent on technologies that most people don't understand, with health and environmental implications we don't realize until damage has been done. We have to keep innovating to clean up the mess we make. This could be what Jane Jacobs (1969) had in mind when she wrote:

> Once we stopped living like the other animals, on what nature provided us ready-made, we began riding a tiger we dare not dismount[1]...

Boserup and Simon's model presumes that all relevant resources are marketed, so that resource scarcity will be registered by an increase in the price of those resources. In real life, population growth threatens resources such as watersheds, pollinators, and climate. Watersheds, pollinators, and climate provide ecosystem services which are not bought and sold in the market. These services will be unpriced unless regulators attach restrictions or taxes to their use. If unpriced, there is no clear incentive to preserve them or provide more of them. If there is no regulation of watersheds, pollinators, climate, etc. these "open-access resources" are likely to be overexploited, and the rosy view of Boserup and Simon must be tempered with warnings from Ehrlich.

A model based on Indigenous teachings

Traditional knowledge-keepers of the Indigenous peoples of Turtle Island (North America) would likely begin any discussion of population and its economic consequences by explaining their understanding of the Land. According to traditional Indigenous thought, the Land is comprised of spiritual beings who take shape or have taken shape in physical form. It includes beings that are often taken to be inanimate – rocks, trees, and winds for example. The Land does not so much belong to human beings as human beings belong to the Land.

All beings on the Land exist in relationship together. These many intersecting relationships are what life is about. People have obligations to gratefully tend the resources they harvest, and to share with one another. There are also obligations to ancestors who have crossed over to the spirit world, and obligations to descendants who will walk the Land seven generations from now.

Ronald Trosper, in his book *Indigenous Economics* (2022, pp.5-6), states:

"*Living well* consists of pursuing actions that strengthen humanity's relational goods created by relationships with nature and with each other. The added value of improved relationships can include additional material goods and services, so long as the additional material income is shared with all beings in the relationships. The aim of good living is to increase the value of all relationships without harming them."

How can we model an understanding of progress that emphasizes relationships among all beings?

The Medicine Wheel is often used by Indigenous knowledge-keepers to illustrate balanced progress that respects relationships. The Medicine Wheel is a made up of concentric circles, divided into four quadrants. Progress is represented by moving outward in all four directions simultaneously.

1. Jane Jacobs (1969), The Economy of Cities, chapter 3.

Figure 25-1. A Medicine Wheel relevant to Population and Economic Change

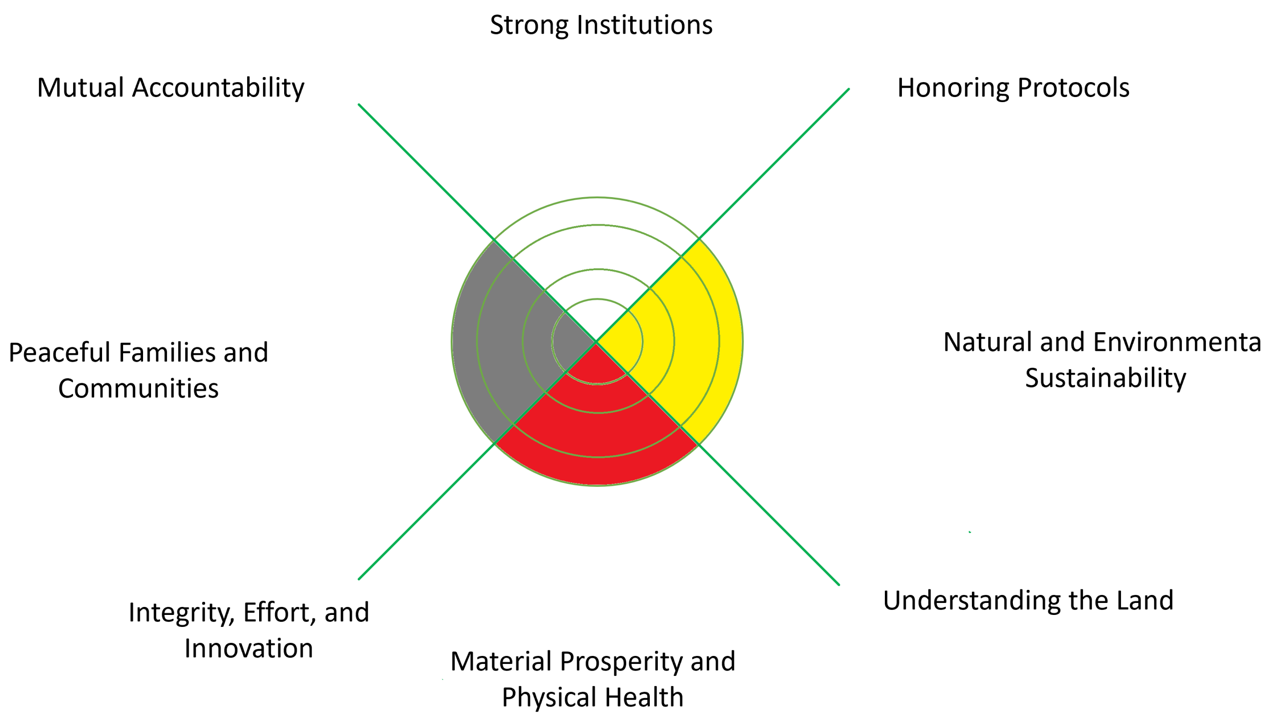


Figure 25-1 is adapted by Anya Hageman from Sherry Salway Black (1994) and other sources.

In the Medicine Wheel illustrated above, progress in material prosperity and physical health is directly related to “Integrity, Effort, and Innovation” as well as “Understanding the Land”.

Photo by Lenore Edman, 2008, flickr.com. CC BY 2.0

Imagine that the medicine wheel is three-dimensional, shaped like a bowl. For the medicine bowl to hold more water, its sides must be built up everywhere. Water will spill from the lowest point along its edge. The bowl will not hold more water if only one quadrant of the bowl gets built higher.

A three-dimensional medicine wheel illustrates that true and lasting gains in well-being can only be made when we progress along all four quadrants of the medicine wheel at the same time. With reference to Figure 25-1, this means that the well-being of a society does not depend on work effort and innovation alone; concomitant improvements in family life, community life, institutions, and natural landscapes must be secured.

Jody Wilson-Raybould, a former Minister of Justice and Attorney General of Canada, writes

> *"...at the core of my Kwakwaka-wakw worldview is the belief that all things are in their greatest state of well-being when there is balance. This includes balance between humans and the natural world, between genders, between groups of peoples, within a family or community, or in how we live and organize our lives. Balance is viewed as the proper state of things, where conditions of harmony and justice flourish, while imbalance is what gives rise to conflict, contention, and harm....A society imbalanced...is like a bird with an injured wing. It cannot fly, its purpose and potential cannot be met, and all are held back."*[2]

Indigenous knowledge-keepers would appreciate the warnings of Malthus and Ehrlich that human beings

2. Wilson-Raybould (2022) pp. 189-190

cannot multiply on the earth without a matching increase in the capacity of the Land. They agree that a growing population must be balanced with, or inevitably will be limited by, the capacity of the Land. If a population is too large to observe the correct protocols and caregiving practices on the Land, its relationship with the Land will be hurt and the population will suffer as the Land withholds its bounty. They may also teach that the full potential of the Land cannot be realized if the population is too small to interact with and care for the Land. [3].

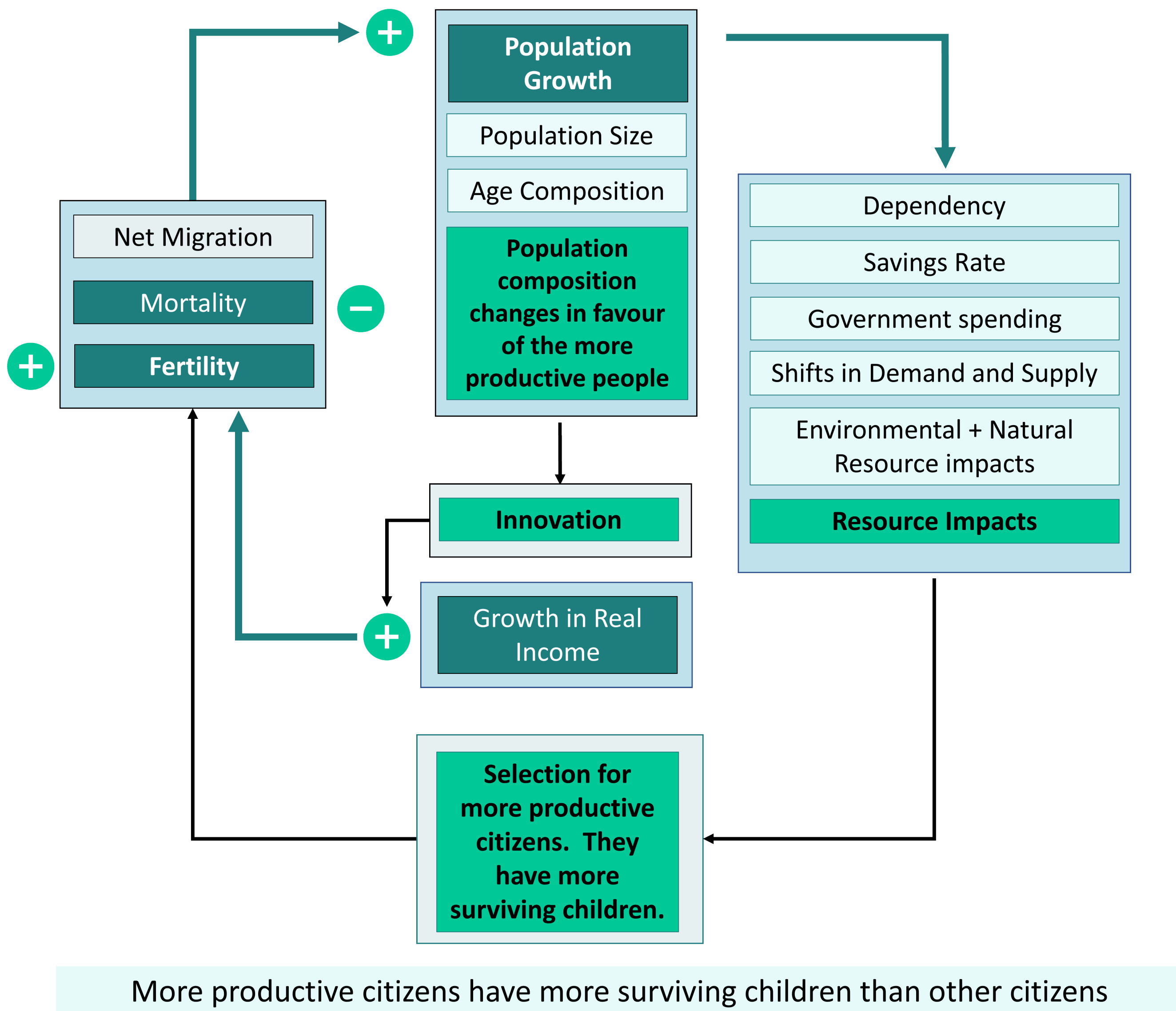
With respect to this three-dimensional medicine bowl, what is the third dimension that fills the bowl in each of the four material directions? Wisdom might be the answer, and Grace. Each generation inherits existing relationships, protocols, institutions, material wealth, and natural environments, but whether the level of water in the bowl will rise or fall depends on how the generation moves forward in wisdom and with grace.

Now that we have explored a holistic understanding of population and economic change, we return to models that focus mostly on innovation and work effort.

Gregory Clark has proposed that, when population growth leads to food scarcity and rising economic pressures, people who are literate, numerate, hard-working, and thrifty are more likely to adapt. If these people have more children than people who are less literate, numerate, hard-working, and inclined to save, the productive capacity of the economy will improve.

3. See "The Teachings of Grass" in Kimmerer (2013) for an example.

Clark Model



Clark argues that literacy, numeracy, thrift etc. spread through the British population at the time of the Industrial Revolution because people with these attributes, whom he identifies as the upper economic classes, had more children than other people. In a sort of "downward mobility", these useful attributes spread through the population of Britain from the upper classes to the lower classes, enabling Britain to continue growing in population and income per person. Today, families of higher education, wealth or income typically have fewer surviving children than other families.

It is always dangerous to generalize about classes of people. Certainly to call the upper classes of England thrifty and hard-working seems a bit of a stretch. Many of these people were idle landowners whose parents and grandparents became wealthy by investing in slavery-based sugarcane plantations.

Clark ignores the fact that innovating activity will not be successful unless society's institutional arrangements reward innovation; in particular, he ignores the fact that educational institutions spread the attributes of literacy and numeracy. In his book, *Farewell to Alms* (2007), Clark disagrees with the idea that good institutions precede good economies. He believes that governments and other institutions reflect economic conditions rather than shape economic conditions.

Clark's position that institutions and beliefs are determined by the economy recalls the views of Karl Marx, who believed that the most important social fact is who owns the capital. This is ironic since, according to Marx, labour is the only source of material value, and the price of something should reflect only the labour which goes into making it. With their intellectual commitment to the primacy of labour, early Marxists did not speak of any disadvantages to population growth. They focused on distributing capital to workers so as to reduce poverty.

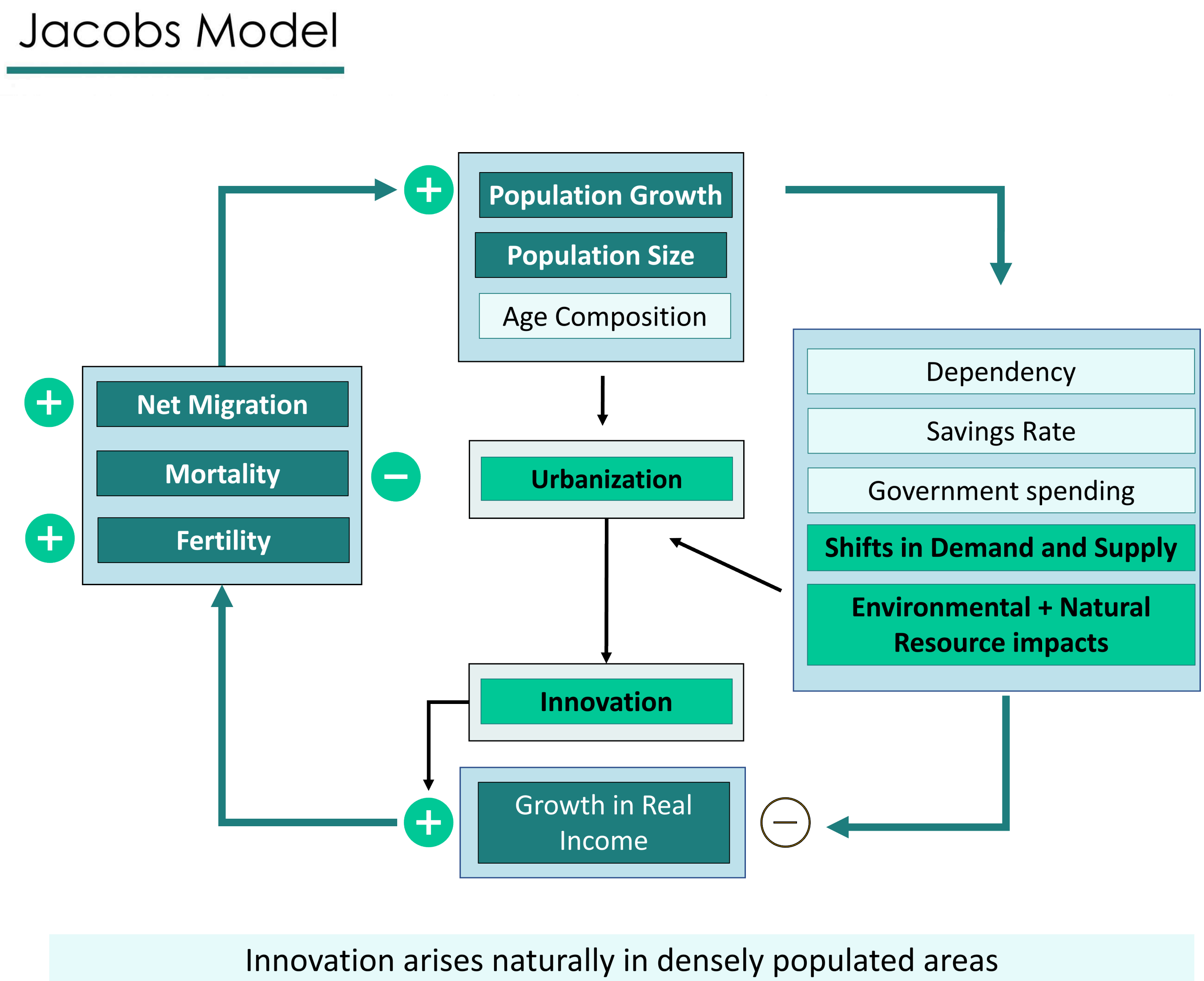
Clark's model reminds us that the composition of population, not just its size or growth rate, can make a difference to the economy.

Jane Jacobs (*The Economy of Cities*, 1969) wrote eloquently on the importance of cities to economic development. For Jane Jacobs, a growing population can promote innovation if population density and settlement are the result. Population growth leads not only to rising prices but also to urbanization, and urbanization leads to innovation and better institutions.

> *Our remote ancestors did not expand their economies much by simply doing more of what they had already been doing: piling up more wild seeds and nuts, slaughtering more wild cattle and geese, making more spearheads, necklaces, [engraving tools], and fires. They expanded their economies by adding new kinds of work. Economies that do not add new kinds of goods and services, but continue only to repeat old work, do not expand much nor do they, by definition, develop.*
>
> *In conjecturing how animal husbandry could have begun in an imaginary prehistoric settlement, I proposed that this new work was logically added to the older work of managing wild animals before slaughter. That work, in its turn, had also been added to older work: trading obsidian to many people who came to [the settlement] seeking to bargain for it. And that trading service, it turn, had been added to the settlement's own way of getting obsidian: bargaining for it with the neighbouring tribe whose people mined it at the volcano. And the volcano people had doubtless added that work to their own still older work of preparing flints and other stones for weapons.*
>
> *In short, I was presuming that each kind of new work, as it appeared in this prehistoric economy, was added logically and "naturally" to a specific bit of older work. That is how innovations are made in our own time. It is also how work has diversified and expanded during historical times.*
>
> *This process is of the essence in understanding cities because cities are places where adding new work to older work proceeds vigorously. Indeed, any settlement where this happens is a city. Because of this process city economies are more complicated and diverse than the economies of villages, towns and farms, as well as*

> *being larger. This is why I have also argued that cities are the primary necessity for economic development and expansion, including rural development.*[4]

Jacobs also celebrates the largeness, disorder, crowdedness, and danger of cities, believing that these features stimulate even more innovation. In her view, nothing must be done to squelch the vitality of the economic organism that is the city.

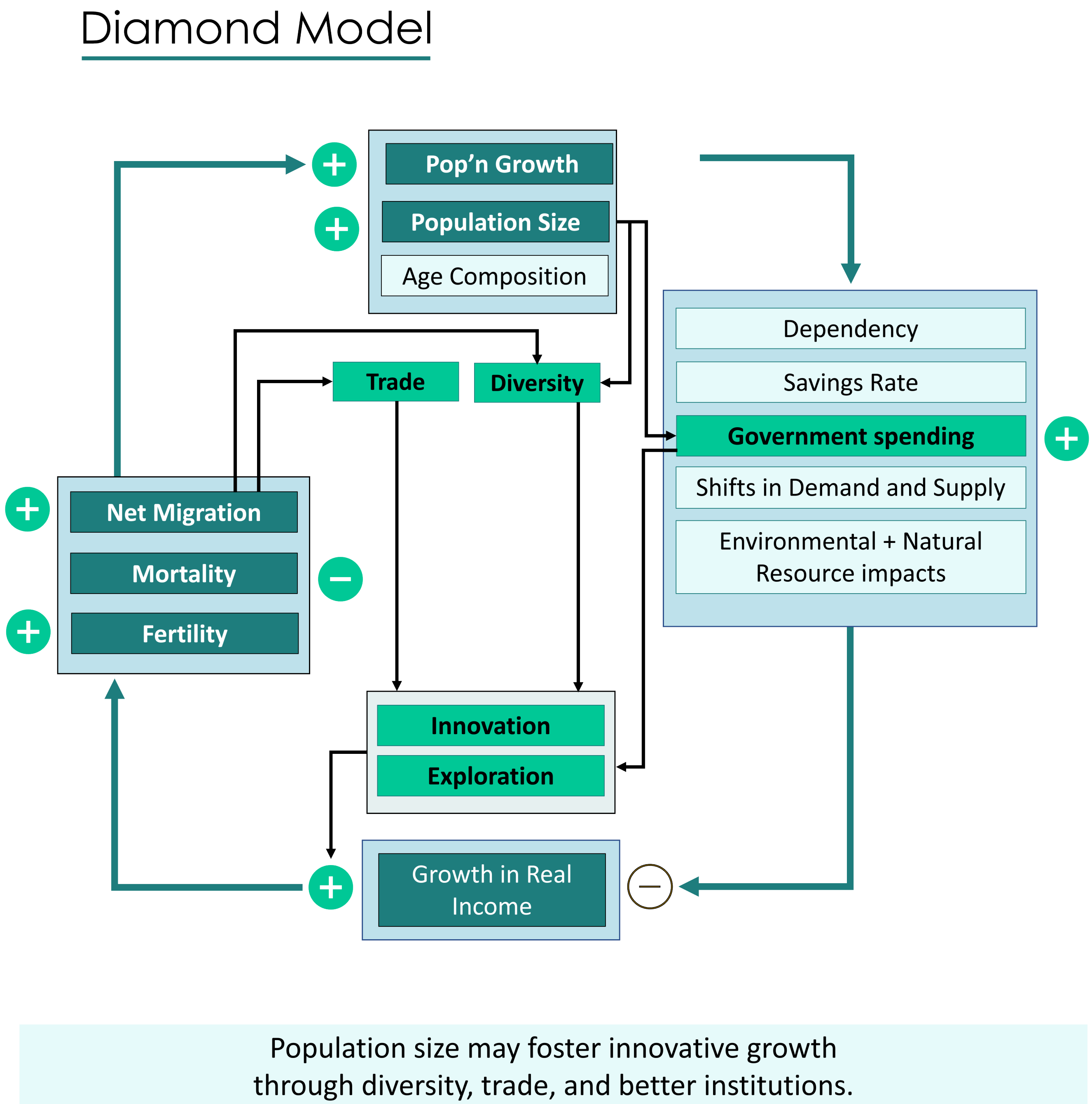


Jared Diamond (*Guns, Germs and Steel* (1999)) agrees that innovations emerge as small populations become larger. In very small populations, everyone knows everyone else's family, and intermediation can happen spontaneously if conflicts arise. In larger societies, however, stranger-to-stranger conflicts are more common, and an independent legal system is needed to resolve disputes. Once the town is so large that most people are strangers to one another, a system of taxation and spending is needed if public goods like bridges

4. Jacobs (1969) chapter 2

and canals are to be built, and if the poor are to be fed. Normally, small populations must grow to a critical mass before they adopt more sophisticated legal and governmental institutions. The new institutions foster innovation and trade.

Diamond, unlike Clark, believes in the importance of institutions.



To Diamond, large populations have several advantages over small populations. Not only do they acquire more sophisticated institutions, they also have more military might. They develop resistance to pandemic diseases. They benefit from a greater diversity of abilities, aptitudes, and ideas within the population.

Class Discussion

Acemoglu and Robinson (2012) distinguish between "extractive" and "inclusive" institutions. Give examples of each.

What do you think of the relationship between economic growth and institutions? Which comes first?

Diamond, once again in contrast to Clark, explains economic development in terms of diversity rather than selection. Regions with more diverse plant and animal life were able to develop richer agriculture. Regions with more diverse trading partners were able to develop richer technology and intellectual life. And regions with larger populations had more ability to attract trading partners, develop new ideas, and develop resistance to contagious disease. Diamond writes about New Guinea and Australia that

> *Human populations of only a few hundred people were unable to survive indefinitely in complete isolation. A population of 4,000 (Tasmania) was able to survive for 10,000 years, but with significant cultural losses and significant failures to invent, leaving it with a uniquely simplified material culture.*[5]

The best model

Which of these is the best model? We do not have to choose among the ones presented in this chapter. The reader can develop their own, blended model using whatever insights have been offered above, plus additional insights.

We have also to remember that a variety of powerful forces, such as secularization, social and religious movements, natural disasters, and war are not entirely determined by economics and demography. They are, to a significant extent, exogenous to any model of population and economic change, and can set it spinning in new directions. They are the "bath" in which our model of economics and demography sits. The "bath"

5. Diamond (1999) chapter 15

of knowledge, politics, inspiration, social norms, and access to resources was very different before and after the Industrial Revolution, and consequently the Malthusian model has become less and less descriptive of the relationship between economics and demography.

We want to be wary of oversimplifying life.

Jared Diamond puts it this way: "We tend to seek easy, single-factor explanations of success. For most important things, though, success actually requires avoiding many separate causes of failure."

Allen Kelley (1988) has said

> *What is clear is that an assessment of the impact of population growth on economic development is highly complex, that problems like unemployment, famine, and malnutrition are caused by many factors (including rapid population growth), and that an emphasis on policies of slowing population growth without simultaneously confronting the other fundamental causes may well lead to disappointing results.*

Perhaps the best thing about this chapter is that we have learned to identify major patterns of thought around population and economic change, and we now know well enough to not put too much stock in any one of them.

Concluding thoughts

Within the natural, cultural, political, and institutional environment we live in, economic pressures and opportunities are mediated through the family and other relationships. These economic pressures and opportunities consequently affect our health, life expectancy, and fertility. They also affect our relationships themselves: our decisions about when to marry or cohabit, whether to break up, how many children to have, and where to live. Ultimately they affect the size, growth rate, and age-sex composition of the population in each particular region.

In turn, the size, growth rate, and age-sex composition in a region make a difference to its economy. Mediated by institutions, markets, beliefs, and traditions, or the lack of institutions and markets, the region's demographics affect prices, sustainability, wages, the standard of living, and well-being.

We have closely examined all these pathways. Our study does not provide us with answers about right and wrong ways to live, or about right and wrong policies to implement. But we know a fair amount about the material consequences set in motion by changes to population or the standard of living, or by policies to affect the population. Let's use this knowledge to calm panic, build a healthy, inclusive, and sustainable future, and enjoy life.

Exercises: Chapter 25

1. Where might "institutions" be added to the Malthusian flowchart?

2. Where might "institutions" be placed in the Boserup-Simon flowchart?
3. Contrast the role of family in the Indigenous model and the Clark model.
4. What might a complete breakdown of family do to any of these models?

The following questions do not have answers provided.

1. Which of the models presented in this chapter do you find most compelling, and why?
2. Design your own model of population and economic change drawing on what you feel are the best features of any of the models in this chapter.

ANSWER KEY

Exercises: Chapter 1

1. The fact that the wage is three times as high as the price of bread means only that, for this community at this point in time, an hour of work trades for 3 loaves of bread.

2. Value-in-trade is the market price. It is determined by the intersection of the supply curve and the demand curve. The supply curve shows the marginal cost of production in that market at that time. The demand curve shows the marginal willingness to pay in that market at that time.

3. The legal system benefits society by protecting the rights of citizens. The marketplace benefits society by giving citizens the opportunity to trade material goods and services. The legal system declares and enforces; the marketplace suggests and negotiates. The legal system enshrines freedom but cannot meet your material needs except by forcing someone to provide for you. The marketplace gives you a way to meet your material needs but cannot prevent inequality or exploitation.

4. An equilibrium is a condition to which the economy or population will always revert.

5. Many answers are possible. For example, a rich nation is better able to wage and win war. Having won the war, the nation gains access to new resources and becomes wealthier. And so on, with the nation becoming ev ery wealthier. Of course in reality things do not always go so smoothly.

6. Many answers are possible. Sleep deprivation reduces attention in class. Because of poor retention of lectures, a student must study further into the night, and so the sleep deprivation continues or worsens.

Exercises: Chapter 2

1. a) when FPP > FPP*, BR>DR. Population grows and FPP drops back to FPP*.

b) when FPP<FPP*, BR<DR. Population shrinks and FPP grows back to FPP*.

c) when births drop across the board, the rate of population growth at the original FPP* is now negative. Population shrinks until a new equilibrium is achieved at a higher level of FPP. This new, higher FPP* is the level that is compatible with zero population growth now that birth rates have fallen.

d) when deaths drop across the board, the rate of population growth at the original FPP* is now positive. Population grows until a new equilibrium is achieved at a lower level of FPP. This new, lower FPP* is compatible with zero population growth now that death rates have fallen.

2. The answer is (d).

3. a) technological innovation was infrequent. The overall pace of technological change was slow.

b) as in (a), productivity was low. Productivity gains were sporadic.

c) population growth was low, at about 1/20th of one percent if taken as growing exponentially at a constant rate.

d) mortality was high compared to today.

e) fertility was high compared to today, but not as high as total fecundity.

f) the standard of living was low, and for most societies it was so low as to leave them vulnerable to extreme weather and other shocks.

Exercises: Chapter 3

1. The rate of population growth is 100 x (105,000-100,000)/100,000 = 5.00 %
2. The rate of population growth is 100 x (100,000-105,000)/105,000 = -4.76%
3. The rate of population growth is 100 x (80,352-75,798)/75,798 = 6.01%
4. The rate of population growth is 100 x (75,798-80,352)/80352 = -5.67%

5a) If the population on July 1, 2012 was 34,880,491 people, and the population on June 30, 2013 was 35,284,483 people, then the population grew by 403,992 people between those two dates.

b) The population growth rate was 100 x 403,992/34,880,491 = 1.16 per cent

c) The mid-year population was 34,880,491 + 403,992/2 = 35,082,487, assuming arithmetic population growth during the year.

d) If there were 383,822 births between July 1, 2012 and June 30, 2013, then the birth rate was 1000 x 383,822/35,082,487 = 10.94 births per 1000.

e) If there were 253,241 deaths over the same period, then the death rate was 1000 x 253,241/35,082,487 = 7.22 deaths per 1000 people.

f) Natural increase = births minus deaths = 130,581

g) The rate of natural increase = the birth rate – the death rate = 10.94-7.22 = 3.72 per 1000

h) If immigration was 312,288, then, using the fundamental equation of population growth, emigration must have been 38,877. Steps:

Population growth = natural increase plus net migration

Population growth = natural increase plus immigration – emigration

Natural increase plus immigration – population growth = emigration

Emigration = 130,581 + 312,288 – 403,992 = 38,877

i) Net migration = immigration – emigration = 312,288 – 38,877 = 273,411

j) The net migration rate = 1000 x net migration/mid-year population = 7.79 per 1000

Note that net migration was 2.09 x higher than natural increase: 273,411/130,581 = 2.09 We call 2.09 the "migration ratio"

Thus net migration contributed twice as much to population change as did natural increase during the period July 1, 2012 to June 30, 2013.

Exercises: Chapter 5

1a) The mortality rate for people under age 30 is 20 per 1000 in Waitku. The mortality rate for people over 30 is 4 in K.U. and 5 in Waitku.

b) The crude death rate for K.U. = 225/60,000 x 1000 = 3.75 deaths per 1000. The crude death rate for Waitku = 60/6,000 x 1000 = 10 deaths per 1000.

The standardized death rates using K.U. as the standard country:

For K.U. , standardized death rate = 3.75, same as its crude rate. The standardized rate for Waitku = (20/1000 *5000 + 5/1000 * 55,000) = 100 + 275 = 375 deaths out of 60,000 people = 6.25 per 1000.

c) After standardization, Waitku looks better *than it did before*. Its overall death rate is still higher than KU's, but it is not relatively as high once its mortality rates are applied to a population with a lower proportion of young people such as KU's. This is because Waitku has a very high death rate for young people.

2. If the flu season kills more 20-24 year old men than women, and the sex ratio is currently 1, the sex ratio for 20-24 year olds will fall below 1.

3. Ignoring medical and other advances, a nation's crude death rate will rise as the population gets older, inasmuch as older people are subject to higher mortality rates. We could adjust for this effect by standardizing the entire time series using the population structure of particular year, or by using the average population structure over the timespan.

4. The population 10 years ago must have been $53{,}460e^{-0.02(10)} = 43{,}769$.

5. Using the Rule of 70, it will take roughly 35 years for the population to double. 70/2=35

6. $7 * e^{r*13} = 8$

$e^{r*13} = 8/7$

$13r = \ln(8/7)$

$13r = 0.133531$

$r=0.010272$

7. For geometric rate solve:

$500 = 100 *(1+r)^{80}$ thus $r = 5^{1/80} - 1 = 0.02$

For exponential rate solve:
$500 = 100\ e^{80\ r}$ thus $r = \ln(5)/80 = 0.02$
For arithmetic rate solve 400/180 = 5 people per year.

8.
Here is one way to create the expression and obtain the answer:

$$\int_{0}^{80} 1\ e^{.04t}\ dt$$

$$=(1/.04)\ (e^{.04(80)} - e^{.04(0)})$$
$$\mathbf{=588\ people}$$

And here is another way:

$$\int_{1900}^{1980} 1\ e^{.04(t-1900)}\ dt$$

$$=(1/.04)\ (e^{.04(80)} - e^{.04(0)})$$
$$\mathbf{=588\ people}$$

Exercises: Chapter 6

1a) According to Table 6-1, the life years remaining for the average Canadian woman born in 2019 will be 21.75 years once she reaches age 50.

1b) In 2069, when and if a Canadian woman born in 2019 reaches age 50, she may or may not have 21.75 life years remaining. If she is average, and if mortality rates have not changed since 2019, then yes, she will have 21.75 life years remaining. If, however, there has have been advances or declines in the standard of living, in medical technology, or in anything else affecting mortality, then the average Canadian woman will not have that same predicted 21.75 life years remaining.

2a)

Age Group	n	q	l	d	L	T	e
<1	1.00	0.30	100,000	30,000	85,000	290,730	2.91
1	1.00	0.10	70,000	7,000.00	66,500	205,730	2.94
2	1.00	0.05	63,000	3,150.00	61,425	139,230	2.12
3	1.00	0.20	59,850	11,970	53,865	77,805	1.3
+4	1.00	1.00	47,880	47,880	23,940	23,940	0.5

b) If gerbils die at a greater rate at the beginning of the year, use 0.9 as the fraction in your L calculation, indicating that the average gerbil which dies misses 90% of a year of life. This means there will be fewer life years lived by the members of that age group. The life years remaining for the average newborn will decrease. The expected life years remaining for older age groups will not change.

Exercises: Chapter 7

1. The probability that a newborn girl in Afghanistan in 2019 lives until at least age 20 is, according to Table 7-1, 93.4%. We get this by dividing the 93,443 women expected to be alive at age 20 by the 100,000 newborns
2. The probability that an Afghan girl who has just reached one year of age lives until at least age 20 is, according to Table 7-1, 97.6 %. We get this by dividing the 93,443 women expected to be alive at age 20 by the 95,722 girls turning one year old.
3. Comparing our answers above, we see that a one year old has a better chance of turning 20 than a newborn does. This is not a paradox. The closer you are to an age, the more likely it is that you will reach it. There *is* a paradox in Table 7-1, however: the average one-year-old has more years of life left than the average newborn, even though the average one-year-old has used up a year of life already. This is because so many newborns die: the child that makes it to age 1 is very much stronger than the average newborn and is part of a cohort that has shrunk significantly in number.
4. First Step: the expected sex ratio at age 25 is (105*0.97000)/*(100*0.98500) = 1.034 Let 105 be the number of newborn males and 100 the number of females. Actual numbers don't matter since we are only interested in the ratio. .97000 and .98500 are the survival probabilities for men and women, respectively, from birth to age 25.Second Step: the expected number of men at age 25 is the sex ratio (males/females) multiplied by the actual number of females. That's 1.034 X 1.5 million = 1.551 million

menThird Step: there are actually 1.2 million men so that means 1.551 million men expected in Alametra – 1.2 million men actually residing in Alametra = 0.351 million men missing from Alametra.These men might have died in conflict: is Alametra involved in a war not affecting its women and girls much, a war mostly fought in another country? Is there discrimination against boys or young men? Another possibility is that many men have migrated to work abroad.

5. The sex ratio at 15 ought to be 0.94 (1.05)/ 0.95 = 1.03895. Given that there are 30,000 males aged 15, there ought to be 30,000/1.03895 = 28,875 females. Since there are only 28,275 females, 600 females are missing.

Exercises: Chapter 8

1) Other things being equal, the poorer nation will have a higher rate of chronic death than the rich nation. Its population is weaker and less able to resist epidemics. Timely vaccinations and treatment will not be available. It is likely that more people per 1000 will die of the new flu in the poorer nation. The poorer nation has more crisis deaths per 1000 people.

There is the possibility that the poorer nation might be less susceptible to the pandemic, perhaps because it exists in a warmer climate or its people spend more time outdoors.

b) Fogel's research showed that, in England and western Europe, crisis deaths were only ever a small fraction of overall deaths, even before modern medicine. A wealthy nation has far fewer crisis deaths per 1000 than a poorer nation; however, its chronic deaths per 1000 are also far fewer. The answer is uncertain. Crises are less devastating and make up a smaller proportion of total deaths as a nation develops. So it's likely that the poorer nation will have more crisis deaths, even as a proportion of its chronic deaths, than the wealthier nation.

Exercises: Chapter 9

1a) One answer is that, during recession, parents may be unemployed or working less overtime. Parents also have less money for diversions. They therefore have more time to spend with their newborns, monitoring their welfare first-hand.

1b) People who have children during recessions may be more employable than those who give birth during boom times. During boom times they are busy with their careers, but during recessions they finally have time to build a family. People who are more employable are usually better educated, better organized, and wealthier, thus better able to care for newborns. Admittedly this is a massive generalization.

2. The Age of Pestilence and Famine is characterized by high mortality rates. In particular, infant mortality rates are high, and the paradox of the life table is observed. Female mortality rates are higher than male rates for

women in their reproductive years. Life expectancy is very low, between 20 and 40 years of age. The society is likely to be resource-based. Technology is primitive, and technical progress is sporadic.

3. The end of the Age of Pestilence and Famine is marked by breakthroughs in disease control due to sanitation, vaccination, other medical discoveries, and a rising standard of living.

4. Medical breakthroughs are not enough to usher in the Age of Manmade and Degenerative Disease a.k.a the Age of Delayed Aging. The overall standard of living must be high enough to banish all malnutrition and significantly manage chronic disease. (Aside: This is likely when a society is organized well enough to produce its own medical innovations, rather than having to import all of them form other societies.)

5. Case and Deaton (2015) noted increasing rates of mortality from substance abuse and suicide among middle-aged American Whites. Elizabeth Arias et al. (2021) found increasing rates of mortality from substance abuse during the pandemic for both Whites and nonWhites (all ages), but decreasing rates of suicide. Both studies showed an uptick in diabetes-related death rates and a decrease in cancer-related death rates.

Arias et al. found that the greatest change to overall mortality came from covid-19 death rates. Covid-19 deaths were more prevalent among Black and Hispanic Americans. Thus the relative life expectancy reduction for Whites noted by Case and Deaton was reversed.

Exercises: Chapter 10

1. In order to reduce mortality rates, the Canadian government decides to send Canadians a rebate of $50 per bicycle purchased.

This subsidy does not discriminate between different brands and models of bicycles. There are many kinds of bikes and many manufacturers around the world. Assuming therefore that the supply of bicycles is quite elastic, consumers should be able to capture most of this subsidy. That is to say, they should be able to get at least thirty dollars or forty dollar off the usual price of a bike at least. But if there are supply chain issues, the increased demand will cause bike prices to be bid up substantially.

In any event, bicycle sellers may be able to take advantage of the moment to capture part of the subsidy by raising bicycle prices, especially if they decide not to not compete with one another on price.

The policy is pretty well targeted because exercise will reduce mortality rates unless mortality from bicycle accidents is going to go up by even more; however, there are many reasons that people are not riding bicycles, and the price of a bike may not be the binding constraint. In fact, many poor and homeless people seem to be able to acquire bicycles. To get more of the population to use bikes, it may be more effect to increase the number of bike lanes, improve the condition of roads in winter, and discourage automobile use.

Further, once people have a bike, they may not actually use it. The policy does not encourage use on a daily basis.

2. Under what conditions will heightened COVID-19 safety protocols increase the price of food at burger chain restaurants?

Most restaurants aspire to be unique and to have a following of loyal customers. If they succeed in this kind of "monopolistic competition", we can't use the supply and demand diagram to model what happens. But burger chains do appear to compete vigorously with one another, so we might use supply and demand for hamburgers without going too far astray from reality.

The question is whether demand for fast food hamburgers and associated items (fries, shakes) is more or less inelastic than supply.

During the pandemic, supply could be quite inelastic because of the difficulty of getting staff to show up for work. Even before COVID-19, there were some labour supply problems, with Canada's Temporary Foreign Worker program being used by some managers.

Demand may be quite inelastic as well. Some people make fast food hamburgers and related items a staple of their diet. They may not feel as though there are many attractive substitute foods available.

If demand is more rigid than supply, firms will be able to pass most of the safety costs on to consumers by raising the price of their meals. But if not, firms will absorb most of the safety costs in order to retain customers.

Exercises: Chapter 11

1. a) The crude birth rate is 10.58 or 10.6 per 1000. =1000* 10,580/1,000,000.
2. b) The general fertility rate is 89.66 or 89.7 per 1000. = 1000 * 10,580/118,000.
3. c) To get the total fertility rate, we need the age-specific fertility rates, computed below. Divide by 1000 and multiply by the number of years in the age group, then add all age groups to get the total fertility rate: 3.36 children per woman.

Age Group	Age-Specific Fertility Rate (per 1000)	Calculations for TFR
15-24	42.667	0.426
25-34	107.143	1.071
35-44	171.875	1.719
45-49	28.571	0.143
		Total = 3.36 children per woman

d) To calculate the completed fertility rate for women aged 50, we would perform the same calculation as we did for TFR, but we would use the age-specific fertility rate applicable at the time. So, for the years when our 50 year old was 25-34, we would use the age-specific fertility rate for 25-34 year olds that existed at that time, not the ASFR for today's 25-34 year olds.

e) Assuming that the sex ratio at birth is 1.05 for all ages of mother, the proportion newborns that are female is 100/205 or 0.487805. Multiply this number by the TFR to get a Gross Reproduction Rate of 1.64 female children per woman.

2. TFR was similar in 2001 and 2004, but in 2001, the average age of a mother was increasing more rapidly than in 2004. This means that 2001's tempo-adjusted TFR is going to be higher than 2004's adjusted TFR. Indeed, 2001's tempo-adjusted TFR is 2.46 compared to 1.79 in 2004.

Exercises: Chapter 12

1. Poverty could limit opportunity to procreate by forcing men to migrate in search of employment. Poverty could limit the ability to procreate if women are too malnourished and overworked to carry an infant to term. Poverty could encourage couples to have children if there is no other way for them to survive in old age than to rely on children.

2. A fertility trap occurs when a person who has delayed having children finds themselves unable to have their intended number of children. This may be because of aging, break-up of a partnership, career, or other factors. At the level of society, an era in which small families are the norm may lead to changes in social norms, institutional arrangements, and the mix of goods and services that are available that will discourage fertility despite the government wanting to encourage fertility.

3. Secularization usually means that men and women are allowed to mingle more freely, increasing opportunities for procreation. Secularization usually means that the idea of limiting family size becomes more acceptable. Secularization also encourages a focus on self-realization which may be at odds with caring for children. Finally, secularization makes it more likely that various forms of birth control are more accessible, and that people have received sex education.

4. Higher income people could have fewer children without children being "inferior goods" if children are part of a "childrearing" package as Willis described. In this configuration, childrearing is a normal good, but parents prefer to spend more per child than have more children. Another explanation is that, in poor areas, children may confer some material benefits which wealthier people do not need to consider. Also, in poorer areas, children are less likely to survive to adulthood, so desired fertility is higher.

5. In the context of demand theory, with children providing non-material benefits to parents, if there is a parent that is not interested in spending time caring for children, and whose role is to provide financial support, that parent's wage has only an income effect on the household. The higher that wage, the richer the household feels, and the more they will spend on children, assuming that children are normal "goods". It is also more likely that the household will have additional children. When that wage declines, less will be spent on children, and it is less likely that the household will have additional children.

Exercises: Chapter 13

1. Implementing a policy to reduce unplanned fertility is not a violation of human rights if you do not use coercion, deception, or callous manipulation. In this case, the people involved would agree with the goal; they probably don't want unplanned fertility either. If you wish to reduce fertility among first-year university students, you should focus on them, and possibly those who have responsibility for them, such as dormitory supervisors and health care providers at the university.

The margin is a sexual encounter. Is it the first sexual encounter for most people who end up conceiving accidentally? If so, we should target people who are virgins, encouraging them to postpone and to plan the first sex act. If most accidental conceptions occur in people who are already sexually active, then we should find a way to prevent most sexually active people from engaging in unprotected sex.

Why is contraception not being used? What is the binding constraint, the immediate reason that protection is not being used? Is it hassle, embarrassment, expense, drunkenness, something else? Perhaps it is failure-to-plan-ahead, so that at the time of sex, finding contraception becomes a hassle. It then makes sense to make contraception such as condoms more readily available, in public bathrooms, for example. There is however the possibility that distributing with condoms will have the unintended effect of increasing unplanned fertility by promoting sexual activity.

2a) an increased day-care subsidy may please the mother, who may like to use some day-care or be using some day-care already, but child-care expense is unlikely to be the binding constraint for a wealthy stay-at-home mom. Not likely to affect fertility.

b) If the lack of parental leave is a reason this woman stayed home, the improved parental leave makes working and childbearing less incompatible. If she is harbouring a desire to go back to work eventually, she may no longer consider that desire an impediment to having more children. This might increase fertility.

c) Cash-for-care will make her feel better about staying home; however, money is not her binding constraint.

d) Same as c).

e) Same as b)

f) This may tempt the woman back to the workforce; the rising average wage makes it less likely she will have an additional child.

3. This plan discriminates against boys; presumably the government would only offer it if it believed boy babies would continue to be wanted. The policy is targeted directly at what the government wants to achieve: more daughters relative to sons. It is only relevant to those rural couples now limited to two children, i.e. non-minority couples. This idea is applied at the correct margin: rural couples who already have one daughter are the couples most likely to reject an additional daughter. Rural poverty was significant in China in the early 1980s, so if having more land means more money or more to eat, this policy targets a binding constraint; however, the family may figure that more land is useless without boys to farm it. If the family can sell or rent the land, they will benefit from owning it; however, if they have usage privileges only, they may need to hire

men to do the farm work. If men are hired to do the farm work, there will be some upward pressure on the material value of boys which reverses the effects of the program to some degree.

Exercises: Chapter 14

1a).. The population projection matrix **A** that could be used to describe the mechanics of this population of gerbils is

0	2.5	1.5
0.3	0	0
0	0.5556	0

1b) If, initally, there are 100 gerbils age 0, and no other gerbils, then next year the age vector will be:

n(t+1) =

0
30
0

for a total of 30 gerbils (all age 1).

2. **n**(t+1) = **A** **n**(t) resulting in **n**(t+1) =

620
40
48

Showing all the steps, the first row is 2(100) + 4(80) + 2 (50) = 620

second row is 0.4(100) + 0(80) +0(50) = 40

And the third row is 0(100) + 0.6(80) + 0(50) = 48

3. We know the intrinsic rate of population growth (-5% in case 1, and 5% in case 2). We also know the

survival probabilities: a 40% chance of living until age 1, and a 40% x 60% = 24% chance of making it until age 2.

Case 1: population decline at 5%.

Let the number of newborns in a year when the age mix has stabilized be NN. The number of newborns the year before was 5% higher, NN $e^{0.05}$ Of this number, only 40% survived, making the number of one-year-olds equal to 0.4 NN $e^{0.05}$ this year. The number of two-year-olds this year should be 0.6 * 0.4 * NN $e^{0.1}$ since two years have gone by since they were born (0.1 = 0.05 x 2).

There are NN newborns, .42 as many one-year-olds, and .265 as many two-year-olds. Let NN + 0.42NN + 0.265NN = 1, then NN = .59 i.e 59% of the population. One-year-olds make up 25% of the population, and two-year-olds make up 16% of the population.

Case 2: population growth at 5%

The math is the same, except that the exponents are negative. Total population of 1 would be made up of NN, 0.38 NN one-year-olds, and 0.217 NN two-year-olds. So 63% of the population is newborn, 24% are one-year-olds, and 13% are two-year-olds.

We do not see a large difference in the population mix. The growing population has more newborns and fewer two-year-olds. It has slightly fewer one-year-olds as well.

4. In a stable population, all age groups increase or decrease at the same rate. Hence the population of newborns will be growing at 2%.

5a). The most fertile gerbils are less than two years old. Currently, the age mix has a greater proportion of these most fertile gerbils. We can conclude that population momentum is positive.

5b). Population will grow before it achieves its stationary size.

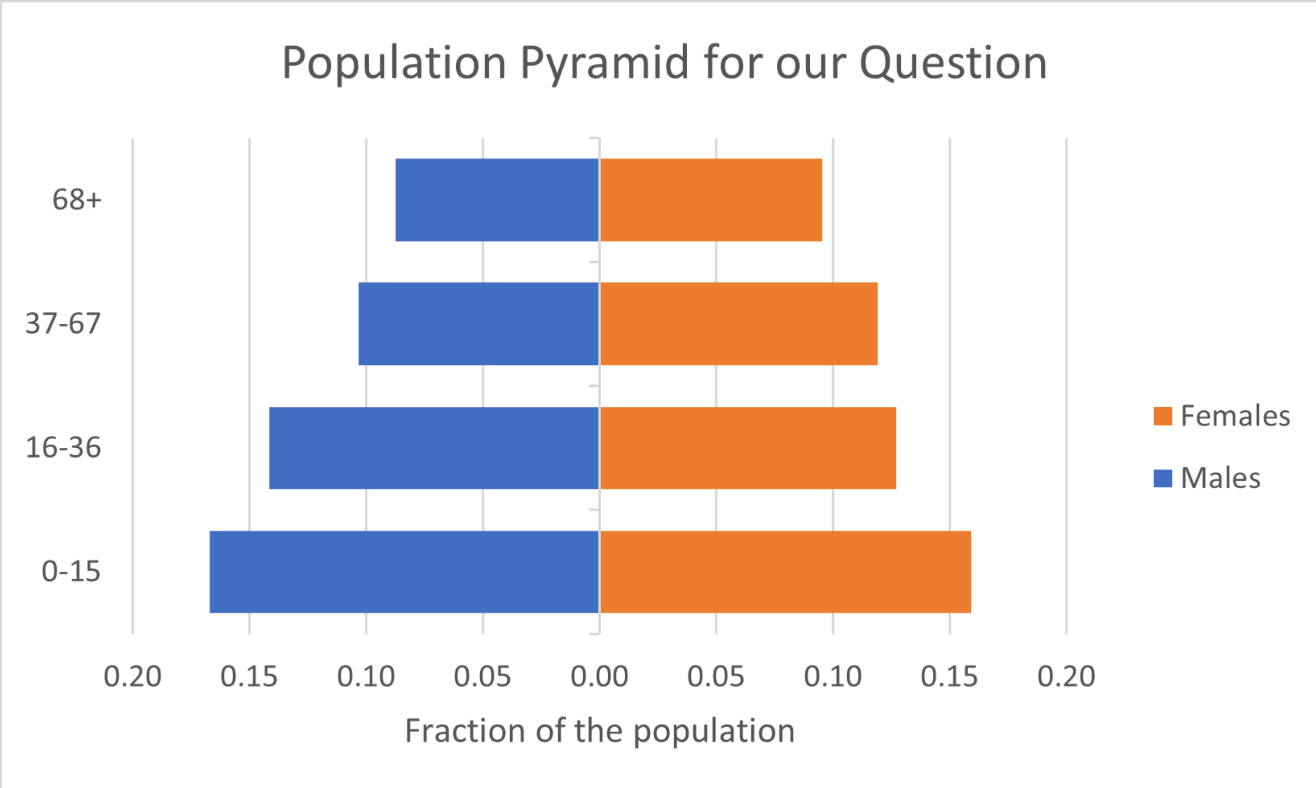
5c). Immigration or emigration will alter the stationary population size, not hasten its achievement. Achievement of the stationary population **age mix** could be hastened by the emigration of part of the child-bearing cohort and/or part of the child cohort, since these otherwise will only decrease (as a proportion of the population) in size gradually.

6. The population momentum of these polar bears is 800/1000 = 0.8, indicating that the population will shrink. The cohorts about to achieve reproductive age are smaller than the current reproducing cohort. In real life there could be other explanations such as pollution or habitat loss.

7. When population momentum is increasing, the current age structure is becoming more and more different from the stationary age structure. The age structure is becoming less and less conducive to zero population growth: the child-bearing cohort is growing in size.

Exercises: Chapter 15

1.



2. Defining age 0-15 as childhood, we find that the Child Dependency Ratio = 205/309 = 0.66, where 309 = 169+140. Eyeballing it we see that children are about 17% of the overall population and people between 16 and 67 are about 24%, which gives us a rough ratio of 17/24 = .71, not too far from the more accurate 0.66. Meanwhile, ADR = 115/309 = 0.37. The total dependency ratio TDR = (205+115)/309 = 1.04. There are 104 people under the age of 16 or over the age of 67 for every 100 people aged 16-67.
3. Check to see Canada's current CDR and ADR, but note that CDR in this case does NOT mean Crude Death Rate. Also note that Canada's CDR and ADR may be defined using slightly different age groups.
4. The total dependency ratio here is very high. The fact that most dependents are kids suggest an early stage of Demographic Transition, but a substantial portion of the population is senior, suggesting a developed economy. Could there have been something that wreaked havoc among the working age population, such as the AIDS pandemic of the 1990s?
5. The sex ratios of each age group, from youngest to oldest, are 1.05, 1.13, 0.87, and 0.91. The 1.05 is approximately the sex ratio at birth and we usually expect it to fall as the children grow, so that the sex ratio for kids 1-15 years of age should be lower than 1.05. There may be some discrimination against girls and there is definitely something that favours young men if the sex ratio rises to 1.13 for young adults! It may be that the childbearing years are very dangerous for women. Thereafter, however, the sex

ratio plunges indicating past or present dangers to this cohort of men. The sex ratio then recovers a bit for the elders, suggesting that men who have survived their middle years fare better than senior women.

6. If 20% of people between 16 and 36 years of age are addicted to heavy drugs, we should remove them from the denominator of the dependency ratios. The effective dependency ratio will be (205 elders +115 kids)/{0.8(169 young adults) + 140 middle-aged} = 1.16.

Exercises: Chapter 16

1. The United States' greater GDP per person may be due to a number of things highlighted in Equation 16.1

    - First, workers may be more productive in terms of output per hour. This is true. The OECD reports that in 2021, GDP per hour worked was indexed at 108 in the US and 105 in Canada. This could be because of higher efficiency A and/or because of more capital per worker. Indeed, American companies have easier access to loans, invest more in R&D, and have better equipment, typically, than Canadian companies. Canadian companies are usually smaller and thus enjoy fewer economies of scale.
    - Second, Americans may work more hours. Again, this is true, as many Canadians work seasonally. In 2021, the average American worker worked 1791 hours compared to 1685 in Canada, according to the OECD.
    - Finally, Americans may have a greater fraction of their population working, either because they have a greater fraction of their population at working age (no) , because they have higher labour force participation rates (no), or because they have lower unemployment rates (yes). It is difficult to determine whether Americans have a greater fraction of their population working does does not exist because the two nations have different definitions of what constitutes being "employed."

2. Immigration may affect Canada's GDP in the following ways.

    - First, there may be a change in output per hour. Immigrants may bring new energy, organization, and knowledge which improve efficiency. Immigrants might also bring enough capital with them to preserve the current capital:labour ratio, but this is unlikely. The capital:labour ratio will likely fall in the short term. The overall effect on productivity could be an increase or a decrease.
    - Second, there may be a change in hours worked per worker. The immigrants may work more hours than other residents, though a significant fraction of the work may not be recorded and counted as GDP. Hours worked will likely rise.

- Third, if immigrants are more likely than other residents to be working age, if they intend to work, and if they can find jobs, there will be an increase in the fraction of the population that works. This, together with the increase in hours worked, could raise GDP per person if the overall effect on productivity is not too detrimental.

3. A prolonged period of high interest rates makes it expensive for a growing population to accumulate the capital its growing workforce requires. It also makes housing, which young families need, difficult to finance. Young people are more likely to borrow than save, so the high interest rates are a burden to them. Though populations with a high rate of child dependency find it difficult to save, at least what they do save will earn a high rate of return. With both high interest rates and a growing population, both kinds of pensions will do well, and the current workforce will not have to pay as much towards pensions.

Exercises: Chapter 17

1. A baby boom cannot immediately yield a demographic dividend. It will take some time for these babies to reach working age. In the meantime, they may push the country back into something like Stage Three of the Demographic Transition, where the population is growing and the child dependency ratio is increasing.
For Canada's current baby boom to yield a demographic dividend eventually, the babies must receive good healthcare and education, so that they will be productive in the workforce. As they approach working age, the business environment must be conducive to expansion of business to employ these new workers, and investment in new capital to equip these workers. In particular, loans must be available at reasonable rates of interest.

The parents of the babies must receive good healthcare so as to reduce their future dependency as seniors, and they should be encouraged to save for their retirements. When the babies are of working age, they must have money to save left over after caring for their children; ditto for the government. The saved money should be invested in things that will improve the productive capacity of the economy.

2. An aging population means that the standard of living is so high, and health care is so advanced, that people are surviving to old age. It is an indicator of economic development. Elders are a source of knowledge. They are often beloved family members and friends. While they may not have the vigour to be in the labour force, they often perform volunteer work in the family or community. Their savings, and the savings of younger people anticipating retirement, are a source of loanable funds for the economy.

3. Aging affects GDP per capita by affecting productivity, hours worked, and dependency. Productivity may be reduced by elders' lessened ability to learn new things and their possibly diminished interest in trends and new inventions; on the other hand, they have experience and institutional knowledge. Hours worked may be reduced as strength and stamina diminish. In terms of dependency, elders eventually become unable to

stay in the workforce. On the whole, tends to reduce GDP per capita; however, there are many other non-demographic factors which help determined GDP per capita.

4. "Net debt" in this chapter is the difference between a government's debt and the present value of the money it can expect to raise in net taxes from the people currently alive. The greater the fraction of elderly in the population, the less the amount of net taxes the government can expect to collect from people currently alive. The greater the fraction of elderly in the population, the more the spending needs of the government and so the more debt they are likely to have taken on. Thus aging increases net debt in two ways; however, aging is only one factor in a government's spending policy or tax policy. An aging population saves more and helps create a low-interest rate environment, making it more likely that some of this debt is owed to the aging population itself.

5. How can a nation prepare for rising aged dependency? We can reduce the likelihood that an older person is dependent on the state and we can improve the productive capacity of the economy. In terms of making older people less dependent, we should keep our population as healthy as possible, encourage elders to remain in the workforce if possible, encourage employers to accept older workers, encourage workers to save for old age, and build up pension and other elder assistance funds for the future. We can also reduce the amount of social assistance given to high-income seniors. In terms of boosting the productive capacity of our economy, we can promote capital accumulation and skills development, encourage and equip people all adults to join and stay in the workforce, invest in research and development, and foster trade relationships.

Exercises: Chapter 18

1. The Solow model assumes

- technological change is possible but is not presently occurring
- only one output is produced
- both labour and physical capital are necessary to production
- output which is saved can produce physical capital
- everyone works
- constant returns to scale
- diminishing marginal returns

2. In the Solow model, the rate of growth of population, n, directly affects steady state capital per worker. As n increases, there is capital shallowing, and the steady state capital:labour ratio falls. "n" can also affect the steady state indirectly if it affects efficiency (A) or savings (s). If n causes efficiency to increase, then the steady state level of output per worker will be higher than otherwise. If n causes savings to decrease, then the steady state level of output per worker will be lower than otherwise.

3. Hartwick's Rule is that nations should save some of the money earned from the extraction of non

renewable resources. They should save the profit on the last ton mined, multiplied by the total amount mined that year. In this way they will have money to invest in different forms of capital as they deplete their natural capital.

Hartwick's Rule has been criticized by those who note that at some point, physical capital or other forms of capital will not be able to make up for a declining amount of natural resource capital. Therefore investing resource rents is no guarantee of a sustainable economy.

4.Total Hotelling Rent is $800,000,000.

5a) Genuine savings is 9.0 percent of GNI.

b) This country seems to have its act together. It is investing almost 16% of GNI in physical capital plus spending 5% on education. Its capital stock is depreciating rapidly – perhaps in the past it could only afford shoddy construction and less-than-cutting edge tools that become obsolete quickly. It is a user of forest resources, but they are not badly exploited. Pollution doesn't seem very bad. This country is obviously not an oil exporter, since Total Hotelling Rent was negligible.

In fact this country is Costa Rica (in 2008).

Exercises: Chapter 19

1. There are many possible answers. I am going to describe a village in the remote Arctic.

Since the village is so far away from other communities, trade with other communities is expensive. For example, fresh vegetables may be prohibitively expensive to import. A larger population would mean that more things could be supplied locally. With a sufficient population size, someone in the community will find it worthwhile to invest in greenhouses and soil enhancement to grow fresh vegetables. With a sufficient number of customers, they may be able to achieve internal economies of scale and a cost of production that makes these vegetables affordable.

2a) There are many vendors on the internet which means that people with specialized interests and talents can find buyers for their niche goods and services. Etsy.com is one website offering an endless variety of handmade goods, even a 1/12 scale model of a 1/12 scale folding paper dollhouse published in Germany more than fifty years ago.

2b) The market for flea ointments like AdvantageTM and RevolutionTM is more competitive now that you don't have to buy them from your local veterinarian but can go online to order them from as far away as Switzerland.

2c) Not only are innovators encouraged by the prospect of innumerable customers on the internet, but there exist websites which channel start-up and research funds to innovators. Wherever they live, innovators can be connected to venture capitalists and angel investors around the world.

3. In a large, dense population, there will be enough fans to support professional athletes, and enough

people wanting soccer lessons for their kids to support professional soccer instructors. People can make a living specializing in the game of soccer, as athletes, coaches, referees, and suppliers.

In a large, dense population it will be easy to find a soccer club or soccer field or soccer game near you in time or space. This is an example of thick markets.

Only large cities will be able to afford to have their own professional soccer team and build a stadium, because they can spread the cost over so many fans. This is an example of internal economies of scale.

In large cities , or particular soccer capitals of the world, soccer specialists will come together to plan events, lobby governments, and scout for talent. This is an example of external economies of scale.

Innovations in soccer shoe design, ball design, and game strategy are more likely to happen where a lot of soccer is being played and watched and where new ways of doing things can be tried, tested, noticed, advertised, and marketed.

Exercises: Chapter 20

1.

	July 1, 2009	**July 1, 2010**	**July 1, '09-July 1, '10**
Canadian population	33,739,900	34,108,800	
Change in population			*368,900*
Mid-year population			*33,924,350*
Births			381,382
Deaths			247,556
Natural Increase			*133,826*
Net Migration			*235,074*
Net Migration Rate			*6.9 per 1000*
Migration Ratio			*1.76*

2. The migration ratio for this nation will be: 0.4 ΔN / 0.6 ΔN = 0.4/0.6 = 0.67.

3. Applying survival rates to the number of newborns, there should be 19,834 males and 19,000 females in the population today. Based on how many males and females there actually are, we can estimate that there has been net immigration of 100 females and net emigration of 834 males over the course of this cohort's first 15 years of life.

4. An early retirement package for people who cannot be terminated from their union-protected or tenure-

protected jobs may be most attractive to those who are doing well in their careers and who can easily find work elsewhere.

5. Unigeniture means that second sons inherit less wealth. They therefore have to take bolder measures, such as emigration, to build wealth. If second and subsequent sons inherit no land, they are less tied to place and more likely to emigrate. Villages who have experienced high emigration in the past have connections to relatives and friends who have emigrated and who can provide information and support for any others who wish to follow their footsteps. Villages with fewer factories presumably have lower levels of economic development, so emigration in search of economic opportunities is more likely. Villages where there are many religious minorities might be expected to be more tolerant and thus to have less emigration per religious minority member. However, religious minorities are more likely to emigrate than non-minorities, in order to find greater freedom to worship, so it is not surprising that villages with a large number of minorities experience greater emigration.

6. An immigrant who poses least economic threat to the nation's automobile assembly workers is an immigrant

- who does not intend to work in the automobile industry unless it is to supply a skill which is in short supply
- who intends to work in an industry which is complementary to the automobile industry
- who has a large amount of cash he/she wishes to invest in that nation's automobile industry
- who has a good marketable idea to improve worker productivity
- who has few dependents and little need for government subsidies such as health care and language training.

7. A large group of unskilled, poor, illiterate refugees arrives in your city. To make sure that all residents benefit economically, the government should

- subsidize language training using local providers
- subsidize other life skills needed using local providers
- subsidize job search training for all residents, using local providers
- make sure employers have the loans needed to expand operations and employment
- attract suitable employers to the city
- liase with leaders of this ethnic group who already live in the city or nearby. They will probably have good advice and job connections
- knowing that local wages for unskilled workers are likely to be affected, offer wage insurance for a period of time, temporarily expand its welfare offerings, or reduce utilities costs and taxes for low income households.

8. If our nation has a shortage of doctors, we can

– expand our medical schools and admit more medical students

– pay doctors more, or reduce their workload, so that more people will want to be doctors, and so that more doctors will stay in our nation

– substitute some doctor care with telephone services, nurse practitioners, or other things

– increase immigration of doctors

– help immigrant doctors become part of our medical system

9. If you want to know whether patrolling the border makes economic sense, you need to know what would happen if the border were not patrolled. Presumably, illegal immigration would surge and the decrease in labour market surplus would be much larger than what is was initially. Hanson does not have enough information to conclude that the border should not be patrolled.

Exercises: Chapter 21

1. It appears that illegal immigrants are more likely to have a net positive effect on GDP than legal immigrants because they contribute to GDP without qualifying for many government services. This assumes that the work they do is actually recorded in GDP, instead of being "under-the-table". Illegal immigrants are less likely to bring kids or elderly parents with them, with the result that government money is not diverted to caring for these dependents and can be used instead to build up the productive capacity of the economy. Illegal immigrants also tend to come and go as needed, and come to the specific sectors which have job vacancies. They do not collect unemployment insurance benefits.

We might argue that in the long run, the maintenance of a second-class category of workers has a corroding effect on our social conscience, and builds a grey zone where criminal behaviour can hide. We could also wonder whether the depressing effect of illegal migrants on the real wage of low-skilled workers is offset by productivity gains or falling prices for goods and services. Or does it keep many native-born workers in poverty?

2. In the 1990s, Canada began to increase the proportion of immigrants from the skilled worker class. However, this policy failed to alleviate poverty among immigrants. Apparently, skill had not been the binding constraint preventing immigrants from achieving well-paying jobs. Other barriers, such as experience, language, racism, and a need for Canadian credentials, were binding.

3. The city may have little say in the nation's international immigration policy, but it could focus on being attractive to immigrants once they have been accepted, and on being attractive to citizens in other parts of the nation. In order to be attractive the city needs to offer a high expected real wage. This can be done in several ways:

-increasing the probability of finding employment by assisting with job search

-stimulating businesses by providing good infrastructure and reducing red tape

-providing sizable unemployment benefits
-reducing the cost-of-living by providing good infrastructure, other public goods, reducing taxes

Exercises: Chapter 22

	Temporary Foreign Workers in Canada today	Indenture	Serfdom	Slavery
Migrate freely?	Yes, but may be misinformed.	May not be willing but obligated.	Serfs unable to migrate. Unwillingly confined to a property.	May have been duped. Once enslaved, no freedom of movement.
Family life, choice of employer?	No	No	May raise a family. No choice of employer.	No
Unpleasant work?	Typically	Typically	Not necessarily	Typically
Permanent condition?	No	No	Yes	Yes

2. Although western Africa was land-rich, and not labour-abundant, its agriculture, mining, and domestic markets were not well-developed. There was little capital or investment. Consequently, it would be profitable to sell people to other land-rich countries which had more developed markets and in which the slaves could be forced to work intensely. However, much of the slave trade was involuntary, with economically more powerful countries forcing the compliance of local authorities in the trafficking of people, or taking advantage of a lack of local governance to steal people away.

3. Polygyny is less likely in an urban environment. Children, and wives who do not work in the marketplace, are of less pecuniary benefit in cities, since they can no longer work the land. The cost-of-living is higher in the city, making it more difficult to support dependants. Theoretically, one's wives could be earning money in the workplace, which would make having multiple wives financially beneficial; however, this would give the wives exposure to other views and possibilities, making it less likely they will tolerate polygyny.

4. In an open-ended question like this, make sure to stick to concepts and terms discussed in this course. Take time to collect your thoughts. Here is a sample answer.

The push-and-pull factors which lead to the victimization of these girls should be identified. Is there any chance the parents do not know who these employers really are? Lack of information may be the problem. You can provide documentation. On the other hand, "outing" these families may lead to the village closing protectively around them against you, the foreigner, or may lead to suicide of those involved. Proceed discretely.

Poverty is probably the constraint that prevents parents from resisting the “employers” and their offers. Lack of respect for women or human rights could be another factor. Economists such as ourselves are trained to address the poverty. Perhaps you, with your foreign connections, can bring employment to this area, and alleviate the poverty of parents. Perhaps you can bring education, and increase formal sector employment opportunities for the girls. Simply cutting off the “employers” will not lead to the girls and their siblings being well fed and properly educated; it could even lead to the girls starving or being killed.

Exercises: Chapter 23

1. Although there were twice as many marriages as divorces this year, we cannot conclude that 50% of marriages end in divorce. There may have been very many more marriages in previous years, of which the 5 d this year represent only a tiny fraction. The marriage rate this year may be low because the underlying population has few people who have never yet been married.

Other possible differences in age structure and marriage patterns could be possible, so that the actual divorce rate is higher or lower than 50% of ever-married couples.

2. In Canada today, relatively few households include grandparents. Grandparents may be relatively independent or the opposite. When they are independent, they can help their adult children with domestic chores and childcare. If quality, affordable daycare is more available outside the home than previously, there will be less incentive or need to have grandparents live with the family. It’s possible that with low interest rates in recent decades, fewer adult children need the grandparents to help them afford a home. And with grandparents being, on average, healthier and wealthier than ever before, fewer may need or desire to live with their children.

The economic consequences of independent seniors living on their own would include more resources allocated to housing, and more senior participation in the labour force and in the community, though less senior participation in the lives of families with young children.

To the extent that grandparents are in need of financial assistance or support with daily living, the fact that fewer live with their children may have something to do with the economy, for example increased participation of their children in the workforce. The opportunity cost to spend time at home caring for parents is higher as the real wage rises, though the real wage hasn’t been doing a lot of that in North America in recent decades. Improved pensions and government assistance to seniors is another explanation.

The economic consequences of needy seniors living on their own would include more taxpayer resources being allocated to supporting seniors, either in their own homes or in long term care facilities.

Exercises: Chapter 24

The following answers are suggestive, not exhaustive.

1a) The mechanization of agriculture will release men from agricultural tasks. It will be less critical to have a large number of sons to work the farm, easing son preference. Bride price should also fall in areas where women work on the farm.

The productivity of the farm and the value of the land will likely rise. This means that more could be given to the bride upon marriage. Both groom price and bridge price could rise.

The mechanization of agriculture will require more ready cash to pay for equipment and fuel. Family members may search for work in other sectors. Exposure to new ideas and opportunities in town may reduce son preference. Groom price may ease if life becomes less precarious. Groom price might rise if income variability leads to different socioeconomic classes competing for the upper class men.

b) Reductions in infant mortality improve the viability of male children, likely leading to a lower target number of sons. Eventually, the increasing availability of men could help reduce groom price or increase bride price, but there are many other things which influence groom price and bride price.

c) We saw in chapter 22 that child labour is not very productive, so the absence of children from the farm may not affect productivity very much; in fact, it may the caregiving parent, typically the reproductive mother, to get more done. On the other hand, once educated, more of the children will take a non-traditional life path. We know that the young women will be less likely to immediately marry and have children of their own, and families will become smaller. The young men may choose alternative careers where they have enough money to send back home to the farm.

Son preference may wane as the family anticipates a mix of careers, and learns that daughters too have career potential.

With education, life and employment become less precarious; this may ease son preference and groom price. Bride price may have to rise if more women are rejecting traditional roles.

Exercises: Chapter 25

1. In the Malthusian flowchart, institutions could show up in between the standard of living and the birth rate or the death rate, showing that institutions are significant in either changing the standard of living (through taxes or transfers, perhaps), or controlling births. Institutions could show up in between the population growth rate and the standard of living, showing that the degree of pressure that population growth puts on resources is moderated by institutional arrangements that protect the environment. Institutions could be shown to be developed when there is an increase in the standard of living, and they could promote innovation and consequently increase the standard of living in a virtuous cycle. Other answers are possible.

2. In the Boserup-Simon flowchart, institutions could show up in the same places described in the answer

to question 1. Additionally, “Innovation” could be placed within a box called “Institutions”, showing that the degree of innovation depends on institutional arrangements. “Rising prices” could be placed within a box called “Market and Property Arrangements”, showing that prices will only rise to register scarcity if resources are marketed and if resource extraction is costly/regulated rather than open access. Other answers are possible.

3. The role of family is different in Chapter 25’s Indigenous model compared to the Clark model. In the Indigenous model presented, particularly the medicine bowl formulation, the achievement of peaceful family life is one of the pillars of well-being. The standard of living cannot grow unless families are peaceful and well. This includes all families. The Clark model agrees that family is important to the standard of living, but only those families which have certain characteristics. These characteristics (literacy, numeracy, thrift, and hard work) are conducive to innovation and important for survival. What matters for the economy is that these characteristics are inherited and become more and more dominant in the population due to these kinds of families having more surviving children than other families.

So in Clark’s model, “upper class” families are important as a means to an end, whereas in the Indigenous model, all families are important as one of the quadrants of the medicine bowl.

4. What might a complete breakdown of family do to any of these models? A complete breakdown of the family

- might reduce the birth rate and increase the death rate at any level of the standard of living
- might exacerbate the effects of population growth on the standard of living
- would empty the medicine bowl and lead to the lowest possible level of wellbeing in the Indigenous model
- might encourage the rapacity described by the Ehrlich model
- might discourage the transfer of literacy, numeracy, thrift, and hard work within the Clark model

Other answers are possible.

References:

1. Abeysinghe, T. (1993), "Time cost, relative income and fertility in Canada", *Journal of Population Economics*, 6, pp. 189-198.
2. Abramitsky, R. , L.P. Boustan and L.P.. Eriksson (2012). "Europe's tired, poor, huddled masses: self-selection and economic outcomes in the age of mass migration", *American Economic Review*, 102(5).
3. Acemoglu, Daron and James A. Robinson (2012). *Why Nations Fail: The origins of power, prosperity, and poverty*. New York: Currency.
4. Ailes, E. (2020). "'Covid ended our marriage': The couples who split in the pandemic," *BBC World Services*. Retrieved from: https://www.bbc.com/news/world-55146909
5. Akee, R. & Feir, D. (2016). "Excess mortality, institutionalization and homelessness among Status Indians in Canada", *IZA Institute of Labor Economics Discussion Paper* No. 10416.
6. Akee, R. & Feir, D. (Feb. 2018). First People lost: determining the state of Status First Nations mortality in Canada using administrative data. *Discussion Paper DDP1802*, University of Victoria.
7. Ambert, A. M. (2005). "Cohabitation and Marriage: How are they related?", *The Vanier Institute of the Family*. Retrieved from: http://www.vifamily.ca/library/cft/cohabitation.html
8. Amir, H., Yaish, I., Oren, A., Groutz, A., Greenman, Y., Azem, F. (2020). "Fertility preservation rates among transgender women compared with transgender men receiving comprehensive fertility counselling", *Reproductive BioMedicine Online*, 41(3), pp. 546-554.
9. Anderson, S. (2003). "Why dowry payments declined with modernization in Europe but are rising in India", *Journal of Political Economy* 111(2), pp. 269-310.
10. Andre, C.M.C. (2006). "The effects of traditional family and gender ideology on earnings: race and gender differences", *Journal of Fertility and Economic Issues*, 27(1), pp. 48-71.
11. Appleman, Laura (2021). "Hiding in plain sight: public health, eugenics, and COVID-19", *HPHR,* 30. DOI:10.54111/0001/DD22
12. Arends-Kuenning, Mary, Kathy Baylis and Rafael Garduño-Rivera (2019). "The effect of NAFTA on internal migration in Mexico: a regional economic analysis", *Applied Economics*, 51(10), pp. 1052-1068, doi: 10.1080/00036846.2018.1524976
13. Arias, Elizabeth, Betzaida Tejada-Vera, Farida Ahmad, and Kenneth D. Kochanek (July 2021). "Provisional Life Expectancy Estimates for 2020", *Vital Statistics Rapid Release*. National Centre for Health Statistics.
14. Associated Press (2021). "US population rises to 331,449,281, Census Bureau says", *US Census Bureau/*

US News.

15. Auerbach, A. J., Gokhale, J. and Kotlikoff, L. J. (1994). "Generational Accounting: a meaningful way to evaluate fiscal policy", *Journal of Economic Perspectives*, 8(1), pp. 73-94.
16. Bartash, J. (Aug. 7, 2020). "The U.S. has only regained 42% of the 22 million jobs lost in the pandemic. Here's where they are", *Market Watch,* Bureau of Labour Statistics (United States).
17. Bast, E. (2018). "Economics and the Transgender Community", *Regional Economic Studies Institute,* Engage Towson University.
18. Becker, G.S. (1960). "An economic analysis of fertility", in Becker, G.S. (ed.) *Demographic and Economic Change in Developed Countries*. Princeton: Princeton University Press.
19. Becker, G.S. (1981). *Treatise on the family*. Chicago: University of Chicago Press.
20. Bertrand, Marianne, Claudia Goldin, and Lawrence F. Katz (2010). "Dynamics of the gender gap for young professionals in the financial and corporate sectors", *American Economic Journal: Applied Economics*, 2(3), pp. 228–255.
21. Bezruchka, S. (2009). "The effect of economic recession on population health 2009," *Canadian Medical Association Journal,* 181(5).
22. Bhat, P.N., Halli, M. & Halli, S.S. (1999). "Demography of brideprice and dowry: causes and consequences of the Indian marriage squeeze", *Population Studies,* 53, pp. 129-148.
23. BIVF (2018). "Lesbian IVF and egg donorship costs", *Boston IVF*. Retrieved from: http://www.gayivf.com/family-building-for-lesbians/costs-and-insurance.cfm
24. Bloom, D.E., Canning, D. & J. Sevilla (2003). *The Demographic Dividend: a new perspective on the economic consequences of population change.* Santa Monica, California: RAND.
25. Boldrin, Michele, Larry E. Jones and Aubhik Khan (October 2005). "Three equations generating an Industrial Revolution", *Ideas.RePEc.org* https://www.researchgate.net/publication/4821119_Three_Equations_Generating_an_Industrial_Revolution
26. Borjas, G.J. (1999). *Heaven's door: immigration policy and the American economy*. Princeton: Princeton University Press.
27. Boserup, E. (1965). *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Oxfordshire: Routledge.
28. Bushnik, T., Tjepkema, M. & Martel, L. (2018). Health-Adjusted Life Expectancy in Canada*. Statistics Canada*. Retrieved from: https://www150.statcan.gc.ca/n1/pub/82-003-x/2018004/article/54950-eng.htm
29. BW (Feb. 10, 2020). "Lockdown love: pandemic has aged the average relationship four years", *Business Wire*. Retrieved from:
30. Cahuc, P., Carcillo, S. & Zylberberg, A. (2004). *Labor economics*. 2nd Edition. Cambridge, Massachusetts: Massachusetts Institute of Technology Press.
31. Canadian Council for Refugees, 2000. A hundred years of immigration in Canada 1900-1999. A hundred years of immigration to Canada 1900 – 1999 | Canadian Council for Refugees (ccrweb.ca)

32. Canadian Institute for Health Information, 2019. "National Health Expenditure Trends 1975 – 2019," *NHE Database*.
33. Canadian Institute for Health Information, 2022. "National Health Expenditure Trends, 2020: Data Tables — Series E1".
34. Cardus Associated Authors (August 2022), "The Canadian Marriage Map," *Cardus*. The Canadian Marriage Map | Cardus
35. Case, Anne, and Angus Deaton (2015), "Rising morbidity and mortality in midlife among White non-Hispanic Americans in the 21st century," *PNAS* 11(49).
36. Caspari, R. (2011). "The evolution of grandparents", *Scientific American*, 305(2).
37. CCR (2011). "A hundred years of immigration to Canada 1900-1999". Canadian Council for Refugees.
38. CDC (Oct. 1, 1999). "Achievements in public health, 1900-1999: healthier mothers and babies", *Morbidity and Mortality Weekly Report,* Centers for Disease Control and Prevention.
39. CDF (2005). *A plan for growth and prosperity*. Ottawa: Canada Department of Finance.
40. Chastko, Karl (July 14, 2021). "Internal Migration: Overview, 2016/2017 to 2018/9", *Report on the Demographic Situation in Canada*. Ottawa: Statistics Canada.
41. Central Intelligence Agency(various years) – See CIA.
42. Chen, Wen-Hao and Feng Hou (February 2019). "Intergenerational educational mobility and labour market outcomes: variation among the second generation of immigrants in Canada", *Analytical Studies Branch Research Paper Series*, Statistics Canada.
43. Chen, Y. (January 7, 2021). "Ministry of Civil Affairs Modifies Divorce Registration Procedures – China Legal News", *China Justice Observer.*
44. Cheng, P.J., Pastuszak, A.W., Myers, J.B., Goodwin, I.A., & Hotaling, J. M. (2019). "Fertility concerns of the transgender patient", *Transl Androl Urol. Journal* 8(3), pp. 209–218.
45. Chesnais, J. C. (1992). *The demographic transition: stages, patterns, and economic implications: a longitudinal study of sixty-seven countries covering the period 1720-1984*. Oxford: Oxford University Press.
46. Chetty R, Stepner M, Abraham S, et al. (2016), "The Association Between Income and Life Expectancy in the United States, 2001-2014" [published correction appears in *JAMA* 2017 317(1) p. 90]. *JAMA* 315(16):1750-1766. doi:10.1001/jama.2016.4226
47. Chin, F. (April 29, 2020). "Marriage licences and registrations plummet across Canada during COVID-19 pandemic Social Sharing". Ottawa: CBC Radio.
48. CIA (2011). "The world and its regions", *The World Factbook.* https://www.cia.gov
49. CIA (2020). "Demographics: Total Fertility Rate, Canada in historical data graphs per year", *CIA World Factbook*.
50. CIA (2021) . See CIA (2011).
51. CIC (2011). "Temporary Foreign Workers – the full story", *Citizenship and Immigration Canada*, e-

newsletter [Summer].

52. CIHI (2016). “National health expenditure trends, 1975-2016 – quarterly administrative data release”, Canadian Institute for Health Information, Citizenship and Immigration Canada.
53. Cipolla, C. M. (1994). *Before the Industrial Revolution: European society and economy 1000-1700.* 3rd edition. New York City: W.W. Norton & Company.
54. Clark, G. (2007). *A Farewell to Alms: a brief economic history of the world*. Princeton, New Jersey: Princeton University Press.
55. Clark, G. & Hamilton, G. (2007). *Economic Status and Reproductive Success in New France*. Montreal: McGill University Press.
56. Coale, A. (1973), “The Demographic Transition”, in *Proceedings of the International Population Conference*, 1, pp. 53-72.
57. Coale, A. & Demeny, P. (1966). *Regional Model Life Tables and stable population*. Princeton, New Jersey: Princeton University Press.
58. Cohen, P. N. (2019). “The coming divorce decline”, *Socius*, 5. doi.org/10.1177/2378023119873497
59. Conroy, Shana and Danielle Sutton (June 9, 2022). “Trafficking in persons in Canada”, Statistics Canada.
60. Corak, M. (2008). *The immigrant baby bonus and the socio-economic progress of second-generation Canadians*. Montreal: Institute for Research on Public Policy.
61. Corbett, Stephen & Courtiol, Alexandre & Lummaa, Virpi & Moorad, Jacob & Stearns, Stephen (2018). “The transition to modernity and chronic disease: mismatch and natural selection”, *Nature Reviews Genetics,* 19.
62. Cowen, T., Clark, G., DeLong, B. (Oct. 18, 2007). “Forum on Gregory Clarks ‘A Farewell to Alms'”, *CHSC Seminar*, University of California.
63. Cox (1970). Reference needed. Please contact author.
64. CRRC (2020). The Global Girlhood Report 2020: How COVID-19 is putting progress in peril. London: *Save the Children International – Child Rights Resource Centre.*
65. Cruz-Cano, R. and Mead, E.L. (July 2019). “Causes of excess deaths in Puerto Rico after Hurricane Maria: a time-series estimation”, *American Journal of Public Heath*, 109(7), pp.1050-1052.
66. Daly, Herman (1990). “Commentary: Towards some operational principles of sustainable development”, *Ecological Economics*, 2, pp. 1-6.
67. Das Gupta, M. (2009). “Family systems, political systems, and Asia’s “missing girls”: the construction of son preference and its unraveling”, *World Bank Development Research Group*, Human Development and Public Services Team Research Working Paper 5148.
68. Das Gupta, M., Chung, W. & Shuzhuo, L. (2009). “Is there an incipient turnaround in Asia’s “Missing Girls” phenomenon?”, *World Bank Development Research Group*, Human Development and Public Services Team Policy Research Working Paper 4846.
69. Dehejia, R., Lleras-Muney A. (2004). “Booms, busts, and babies’ health”, *Quarterly Journal of*

Economics, 119, pp. 1091–130.

70. Denton, Frank T. and Byron G. Spencer (March 2019). "Effects of population aging on Gross Domestic Product per capita in the Canadian provinces: could productivity growth provide an offset?", *Canadian Public Policy*, 5(1), pp. 16-31. https://doi.org/10.3138/cpp.2018-003
71. Diamond, J. (1997). *Guns, germs, and steel: the fates of human societies*. New York City: W.W. Norton & Company.
72. Diamond, J. (2005). *Collapse: how societies choose to fail or succeed*. New York City: Viking Penguin.
73. Ding, Weili and Yuan Zhang (2014), "When a son is born: the impact of fertility patterns on family finance in rural China", *China Economic Review,* 30C, pp. 192-208.
74. Doctor NDTV (July 11, 2017). "World population day: how many children can a woman safely deliver?", *NDTV.com*
75. Domar, E. (1970). "The causes of slavery or serfdom: a hypothesis", *Journal of Economic History,* 30(1), pp. 18-32.
76. Douthat, Ross (Nov. 7, 2015). "The dying of the whites", *New York Times*.
77. Downie, Caitlin (2019). *LGBTQ2+ inclusivesness: toolkit for inclusiveness in Canadian municipalities and beyond.* Ottawa: Canadian Commission for UNESCO.
78. Drimie, S. (2004). A study to determine the links between HIV/Aids, current demographic status and livelihoods in rural Swaziland. *Swaziland Vulnerability Assessment Committee*.
79. Duncan, Karen A., Kristyn Frank, and Anne Guèvremont (Sept. 29, 2023). "Estimating expenditures on children by families in Canada, 2014-2017", *Analytical Studies Branch Research Paper Series, Statistics Canada.* https://www.doi.org/10.25318/11f0019m2023007-eng
80. Ehrenberg, R. G. & Smith, R. S. (2003). *Modern labor economics: theory and public policy*. 8th edition. Boston: Addison Wesley.
81. Ehrlich, P. (1968). *The population bomb*. New York City: Ballantine Books.
82. Eltis, D., Lewis, F., & Richardson D. (2004). "Slave Prices, the African slave trade and productivity in the Caribbean, 1674-1807. Paper presented at *Queen's University* [October 7].
83. Enke, S. (1960). "The economics of government payments to limit population", *Economic Development and Cultural Change* 8(4), part I: pp. 339-48.
84. Epstein, R. (2007). *The case against adolescence*. Fresno, CA: Quill Driver Books/Word Dancer Press, Inc.
85. The Economist (January 17, 2022), "The pandemic's true death toll: our daily estimate of excess deaths around the world."
86. Euromonitor International (March 14, 2014), "Economic growth and life expectancy – do wealthier countries live longer?"
87. Evans, M.L., Lindauer, M., & Farrell, M.E. (2020). "A Pandemic within a pandemic — intimate partner violence during Covid-19", *New England Journal of Medicine*, 383, pp. 2302-2304. Retrieved from: https://www.nejm.org/doi/full/10.1056/NEJMp2024046

88. Feeny, D., Furlong W., Torrance G.W. et al. (2002). "Multi-attribute and single-attribute utilities functions for the Health Utilities Index Mark 3 system", *Medical Care* 40(2), pp. 113-28.
89. Feng, X.T., Poston, D.L., & Wang, X.T. (2014). "China's One-child Policy and the changing family", *Journal of Comparative Family Studies* [Winter], 45(1), pp. 17-29.
90. Fenske, J. E. (2009). "Does land abundance explain African institutions?", *Economic Growth Center – Yale University* Discussion Paper No. 981.
91. Fogel, R.W. & Engerman, S. (1974). *Time on the cross: the economics of negro slavery*. Boston: Little, Brown and Company.
92. Fogel, R. W. (1992). Second thoughts on the European escape from hunger: famines, chronic malnutrition, and mortality rates", Chapter 9 in Osmani, S.R. (ed.) (1992) *Nutrition and poverty*. Oxford: Clarendon Press.
93. Gallo, L.C.; Troxel, W.M.; Matthews, K.A.; & Lewis, H. (2003). "Marital status and quality in middle-aged women: associations with levels and trajectories of cardiovascular risk factors", *Health Psychology* 22(5), pp. 453-463.
94. Gates, Gary J. (April 2011). "How many people are lesbian, gay, bisexual and transgender?", UCLA School of Law Williamson Institute.
95. GEO (2018). "Trans people in the UK – fact sheet", United Kingdom: Government Equalities Office.
96. Gladwell, M. (July 2, 2001). "The mosquito killer", *The New Yorker* , pp. 42-51.
97. Globe and Mail (2021): see Vanderklippe (2021).
98. Globe and Mail (2023): see Woolf (2023).
99. Glover, C., Gomez, C., Clementson, L. (March 2, 2020). "Why a lack of oversight of surrogacy in Canada leaves some parents feeling taken advantage of". Ottawa: CBC News.
100. GMI (June 9, 2021). "Surrogacy market revenue to cross USD 33.5B by 2027". Selbyville, Delaware: Global Market Insights Inc.
101. Goldin, Claudia, and Lawrence F. Katz (2002). "The power of the pill: oral contraceptives and women's career and marriage decisions",*Journal of Political Economy* 110(4), pp. 730-770.
102. Golubev, A.G. (2019). "Where does the preston curve lead us?" *Adv Gerontol* 9, pp. 115–125. https://doi.org/10.1134/S2079057019020103
103. Goodman, M. & Noah Adams, Trevor Corneil, Baudewijntje Kreukels, Joz Motmans, and Eli Coleman (2019). "Size and distribution of transgender and gender nonconforming populations: a narrative review", *Endocrinology and Metabolism Clinics of North America* 48(2), pp. 303-321. https://doi.org/10.1016/j.ecl.2019.01.001.
104. Government Equities Office, United Kingdom (2018), "Trans people in the UK".
105. Government of India (2001). Census of India "Provisional Population Totals", Chapter 6, Statement 19, Series 1.
106. Graunt, John (1662). *Natural and political observations, mentioned in a following index, and made upon the bills of mortality*. London : Thomas Roycroft, for John Martin, James Allestry, and Thomas

Dicas.

107. GT (April 14, 2020). "Wuhan sees divorce rate soar after lockdown is lifted". Beijing: Global Times.
108. GWR (2021). "Most prolific mother ever", in *Guinness World Records*.
109. Hageman, A. and P. Galoustian (2021). *Economics of the Indigenous experience in Canada*. Kingston, Ontario: Queen's University, https://ecampusontario.pressbooks.pub/indigenouseconomics244/
110. Hanson, G. H. (2007). The economic logic of illegal immigration. *Council on Foreign Relations CSR*, [April], No. 26.
111. Hanson, G. H. (2009). *The economics and policy of illegal immigration in the United States*. Washington, D.C.: Migration Policy Institute.
112. Harkness, S. & Waldfogel, J. (1999). "The family gap in pay: evidence from seven industrialized countries", *Centre for Analysis of Social Exclusion*, London School of Economics [November] Paper 29.
113. Hartwick, J. M. (1977). "Intergenerational equity and the investing of rents from exhaustible resources", *American Economic Review* 67, pp. 972-974.
114. Haub, C. (2002). "How many people have ever lived on Earth?", *Population Reference Bureau*.
115. Hesketh, T., & Xing, Z. W. (2006). "Abnormal sex ratios in human populations: causes and consequences", *Proceedings of the National Academy of Sciences of the United States of America* [September], 103(36), pp. 13271-5.
116. Hollingsworth. T. H. (1969). *The population of Egypt 664 BC – AC 1966*. Ithaca, New York: Cornell University Press.
117. Hong, Lily Toy (1991). *How the Ox Star fell from Heaven*. Morton Grove, Illinois: Albert Whitman & Company.
118. HRSDC (2011). "Family life – age of mother at childbirth", *Indicators of Well-Being in Canada*, Human Resources and Skills Development Canada.
119. Hunt, T. L. & Lipo, C. P. (2006). "Late colonization of Easter Island", *Science* [March], 311(5767), pp. 1603-1606.
120. Hvistendahl, M. (2011). *Unnatural selection: choosing boys over girls, and the consequences of a world full of men*. New York City: *PublicAffairs*.
121. Hymowitz, K. (2006). *Marriage and caste in America: separate and unequal families in a post-marital age*. Chicago, Illinois: Ivan R. Dee Publisher.
122. ICCAR (2019). LGBTQ inclusiveness – toolkit for inclusive municipalities in Canada and beyond. *Canadian Commission for UNESCO,* UN, ICCAR.
123. IGLA (2019). "Sexual orientation laws in the world – map". The International Lesbian, Gay, Bisexual, Trans and Intersex Association.
124. Institut de la Statistique du Québec (March 3, 2021) "Press Release: life expectancy in Québec drops in 2020 after sharp increase in number of deaths".
125. International Justice Resource Centre (2019), "Forced sterilization of Indigenous women in Canada".
126. Jacobs, J. (1969). *The economy of cities*. New York City: Random House.

127. James, S. E., Herman, J. L., Rankin, S., Keisling, M., Mottet, L., & Anafi, M. (2016). *The Report of the 2015 U.S. Transgender Survey*. Washington, DC: National Center for Transgender Equality
128. Jiang, Q., Feldman, M.W. & Jin X. (2005). "Estimation of the number of missing females in China". Stanford University Morrison Institute for Population and Resource Studies.
129. Jiang, Q., Li, S., Feldman, M., & Sánchez-Barricarte, J. (2012). "Estimates of missing women in twentieth-century China", *Continuity and Change, 27*(3), 461-479. doi:10.1017/S0268416012000240
130. Jones, J.M. (2021). "LGBT identification rises to 5.6% in latest U.S. estimate." Washington, D.C.: Gallup Inc.
131. JRF (2017). *LGBT realities survey, 2017*. Montreal: Jasmine Roy Foundation, CISION.
132. Kannisto, V., Nieminen, M. & Turpeinen O. (1999). "Finnish Life Tables since 1751", *Demographic Research* 1(1).
133. Kapsalis, Constantine (2021). "Fiscal Impact of Recent Immigrants to Canada", *Canadian Public Policy* 47(2), pp. 170-179.
134. Kelley, A. C. (1988). "Economic consequences of population change in the Third World", *Journal of Economic Literature* , 26, pp. 1685-1728.
135. Kelton, Stephanie (2020). *The Deficit Myth: Modern Monetary Theory and the birth of the people's economy*. New York City: PublicAffairs Books.
136. Kershaw, Paul (March 11, 2023). "Boomers didn't live within their means – and younger generations will pay the price", *Globe and Mail.*
137. Keyfitz, N. & Caswell, H. (2005). *Applied mathematical demography.* Third edition. Luxembourg: Springer Science & Business Media Inc.
138. Kimmerer, Robin Wall (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge, and the teachings of plants*. Minneapolis: Milkweed Editions.
139. Klobucista, Claire and Diana Roy (June 8, 2023). *U.S. temporary foreign worker visa programs*. New York City: Council on Foreign Relations, https://www.cfr.org/.
140. Kögel, T. (2006). "Swedish family policy, fertility and female Wages", Discussion Paper WP 2006-7, Loughborough University, United Kingdom.
141. Kolata, G. (August 12, 2007). "The Myth, the Math, the Sex", *New York Times Week*.
142. Kukreja, Reena (2022). *Why would I be married here? Marriage migration and dispossession in neoliberal India*. Ithaca, New York: Cornell University Press.
143. Kumon, Y. (2021). "Wealth inequality in pre-industrial rural England", Working Paper, Institute for Advanced Study in Toulouse.
144. Lee, E.S. (1966). "A Theory of Migration", *Demography*, 3(1), pp. 47-57.
145. Lee, R. (2001). "Externalities to childbearing", *International Encyclopedia of the Social and Behavioural Sciences* 3, pp. 1686-9
146. Lee, R. (2003). "The Demographic Transition: three centuries of fundamental change", *Journal of Economic Perspectives* 17(4), pp. 167-90.

147. Lee, R. & Miller T. (1990). "Population growth, externalities to childbearing, and fertility policy in the Third World", in *Proceedings of the World Bank Annual Conference on Development Economics, The World Bank Economic Review and World Bank Research Observer*, pp. 275-304. Oxford: Oxford University Press.
148. Li, Haiming and Xiuli Zhang (2015). "Population aging and economic growth", *International Journal of Economics and Finance*, 7(3), pp. 199-205.
149. Li, Shuzhuo & Jiang, Quanbao & Feldman, Marcus & Jin, Xiaoyi. (July 15, 2005). "Estimation of the number of missing females in China: 1900-2000", ResearchGate Working Paper.
150. Lillard, L.A. & Panis C.W.A. (1996). "Marital status and mortality: the role of health", *Demography* 33(3), pp. 313-327.
151. Lombard, A. & Shaheen-Hussain, S. (March 8, 2021). "Coerced and forced sterilization of Indigenous women and girls: This is what genocide looks like in Canada",*Toronto Star*.
152. Lu, Yuqian (June 3, 2020). "The distribution of Temporary Foreign Workers across industries in Canada", Statistics Canada, catalog no. 45280001.
153. Malthus, T. R. (1798). "An essay on the principle of population as it affects the future improvement of society" in Simon, J. (ed.) (1988) *The economics of population: classic writings*, *volumes 1-2*. Piscataway, New Jersey: Transaction Publishers.
154. Marshall, K. (2006). "Converging gender roles – perspectives on labour and income", Statistics Canada, Catalogue No. 75-001-XIE.
155. Mathers, C.D., Lopez, A.D. & C.J.L. Murray (2006). "The burden of disease and mortality by condition: data, methods, and results for 2001" in Lopez, A.D. (ed.) (2006) *Global Burden of Disease and Risk Factors*. Oxford: Oxford University Press.
156. McGrail, Kimberlyn (2022). "Excess mortality, COVID-19, and health care systems in Canada", CMAJ 194(21), pp. E741-E745. https://doi.org/10.1503/cmaj.220337
157. Milken Institute School of Public Health (MISPH) (2018). *Ascertainment of the estimated excess mortality from Hurricane Maria in Puerto Rico*. Washington, D.C.: The George Washington University.
158. Mitchell, Brian (ed.) (2013). *International historical statistics*. online at International Historical Statistics • European University Institute (eui.eu)
159. Moazzami, B. (2014). *Strengthening rural Canada: fewer and older – the coming demographic crisis in rural Ontario*. Toronto: Essential Skills Ontario.
160. Mocan, N. H. (1990). "Business cycles and fertility dynamics in the United States: a vector autoregressive model", *Population Economics* 3, pp. 125-146.
161. Morgan, S. & Cunningham, C. (2011). "Population aging and the determination of health care expenditures: the case of hospital, medical, and pharmaceutical care in British Columbia, 1996-2006", *Health Care Policy* 7(1), pp. 68-79.
162. Moser, Petra and San, Shmuel (March 21, 2020). "Immigration, science, and invention. Lessons from

the Quota Acts". http://dx.doi.org/10.2139/ssrn.3558718

163. Munro, J. (2004). "Before and after the Black Death: money, prices, and wages in fourteenth century England", University of Toronto Working Paper No. 24, UT-ECIPA-MUNRO-04-04.
164. Murray, C.J.L, Ahmad, O.B., Lopez A.D., & Salomon, J.A. (2003). "*WHO System of Model Life Tables",* GPE Discussion Paper Series No.8, World Health Organization.
165. Myrskyla, M., Kohler, H, & Billari F.C. (2009). "Advances in development reverse fertility declines", *Nature 460* [August], pp.741-743.
166. National Center for Health Statistics (July 21, 2021). "Life expectancy in the U.S. declined a year and half in 2020", press release of Centers for Disease Control and Prevention/National Center for Health Statistics.
167. NCTE (2015). See James et al. (2016).
168. Ndugwa, R.P., Ramroth, H., Muller, O., Jasseh, M., Sie, A., Kouyate, B.., Greenwood, B. & Heiko Becher (2008). "Comparison of all-cause and malaria-specific mortality from two West African countries with different malaria transmission patterns", *Malaria Journal*, 7(15).
169. NIDA (2021). "Italy's divorce rate shoots up by 60 percent during pandemic," *National Italy Divorce Association*. Retrieved from: https://scrambledeggsinglese.it/italys-divorce-rate-shoots-up-by-60-percent-during-pandemic/
170. Nordqvist, S., Sydsjö, G., Lampic, C., Åkerud, H., Elenis, E., Skoog Svanberg, A. (2014). "Sexual orientation of women does not affect outcome of fertility treatment with donated sperm", *Human Reproduction*, 29 (4), pp. 704–711.
171. Oberzaucher, E. & Grammar, K. (2014). "The case of Moulay Ismael – fact or fancy?" PLOS One. https://doi.org/10.1371/journal.pone.0085292
172. OECD (10/04/2019). "Development aid drops in 2018, especially to neediest countries", OECD Web Archive.
173. OECD (2019). *Society at a glance*. OECD iLibrary. https://doi.org/10.1787/19991290
174. OECD (2021). *Compendium of productivity indicators*. OECD iLibrary. https://doi.org/10.1787/22252126
175. Office for National Statistics, United Kingdom. Births, deaths and marriages – Office for National Statistics (ons.gov.uk)
176. Ogburn, William F. and Dorothy S. Thomas. 1922. "The influence of the business cycle on certain social conditions", *Journal of the American Statistical Association*, 18(139), pp. 324-40.
177. Omran, A. R. (1971). "The epidemiologic transition: a theory of the epidemiology of population change", *Milbank Memorial Fund Quarterly*, 49, p. 509.
178. ONS (2019). *Birth Characteristics in England and Wales: 2017*. United Kingdom: Office for National Statistics.
179. Oosthuizen, M. (2019). "Inequality and the generational economy: race-disaggregated National Transfer Accounts for South Africa, 2015", United Nations University World Institute for Development

Economics Research (WIDER) Working Paper 2019/24.

180. Pabst, Jennifer, Scott M. Walfield and Ryan Schacht (2022). "Patterning of sexual violence against women across US cities and counties", *Social Sciences*, 11(5), https://doi.org/10.3390/socsci11050208
181. Palen, J. J. (1986). "Fertility and eugenics: Singapore's population policies", *Population Research and Policy Review* 5, pp. 3-14.
182. Parr, J. (1980). *Labouring Children: British immigrant apprentices to Canada, 1869-1924*. Toronto: University of Toronto Press.
183. Passel, Jeffrey S. and Jens Manuel Krogstad (November 16, 2023). *What we know about unauthorized immigrants living in the U.S.* Washington, D.C.: Pew Research Center, https://www.pewresearch.org/
184. Pearce, F. (2010). *Peoplequake: Mass migration, ageing nations, and the coming population crash*. London: Transworld Publishers.
185. Peng, X. ed. (1991). *Demographic transition in China: fertility trends since the 1950s*. Oxford: Oxford University Press.
186. Pew Research Center (Oct 1, 2021). "A rising share of US adults are living without a spouse or partner", A rising share of U.S. adults are living without a spouse or partner | Pew Research Center
187. Philipov, D. & Sobotka T. (2006). *Estimating Tempo Effect and Adjusted TFR*. Wittgenstein Centre Vienna Institute of Demography, Austrian Academy of Sciences.
188. Picot, G., Hou, F. & Coulombe S. (January 2007). 'Chronic low income and low-income dynamics among recent immigrants", Statistics Canada.
189. Pinheiro, J. (2020). "Generational Accounting in Portugal: An assessment of long-term fiscal sustainability and intergenerational inequality", *Portuguese Economic Journal* 20, pp.181-221.
190. Pinker, S. (2011). *The Better Angels of our Nature*. New York City: Viking Publishing.
191. Provencher, C., Milan, A., Hallman, S., D'Aoust, C. (2018). "Report on the Demographic Situation in Canada Fertility: Overview, 2012 to 2016", in *Report on the Demographic Situation in Canada*, Statistics Canada.
192. Puckett, J.A. (April 26, 2021) "Trans youth are coming out and living in their gender much earlier than older generations", *The Conversation*, Michigan State University.
193. PULSE (2019). *Trans PULSE Canada Survey.* Trans Pulse Canada.
194. Raffelhüschen, B. (2001). "Aging, fiscal policy, and social insurance: a european perspective", in A.J. Auerbach and R.D. Lee (eds.) (2001) *Demographic Change and Fiscal Policy.* Cambridge University Press.
195. Rao, V. (2006). "The economics of dowries in India", in Kaushik Basu (ed.) (2007) *Oxford Companion to Economics*. Oxford: Oxford University Press.
196. Ratha, D. et al. (Oct. 16, 2019), "Data Release: Remittances to low- and middle-income countries on track to reach $551 billion in 2019 and $597 billion by 2021", *World Bank Blogs*.
197. Ravenstein, E.G. (1889). "The laws of migration", *Journal of the Royal Statistical Society*, LII [June], pp. 241-301.

198. RCMP (2004). "Human Trafficking", in RCMP (ed.) *Environmental scans*. Ottawa: Strategic Policy and Planning Branch, RCMP.
199. Reese, T. (2019). *Trans women and fertility: what we know, what we don't know, and what you can do.* New York: Family Equality Council.
200. Reinhardt, Uwe E. (March 28, 2014), "The dollar value of an extra year of life", *New York Times.*
201. RHO (June 3, 2019). *LGBTQ2 health in Canada: study brief for the Standing Committee on Health*. Toronto: Rainbow Health Ontario/Sherbourne Health.
202. Rosenfeld, M. J. & Roesler K. (Nov. 27, 2018). "Response to Arielle Kuperberg's 'Cohabitation and divorce: the importance of accounting for age at residence", *Council on Contemporary Families*. https://thesocietypages.org/ccf/2018/11/27/response-to-arielle-kuperberg-cohabitation-and-divorce-the-importance-of-accounting-for-age-at-coresidence./
203. Ross, D. P., Roberts, P. A., and Scott K. (1998). "Variations in child development outcomes among children living in lone-parent families", Human Resources Development Canada, Applied Research Branch, Strategic Policy Working Paper W-98-7E.
204. Rowland, D. T. (1996). "Population momentum as a measure of ageing", *European Journal of Population*, 12, pp. 41-61.
205. Rowland, D. T. (2003). *Demographic methods and concepts*. Oxford: Oxford University Press.
206. Sachs, J. D. (2005). *The end of poverty*. London: Penguin Press.
207. Salway Black, Sherry (1994), "Redefining success in community development: a new approach for determining and measuring the impact of development", Shramm Paper on Community Development. Boston: The Lincoln Filene Centre.
208. Saunders, D. (2017). *Maximum Canada: why 35 million Canadians are not enough*. Toronto: Penguin Random House.
209. Saunders, D. (Feb 8, 2020). "You can't fight anti-immigration politics with immigration policies," *The Globe and Mail.*
210. Savage, M. (2020). "Why the pandemic is causing spikes in break-ups and divorces", *BBC News*.
211. Schacht, Ryan, K.L. Rauch and M.B. Mulder (2014). "Too many men: the violence problem?", *Trends in Ecology and Evolution*, 29(4), pp. 214-222.
212. Schacht, Ryan, Douglas Tharp and Ken R. Smith (2016). "Marriage markets and male mating effort: violence and crime are elevated when men are rare", *Human Nature,* 27 pp. 489-500.
213. Sciubba, J. D. (Nov 11, 2022), "Eight billion people: a milestone by the numbers." Washington D.C.: Population Reference Bureau.
214. Schøne, P. (2005). "The effect of a family policy reform on mother's pay: a natural experiment approach", *Review of Economics of the Household*, 3, pp. 145-170.
215. Schoumaker, B. (2019). "Male fertility around the world and over time: how different is it from female fertility", *Population and Development Review*, 45(3), pp. 459-487.
216. Schultz, T. P. (2005). "Fertility and income", Economic Growth Centre Discussion Paper No. 925.

New Haven: Yale University.

217. Seifman, R. (March 25, 2021). "COVID-19 impacts on marriage and divorce", *Impakter.com.*

218. Simon, J. (1998). *The economics of population: classic writings, volumes I and II*. Piscataway, New Jersey: Transaction Publishers.

219. Solow, R. M. (1956). "A contribution to the theory of economic growth", *Quarterly Journal of Economics*, 70(1), pp. 65-94.

220. Solow, R. M. (1974). "Intergenerational equity and exhaustible resources", *Review of Economic Studies*, Symposium on the economics of exhaustible resources, 41: pp. 29-45.

221. Spizzirri, G., Eufrásio, R., Lima, M.C.P. et al. (2021)."Proportion of people identified as transgender and non-binary gender in Brazil", *Scientific Reports* 11, p. 2240 (2021). https://doi.org/10.1038/s41598-021-81411-4.

222. SSCHR (2019). *The Standing Senate Committee on Human Rights evidence*. Ottawa: Standing Senate Committee on Human Rights, Senate of Canada – Parliament of Canada.

223. SSCHR (2021). *Forced and coerced sterilization of persons in Canada*. Ottawa: Standing Senate Committee on Human Rights, Senate of Canada – Parliament of Canada.

224. Statistics Canada (2005). *Annual demographic statistics, 2005*. Catalogue no. 91-213-XIB. Ottawa: Government of Canada.

225. Statistics Canada (2006). *Canadian social trends.* Catalogue no. 11-008. Ottawa: Government of Canada.

226. Statistics Canada (2008). *Health indicators – 2007*. Catalogue no. 82-221. Ottawa: Government of Canada.

227. Statistics Canada (2009). *Mortality, summary list of causes, 2007*. Catalogue no. 84-0209x. Ottawa: Government of Canada.

228. Statistics Canada (Nov. 2009). *Report on the demographic situation in Canada, 2005, 2006, and 2008*. Catalogue no. 91-209-XWE. Ottawa: Government of Canada.

229. Statistics Canada (2012). *2006 Census: data products/topic-based tabulations*. Ottawa: Government of Canada.

230. Statistics Canada (2015). *Fifty years of families in Canada: 1961-2011*. Ottawa: Government of Canada.

231. Statistics Canada (2016). *Leading causes of death in Canada – 2008.* Catalogue no. 84-215 XWE. Ottawa: Government of Canada.

232. Statistics Canada (Jan. 2017). *Fathers Day by numbers – fathers in Canada*. Ottawa: Government of Canada.

233. Statistics Canada (April 2017). *Population projections for Canada (2013 to 2063), provinces and territories (2013 to 2038).* Ottawa: Government of Canada.

234. Statistics Canada (Sept. 29, 2017). "Study: Chronic low income among immigrants in Canada", *The Daily.* Ottawa: Government of Canada.

235. Statistics Canada (Oct. 25, 2017). *Immigration and ethnocultural diversity: key results from the 2016*

Census. Ottawa: Government of Canada.

236. Statistics Canada (Nov. 2017). *Census in brief: working seniors in Canada*. Ottawa: Government of Canada.
237. Statistics Canada (June 2018). Fertility: Overview, 2012-2016. *Report on the demographic situation in Canada.* Ottawa: Government of Canada.
238. Statistics Canada (July 23, 2018). *Fifty years of families in Canada*. Ottawa: Government of Canada.
239. Statistics Canada (Sept. 17, 2019). *Population projections for Canada (2018 to 2068), provinces and territories (2018 to 2043)*, Section 2. Ottawa: Government of Canada.
240. Statistics Canada (Oct. 8, 2019), *Coverage technical report, Census of Population, 2016,* Chapter 11. Ottawa: Government of Canada.
241. Statistics Canada (July 2020). *Sex at birth and gender: technical report on changes for the 2021 Census*. Ottawa: Government of Canada.
242. Statistics Canada (Dec. 2020). *Survey of financial security*. Ottawa: Government of Canada.
243. Statistics Canada (Feb. 2021). *Study: Family matters: parental leave in Canada*. Ottawa: Government of Canada.
244. Statistics Canada (June 15, 2021), "A statistical portrait of Canada's diverse LGBTQ2+ communities", *The Daily.* Ottawa: Government of Canada.
245. Statistics Canada (Sept 28 ,2021), "Contact with children after divorce or separation", *The Daily.* Ottawa: Government of Canada.
246. Statistics Canada (February 3, 2022), "Socioeconomic outcomes of immigrants admitted to Canada as children", *The Daily*. Ottawa: Government of Canada.
247. Statistics Canada (March 9, 2022), "A fifty-year look at divorces in Canada, 1970-2022", *The Daily*. Ottawa: Government of Canada.
248. Statistics Canada (April 27, 2022), "Canada is the first country to provide census data on transgender and non-binary people", *The Daily.* Ottawa: Government of Canada.
249. Statistics Canada (June 2022). *CIMM – undocumented populations – March 3, 2022.* Ottawa: Government of Canada.
250. Statistics Canada (June 22, 2022), "Immigration as a source of labour supply", *The Daily.* Ottawa: Government of Canada.
251. Statistics Canada (Sept. 7, 2022), "Tuition fees for degree programs, 2022/2023", *The Daily.* Ottawa: Government of Canada.
252. Statistics Canada (Nov. 9, 2022). Disaggregated trends in poverty from the 2021 Census of Population. Ottawa: Government of Canada.
253. Statistics Canada (Nov. 14, 2022), "I don't: historic decline in new marriages during the first year of the pandemic", *The Daily*. Ottawa: Government of Canada.
254. Statistics Canada (Aug. 2023). *Life expectancy and other elements of the complete Life Table, single-year estimates, all provinces except Prince Edward Island.* Table 13-10-0837-01. Ottawa: Government of

Canada.

255. Stevenson, B. & Wolfers J. (2007). "Marriage and divorce: changes and their driving forces", *Journal of Economic Perspectives* 21(2), pp. 27-52.
256. Stewart, D. E. & Gajic-Veljanoski, O. (2005). "Trafficking in women: the Canadian perspective", *Canadian Medical Association Journal*, 173 (1), pp. 25-26.
257. Sudharsanan, N., Didzun, O., Barnighausen, T., and P. Geldsetzer (July 22, 2020). "The contribution of the age distribution of cases to COVID-19 case fatality across countries: a 9-country demographic study", *Annals of Internal Medicine.* https://dx.doi.org/10.7326%2FM20-2973.
258. Tadman, M. (2008). "The demographic cost of sugar: debates on slave societies and natural increase in the Americas", *American Historical Review,* 105(5), pp. 1534-1575.
259. Tang, Jackie, Nora Galbraith and Johnny Truong (March 6, 2019). *Living alone in Canada.* Ottawa: Statistics Canada.
260. TASCC (2021). *LGBTQ2s+ definitions.* Calgary: Talking About Sexuality in Canadian Communities.
261. Thibodeau, L. (2015). "Suicide mortality in Canada and Quebec, 1926-2008: an age-period-cohort analysis", *Canadian Studies in Population* 42 (3-4), pp. 1-23.
262. Tjepkema, Michael, Tanya Christidis, Tracey Bushnik, and Lauren Pinault (Dec 18, 2019). *Cohort profile: the Canadian Census health and environment cohorts (CanCHECs).* Ottawa: Statistics Canada https://www.doi.org/10.25318/82-003-x201901200003-eng.
263. Trent, Katherine, Scott J. South and Sunita Bose (2015). "The consequences of India's male surplus for women's partnering and sexual experiences", *Journal of Family Issues*, 36(8), pp. 1062-1086.
264. Trosper, Ronald (2022). *Indigenous Economics: sustaining peoples and their lands*. Tucson: University of Arizona Press, 2022.
265. Turnbull, S. & Aiello, R. (2021). "MPs pass motion declaring genocide against Uighurs in China, despite cabinet abstentions". Toronto: CTV News.
266. TVO (2010). *David Foot: the interview*. Toronto: TVO The Agenda [March 28].
267. UCLA (2011). *How many people are lesbian, gay, bisexual, and transgender?* Los Angeles: UCLA Williamson Institute.
268. UN (1955). "Age and sex patterns of mortality: Model Life Tables for under-developed countries", *Population Studies* 22.
269. UN (1999). "Table 1: World population from year 0 to stabilization" of UN (1999)*The world at six billion.* New York City: United Nations Department of Economic and Social Affairs, Population Division.
270. UN (2008). *World population prospects: the 2008 revision*. New York City: United Nations Department of Economic and Social Affairs, Population Division.
271. UN (2010). *World population prospects: the 2010 revision*. New York City: United Nations Department of Economic and Social Affairs, Population Division.
272. UN (2019). *World population prospects 2019.* New York City: United Nations Department of

Economic and Social Affairs, Population Division.

273. UN (2020). *World population prospects 2019, highlights*. New York City: United Nations Department of Economic and Social Affairs, Population Division.
274. United States Department of State (2023). *2023 Trafficking in persons report.* Washington, D.C.: Office to Monitor and Combat Trafficking in Persons.
275. University of Michigan (2010). *Panel study of income dynamics, PSID 2007 Main Family Data public use dataset*. https://psidonline.isr.umich.edu/
276. Urquia, Marcelo L. et al. (June 2016). Sex ratios at birth after induced abortion. *Canadian Medical Association Journal*, 188(9), pp. E181-E190. https://doi.org/10.1503/cmaj.151074
277. USBC (2020). *International database: world population estimates and projections*. Suitland, Maryland.
278. USDS (2004). *Trafficking in persons report*. Washington, D.C.: Office to Monitor and Combat Trafficking in Persons, United States Department of State.
279. Vallin, J. et al. (2002). "A new estimate of Ukrainian population losses during the crises of the 1930s and 1940s", *Population Studies* 56(3), pp. 249-264.
280. van de Kaa, D. (1987). "Europe's second Demographic Transition", *Population Bulletin* 42(1), pp. 3-24.
281. van de Kaa, D. (2003). "Second Demographic Transition", in P. Demeny & G. NcNicoll (eds.)(2003) *Encyclopedia of population*. New York City: McMillan Reference USA.
282. Van Gaasbeck, Kristin, "Notes on the Golden Rule capital stock in the Solow Growth Model", Notes for Econ 100A, California State University, Sacramento. Downloaded 2022.
283. Vanderklippe, N. (Dec. 23, 2021). "US life expectancy declined in 2020 because of COVID-19." Toronto: The Globe and Mail.
284. Vanier Institute of the Family (VIF) (2017). *Family diversity in Canada: 2016 Census update*. Ottawa: The Vanier Institute of the Family.
285. Vienna Institute of Demography (VID) (2022). *European Demographic Datasheet 2022*. Vienna: Wittgenstein Centre, University of Vienna.
286. Wagner, B.G., Choi, K.H., and Cohen, P.N. (2020). "Decline in marriage associated with the COVID-19 pandemic in the United States", *Socius*, 6. https://doi.org/10.1177/2378023120980328
287. Ward, J.L. and R. M. Viner (2017), "The impact of income inequality and national wealth on child and adolescent mortality in low and middle-income countries", *BMC Public Health* 17, p. 429. https://doi.org/10.1186/s12889-017-4310-z
288. Ware, Kallistos (1995). *The Orthodox Way.* Revised edition. Chapter 3, p. 49. Crestwood, New York: St. Vladimir's Seminary Press.
289. WDI (2009). *World development indicators online*. Washington, DC: The World Bank.
290. Wee, S.L., & Chen E. (Feb. 27, 2021). "China tried to slow divorces by making couples wait. Instead, they rushed", *Wion News China*, originally in the New York Times.
291. Weeks, J. R. (1989). *Population: an introduction to concepts and issues.* Fourth edition. Belmont, California: Wadsworth Publishing Company.

292. Wegge, S. (Nov. 20, 2009). "Do migrant origins matter? Migrants vs. non-migrants: self-selection of migrants out of the home population," College of State Island and Graduate Center, City University of New York Working Paper.
293. WHO (2004). *The global burden of disease, 2004 update*. Geneva: World Health Organization.
294. WHO (2007). *Life Tables for WHO member states.* Geneva: WHO Statistics, World Health Organization.
295. WHO (2016). "Global health observatory data repository", in *Life Tables for WHO Member States*. Geneva: World Health Organization.
296. WHO (2019). "Life table for Canadian females 2019" in *Life Tables for WHO Member States*. Geneva: World Health Organization.
297. WHO (2021a). *One in 100 deaths is by suicide*. Geneva: World Health Organization.
298. WHO (2021b). "Suicide worldwide in 2019" in *Global Health Estimates*. Geneva: World Health Organization.
299. WHO (2022). "Global health observatory data repository", in *Life Tables for WHO Member States*. Geneva: World Health Organization.
300. Williamson, S. (2004). *Macroeconomics.* Second edition, chapter 8. Boston: Addison=Wesley.
301. Williamson Institute (WI) (2021). *LGBT proportion of population*. Los Angeles: UCLA.
302. Willis, R. J. (1973). "A new approach to the economic theory of fertility behavior", *Journal of Political Economy* 81(2, II). Retrieved from: https://www.journals.uchicago.edu/doi/abs/10.1086/260152
303. Wilson-Raybould, Jody (2022). *True reconciliation: how to be a force for change*. Toronto: McClelland and Stewart.
304. Withers, G. (1987). *The immigration contribution to human capital formation*. Australian National University Department of Economic History Working Paper No. 96 [September].
305. Wong, S.T., Homma, Y., Johnson, J.L., and Saewyc, E. (2010). "The unmet needs of East Asian high school students: are homestay students at risk?" *Canadian Journal of Public Health*, 101(3), pp. 241-245.
306. Wong, Theresa and Brenda S. A. Yeoh (2003), "Fertility and the family: an overview of pro-natalist population policies in Singapore," Asian MetaCentre Research Paper Series No. 12.
307. Woolf, Marie (Dec. 14, 2023). "Ottawa planning path to citizenship for undocumented immigrants", *The Globe and Mail.*
308. World Bank (2011). *The changing wealth of nations: measuring sustainable development in the new millenium*. Washington, DC.
309. World Bank (2014). *Purchasing power parities and the real size of world economies: a comprehensive report of the 2011 International Comparison Program*. Washington, DC.
310. World Health Organization – see WHO
311. World Population Review (WPR) (2011). *What percentage of the population is gay*? Walnut, California.
312. Wrigley, Edward A. (1985) "The fall of marital fertility in nineteenth-century France: exemplar or

exception?(Part I)", *European Journal of Population/Revue européenne de demographie,* 1985, pp. 31-60.

313. Wrigley E.A. & Scholfield, R.S. (1981). *The population history of England, 1541-1871: a reconstruction*. Cambridge, Massachusetts: Harvard University Press.
314. Ye, Xibao, Jenny Sutherland, Bonnie Henry, Mark Tyndall, Perry R.W. Kendall (2018), "At a glance – impact of drug overdose-related deaths on life expectancy at birth in British Columbia", Government of Canada. https://doi.org/10.24095/hpcdp.38.6.05
315. Zenz, Adrian. (2020). *Sterilizations, IUDs, and mandatory birth control: The CCP's campaign to suppress Uyghur birthrates in Xinjiang*. Washington, D.C.: The Jamestown Foundation.
316. Zhao, Z. & Guo F. (2007). *Transition and challenge: China's population at the beginning of the 21st century.* Oxford: Oxford University Press. Retrieved from: https://www.amazon.ca/Transition-Challenge-Population-Beginning-Century/dp/0199299293
317. Zimonjic, Peter (April 27, 2022), "Canada's working-age population is older than ever, StatsCan says", CBC News, www.cbc.ca
318. Zingel, A. (April 18, 2019). "Indigenous women come forward with accounts of forced sterilization, says lawyer". Ottawa: CBC News.
319. Zrill, L. (2007). Dost thou love thy neighbour? M.A. Essay written for Queen's University at Kingston, Ontario.

GLOSSARY

abortion

Abortion causes a fertilized egg to fail to implant in the uterus, or it causes an embryo or fetus to die.

abstinence

Abstinence means not having sexual relations with another person.

age-specific fertility rate

Age-specific fertility rates (ASFR) pertain to specific age groups. For example, the ASFR for 15-19 year-olds is the number of live births experienced by women ages 15-19 during the year, divided by the midyear population of women ages 15-19, all multiplied by 1000.

age-specific mortality rate

Age-specific mortality rates (ASMR) pertain to different age groups. For example, the mortality rate for 95-99 year-old women is the number of 95-99 year-olds who die during the year, divided by the midyear population of women ages 95-99, all multiplied by 1000.

Aged Dependency Ratio

The Aged Dependency Ratio is the number of people of retirement age divided by the number of people of working-age. The number of people of retirement age is typically taken to be people sixty-five years of age and older.

birth control

Birth control comprises many different ways to avoid having children, including abstinence, contraception, abortion, and sterilization.

birth rate

The birth rate is the number of live births during the year, divided by the midyear population, all multiplied by 1000.

Black-White Crossover Effect

The Black-White Crossover Effect is the phenomenon of Black people age x having more expected life years remaining than White people age x, for x>75 years of age

brain-drain

Brain-drain occurs when talented, wealthy, or otherwise useful citizens emigrate to another community or another country

bride price

Bride price is a payment from the man's family to the woman's family upon the occasion of their marriage

capital shallowing

In this text, capital shallowing refers to any decrease in the capital-to-labour ratio that is due to increases in the size of the labour force.

ceteris paribus

Ceteris paribus is a Latin phrase meaning "all other things being equal" or "holding everything else constant".

Child Dependency Ratio

See "Young Dependency Ratio".

chronic deaths

Chronic deaths are the result of usual conditions and include the usual incidence of endemic diseases like chicken pox, pneumonia, and stroke.

chronic living conditions

Chronic living conditions are everyday living conditions, with the usual risks of dying.

cohabitating

Cohabitation refers to adults living together in a sexual relationship without being legally married.

cohort

A cohort is a group of people born during the same time period, typically one year.

completed fertility rate

The completed fertility rate is the average number of children per woman, for women belonging to a particular cohort. It cannot be computed until the women have completed their childbearing years, typically assumed to be age 50. Thus, after 2025 we can compute the completed fertility rate for women born in 1975.

consumer surplus

Consumer surplus is the amount by which the amount paid by buyers falls short of what they would have been willing to pay. It is measured as the area between the Demand curve and the price or wage.

contraception

Contraception prevents sperm from fertilizing an ovum.

crisis deaths

Crisis deaths are deaths caused by unusual situations such as natural disasters and wars.

crude birth rate

The crude birth rate is the birth rate as defined above under "birth rate", without any adjustments having been made.

crude death rate

The crude death rate is the death rate as defined below under "death rate", without any adjustments having been made.

death rate

The death rate is the number of deaths in the population during the year, divided by the midyear population, all multiplied by 1000.

Demographic Dividend

The Demographic Dividend is the material benefits a society may reap when it has a low Total Dependency Ratio. See Chapters 16 and 17 for details.

Demographic Transition

The Demographic Transition is a process of change in birth and death rates. It is associated with industrialization and secularization. By the end of the Demographic Transition, birth and death rates are much lower than they were before the Demographic Transition

Demographic Trap

The Demographic Trap, illustrated in Figure 15-3, is a situation in which low educational achievement for women is correlated with high fertility. For details, see Chapter 15.

Domar's Hypothesis

See Chapter 22 for a traditional and a modern statement of Domar's Hypothesis.

doubling time

Doubling time is the length of time it takes for a population (or anything else) to double. It can be approximated by the formula 70/r, where r is the growth rate expressed as a percentage.

dowry

See groom price.

emigration

Emigration refers to people leaving a country. In a national context, the word "emigrant" is usually reserved for people leaving the country permanently.

Eugenics

Eugenics is a program of altering the human gene pool by encouraging some kinds of people to have children and some kinds of children to be born, predicated on the belief that genes are the most important thing about a person and that we can understand what the human gene pool needs to become

excess deaths

Deaths over and above the usual number of deaths are called "excess deaths". To find the number of excess deaths, we have to estimate the number of chronic deaths, i.e. how many deaths we would normally expect.

expected life years remaining

Expected life years remaining depends on a person's age. For a person age x, expected life years remaining is the number of additional years of life the average person age x can expect to experience, assuming that mortality rates do not change from today's levels

expected real wage

The expected real wage is the probability-weighted sum of the different possible after-tax real wages or incomes you might receive in a particular location.

external economies of scale

External economies of scale refers to the profits a firm can realize by being part of a group of similar firms located near one another.

fecundity

Fecundity is the physiological ability to conceive, have a successful pregnancy, and give birth.

fertility

Fertility refers to how many biological children people have. See Age-specific fertility rate, Completed fertility rate, General fertility rate, and Total fertility rate for some precise definitions.

fertility gap

The fertility gap is the difference in a cohort's self-professed intended fertility rate and their completed fertility rate.

Fertility Trap

The Fertility Trap is a situation where postponing or discouraging childbearing at one time makes having children more difficult later on, to a degree that was not anticipated.

fiscal

The word "fiscal" refers to government budgets. The net fiscal cost of an immigrant is the money the government spends on them and how much of the nation's shared infrastructure they use, minus the taxes the immigrant pays to the government.

fundamental equation of population growth

fundamental equation of population growth:
population growth during the year = number of people who were born - number of people who died + number of people who immigrated - number of people who emigrated

general fertility rate

The general fertility rate is the number of live births during the year, divided by the midyear population of women of child-bearing age, all multiplied by 1000.

generational account

A generational account for a person age x, evaluated in year y, is the present value (at year y) of all the taxes and all the transfers the average person age x will have to pay as time t progresses from date y to the end of the person's life. It is the net tax that a person age x owes from now on, measured in today's dollars.

Genuine Savings

Genuine Savings, also known as Adjusted Net Saving, is an estimate of changes to a nation's income-generating capacity. If Genuine Savings is positive, then the nation is building up its various forms of capital and its ability to earn income/produce output. If Genuine Savings is negative, then the nation is dissipating its capital and its ability to earn income. See Chapter 18 for the calculation.

groom price

Groom price is a payment from a woman's family to a man's family on the occasion of their marriage.

Gross Reproduction Rate

The Gross Reproduction Rate is the number of female babies the average woman can be expected to have, based on today's age-specific fertility rates and sex ratio at birth.

Health-Adjusted Life Expectancy

Health-Adjusted Life Expectancy at age x is expected life years remaining for the average person age x, adjusted for how healthy those life years will be.

Hispanic Paradox

This Hispanic Paradox refers to the fact that, in the United States, people of Hispanic origin live longer than "non-Hispanic Whites", even though they are, on average, lower-income than non-Hispanic Whites.

immigration

Immigration refers to people entering a country. In a national context, the word "immigrant" is usually reserved for people coming through legal channels, and coming to stay permanently.

income effect

The income effect of a wage change is the degree to which it causes people to feel wealthier and spend more on something.

indenture

Indenture is the state of being contracted to another person or a firm to work without pay for a specified period of time.

infant mortality

Infant mortality describes the age-specific mortality rate for babies during their first twelve months of life.

Intergenerational Fairness

Intergenerational fairness means treating different cohorts of people equitably. One definition of intergenerational fairness is that each cohort or each generation of people can expect the same net tax burden over their lifetime, i.e. the same generational account at birth.

internal economies of scale

Internal economies of scale refers to the profit a firm can earn by expanding its operations to the point where its average cost per unit produced is lowest.

intrinsic rate of natural increase

The intrinsic rate of natural increase is the population growth rate that will eventually emerge when fertility rates and mortality rates are unchanged for a sufficiently long time and there is no migration.

labour productivity

Labour productivity is a measure of how much output is produced per unit of labour. Labour units are usually hours worked.

Leslie matrix

A Leslie matrix contains fertility and survival information about a population. It is used mathematically to transform today's population count by age to next year's population count by age, assuming no migration.

life expectancy

Life expectancy refers to expected life years remaining for the average person age x. If age is not specified, life expectancy refers to expected life years remaining for the average newborn.

Life Table

The Life Table computes expected life years remaining for each age group using age-specific mortality rates. It assumes that age-specific mortality rates will not change.

migration

Migration refers to the movement of people from one place to another. See Emigration, Immigration, and Net Migration for more specific definitions.

minimum efficient scale

The minimum efficient scale for a firm is reached when the amount of output it produces coincides with its lowest average cost per unit.

model Life Tables

Model Life Tables are generalized Life Tables for a particular group of countries, based on their typical age-specific mortality rates.

mortality

Mortality refers to death. See Age-specific mortality, Crude death rate, Expected life years remaining, and Standardized death rate for more specific definitions.

natural increase

Natural increase is the number of births during a period of time, typically a year, minus the number of deaths during that same period of time.

net migration

Net migration is the number of immigrants during a period of time minus the number of emigrants during that same period of time.

net migration rate

The net migration rate is the number of immigrants (net of emigrants) during the year, divided by the midyear population, all multiplied by 1000. This number will be negative if there were more emigrants than immigrants.

Net Reproduction Rate

The Net Reproduction Rate is the the number of female children - who survive to their mother's age - that the average woman can be expected to have, given today's age-specific fertility rates, today's sex ratio, and today's age-specific mortality rates.

Paradox of the Life Table

The Paradox of the Life Table occurs whenever an older age group has a greater number of expected life years remaining than does a younger age group.

Pareto criterion

The Pareto criterion is one of the norms of Economics, though it is often ignored. It says that one situation cannot be preferred to another if someone will be made worse off. For a situation to be preferable, someone must be made better off and no one can be made worse off. Thus, for a new situation to be preferred to an existing situation, there must be enough gain available to compensate those who are hurt by the change, and the compensation must take place.

peasant

A peasant is a farmer without much social status who owns or rents a small area of land.

polygyny

Polygyny occurs when it is normal for men to be married to multiple women at the same time.

population momentum

Population momentum is the population growth or shrinkage due to existing cohorts of people surviving to childbearing age, with the number of people of childbearing age consequently growing or shrinking.

population pyramid

A population pyramid is a two-dimension object showing a population's age structure and its biological sex ratio at each age. For examples, see Chapter 15.

present value

The amount you would be willing to pay today for the privilege of receiving $x tomorrow will be some $y<$x. We say that this $y is the present value of $x. Generally, we calculate the present value of $x received t years from now to

be equal to $x divided by j, where j =(1+r) raised to the exponent t. "r" is the relevant interest rate. An additional adjustment can be made for inflation.

producer surplus

Producer surplus is the benefit received by workers or sellers over,-and-above the minimum they require to provide the service or good. It is calculated as the difference between the wage received and the lowest acceptable wage, for the entire quantity supplied at that wage.

real income

Real income is income divided by a price index. The price index measures the cost of living. Thus, your real income measures how much stuff you can buy with your income.

real wage

The real wage is the wage divided by a price index. The price index measures the cost of living. Thus your real wage measures the stuff you can buy for each hour worked.

remittances

Remittances are monies earned by citizens of country x who work abroad temporarily, or gifts of cash to citizens of country x by those who no longer live in country x.

replacement

Replacement exists when the average woman is expected to generate one or more female children by age x who will also survive to age x. A Total Fertility Rate of 2.1 children per woman is usually enough to guarantee replacement.

serfs

Serfs are legally bound to a piece of land and have obligations to work that land for the landlord.

sex ratio

The sex ratio has been defined only in binary terms and relies on official documents recording each person's sex. It is the number of males divided by the number of females. It is often expressed as the number of males for every 100 females.

stable

see "stable population"

stable population

A stable population is one where there is no migration, and fertility rates and mortality rates have been constant for enough time to make the birth and death rates constant also. With constant birth and death rates, the population growth rate is constant. The age structure is constant as well, with each age group growing at the same constant rate of population growth, known as the intrinsic rate of natural increase. In the special case of a stationary population, the population growth rate is zero.

standard of living

The standard of living measures how well off people are, materially speaking. It refers generally to the quantity and quality of food, housing, medical care, education, and recreation that they can afford.

standardized death rate

Death rates can be adjusted to account for differences in countries that might bias the crude death rate. A death rate is that is adjusted in this way is called a standardized death rate. Death rates can be standardized for age, sex, or other factors.

stationary population

A stationary population is a stable population that has its birth rate equal to its death rate. See "stable population".

sterilization

Sterilization renders someone incapable of having children. Two medical procedures that accomplish sterilization are tubal ligation (for biological women) and vasectomy (for biological men).

substitution effect

The substitution effect of a wage change is the degree to which it causes people to feel their time is more valuable. Due to the substitution effect, they will work more and cut back on leisure, child care, or other time-intensive activities.

tempo-adjusted TFR

Tempo-adjusted TFR is the Total Fertility Rate (TFR) adjusted for the fact that the average age of mothers is changing. The definition and a calculation can be found in Chapter 11.

Total Dependency Ratio

The Total Dependency Ratio is the number of people not of working age divided by the number of people of working age. It is typically calculated as the number of people under fifteen years of age or over sixty-five years of age, divided by the number of people ages 15-64.

Total Fertility Rate

The Total Fertility Rate is the number of biological children the average woman is expected to have during her lifetime. It is an estimate based on today's age-specific fertility rates.

Total Hotelling Rent

Total Hotelling Rent is equal to rent multiplied by quantity, where rent = price minus marginal cost on the last unit sold, and quantity is the total amount of resource extracted during the period.

Value of a Statistical Life

The Value of a Statistical Life (VSL) is a dollar value assigned to a statistical life saved or lost. A statistical life is the life of an unknown person who is a member of a large group of people who experience similar risks of dying. The VSL is calculated using people's willingness to pay for a reduced chance of dying.

Young Dependency Ratio

The Young Dependency Ratio is the number of people too young to work divided by the number of people of working-age. Typically, people too young to work are defined as being less than fifteen years old.