Paul Krugman, Robin Wells (2018). Macroeconomics (5th ed.). Worth Publishers. ISBN: 978-1319098759.
Pages:118-119, 344-347, 706

Graphs That Depict Numerical Information

Graphs can also be used as a convenient way to summarize and display data without assuming some underlying causal relationship. Graphs that simply display numerical information are called *numerical graphs*. Here we will consider four types of numerical graphs: *time-series graphs, scatter diagrams, pie charts*, and *bar graphs*. These are widely used to display real, empirical data about different economic variables because they often help economists and policy makers identify patterns or trends in the economy. But as we will also see, you must be aware of both the usefulness and the limitations of numerical graphs to avoid misinterpreting them or drawing unwarranted conclusions from them.

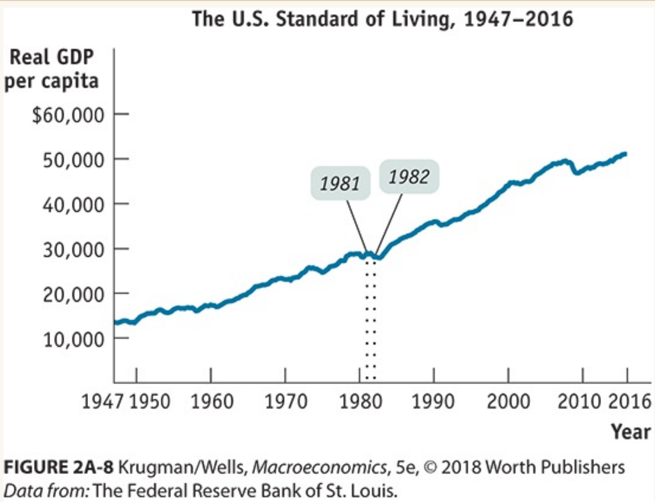
Types of Numerical Graphs

You have probably seen graphs that show what has happened over time to economic variables such as the unemployment rate or stock prices. A **time-series graph** has successive dates on the horizontal axis and the values of a variable that occurred on those dates on the vertical axis.

A **time-series graph** has dates on the horizontal axis and values of a variable that occurred on those dates on the vertical axis.

For example, Figure 2A-8 shows real gross domestic product (GDP) per capita—a rough measure of a country's standard of living—in the United States from 1947 to 2016. A line connecting the points that correspond to real GDP per capita for each calendar quarter during those years gives a clear idea of the overall trend in the standard of living over these years.

FIGURE 2A-8 Time-Series Graph



Time-series graphs show successive dates on the x-axis and values for a variable on the y-axis. This time-series graph shows real gross domestic product per capita, a measure of a country's standard of living, in the United States from 1947 to early 2016.

Figure 2A-9 is an example of a different kind of numerical graph. It represents information from a sample of 186 countries on the standard of living, again measured by GDP per capita, and the amount of carbon emissions per capita, a measure of environmental pollution. Each point here indicates an average resident's standard of living and his or her annual carbon emissions for a given country.

FIGURE 2A-9 Scatter Diagram

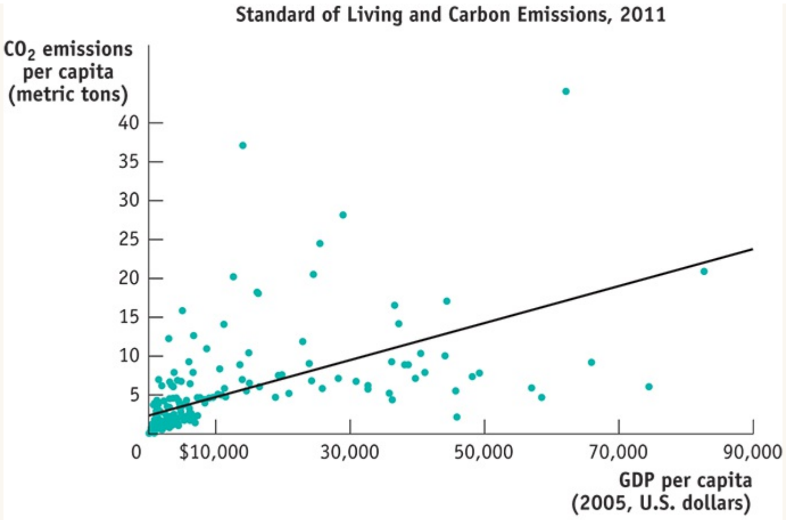


FIGURE 2A-9 Krugman/Wells, *Macroeconomics*, 5e, © 2018 Worth Publishers
Data from: World Development Indicators.

In a scatter diagram, each point represents the corresponding values of the x- and y-variables for a given observation. Here, each point indicates the GDP per capita and the amount of carbon emissions per capita for a given country for a sample of 186 countries. The upward-sloping fitted line here is the best approximation of the general relationship between the two variables.

The points lying in the upper right of the graph, which show combinations of a high standard of living and high carbon emissions, represent economically advanced countries such as the United States. (The country with the highest carbon emissions, at the top of the graph, is Qatar.) Points lying in the bottom left of the graph, which show combinations of a low standard of living and low carbon emissions, represent economically less advanced countries such as Afghanistan and Sierra Leone.

The pattern of points indicates that there is a positive relationship between living standard and carbon emissions per capita: on the whole, people create more pollution in countries with a higher standard of living.

This type of graph is called a **scatter diagram**, in which each point corresponds to an actual observation of the *x*-variable and the *y*-variable. In scatter diagrams, a curve is typically fitted to the scatter of points; that is, a curve is drawn that approximates as closely as possible the general relationship between the variables. As you can see, the fitted line in Figure 2A-9 is upward sloping, indicating the underlying positive relationship between the two variables. Scatter diagrams are often used to show how a general relationship can be inferred from a set of data.

A **scatter diagram** shows points that correspond to actual observations of the *x*- and *y*-variables. A curve is usually fitted to the scatter of points.

A **pie chart** shows the share of a total amount that is accounted for by various components, usually expressed in percentages. For example, Figure 2A-10 is a pie chart that depicts the education levels of workers who in 2015 were paid the federal minimum wage or less. As you can see, the majority of workers paid at or below the minimum wage had no college degree. Only 19% of workers who were paid at or below the minimum wage had a bachelor's degree or higher.

A **pie chart** shows how some total is divided among its components, usually expressed in percentages.

FIGURE 2A-10 Pie Chart

How large are the supplies of key natural resources?
How effective will technology be at finding alternatives to natural resources?
Can long-run economic growth continue in the face of resource scarcity?

It's mainly up to geologists to answer the first question. Unfortunately, there's wide disagreement among the experts, especially about the prospects for future oil production. Some analysts believe there is enough untapped oil in the ground for world oil production to continue to rise for several decades. Others, including a number of oil company executives, believe that the growing difficulty of finding new oil fields will cause oil production to stop growing and eventually begin a gradual decline in the fairly near future. Some analysts believe that we have already reached that point.

The answer to the second question, whether there are alternatives to natural resources, will come from engineers. However, there are already many alternative natural resources being exploited. Since 2005 there have been dramatic developments in energy production, with large amounts of previously unreachable oil and gas extracted through fracking, and with a huge decline in the cost of electricity generated by wind and solar power.

The third question, whether economies can continue to grow in the face of resource scarcity, is mainly a question for economists. And most, though not all, economists are optimistic. They believe that modern economies can find ways to work around limits on the supply of natural resources. One reason for this optimism is the fact that resource scarcity leads to high resource prices. These high prices, in turn, provide strong incentives to conserve the scarce resource and find alternatives. For example, after the sharp oil price increases of the 1970s, American consumers turned to smaller, more fuel-efficient cars as U.S. industry greatly intensified its efforts to reduce energy bills.

Given such responses to prices, economists generally tend to see resource scarcity as a problem that modern economies handle fairly well, and not as a fundamental limit to long-run economic growth. Environmental issues, however, pose a more difficult problem for economies because dealing with them requires effective political action.

Economic Growth and the Environment

Economic growth, other things equal, tends to increase the adverse impact of human activity on the environment, including an increase in pollution, the loss of wildlife habitats, the extinction of species, and reduced biodiversity. As we saw in this chapter's opening story, China's spectacular economic growth has also brought a spectacular increase in air pollution in its cities.

In analyzing economic growth and its environmental impact, it is useful to distinguish between *local* environmental degradation, which affects a geographically limited area, and *global* environmental degradation, which is far-reaching, with worldwide impact. As we'll see, it has proven to be far more difficult to address global environmental degradation and, in particular, the problem of *climate change*.

In fact, the improved air quality in the cities of today's advanced economies indicates that local environmental harm can be greatly reduced when there is sufficient political will and resources are devoted to finding a solution. Decades ago, before regulations virtually eliminated the use of coal heat, air pollution in London was so bad that it killed 4,000 people over two weeks in 1952. And as recounted in the opening story, the smog that once afflicted Los Angeles has disappeared thanks to regulations mandating cleaner-burning gasoline. In both of these cases, government intervention and expending some resources made everyone better off.

However, tackling climate change—a problem of global environmental degradation—has been a much harder problem to solve because policies must be implemented on a global scale, requiring the cooperation of many countries. There is broad scientific consensus that burning fossil fuels—coal, oil, and natural gas—leads to increasing levels of carbon dioxide in the atmosphere. Carbon dioxide is a type of *greenhouse gas*. Such gases trap the sun's energy, raising the planet's temperature, and lead to climate change, which, in turn, imposes high human, economic, and environmental costs. These costs include extreme weather, increased flooding, the disruption of agriculture, including crop failures, and more. A recent estimate put the cost of unmitigated climate change at 20% of world gross domestic product by 2100. Moreover, these costs tend to fall more heavily on poor countries.

The problem of climate change is linked to economic growth: the larger the economy, the more homes, factories, and vehicles, will have to be powered, typically by burning fossil fuels. At present, world energy consumption is overwhelmingly dependent upon fossil fuels, which account for 81.4% of total consumption, while clean, renewable sources account for only 2.6%. Why? Because historically, fossil fuels have been cheaper to use. Most of today's wealthy countries grew their economies through industrialization and the burning of fossil fuels over the last century. To reduce the global emission of greenhouse gases, developed countries and large rapidly developing countries, such as China and India, will have to undertake a transition from a heavy reliance on fossil fuels to greater use of clean, renewable energy sources such as wind and solar power. We refer to this process as the *great energy transition*.

Until recently, effective action against climate change had been stymied by disagreement among countries on how to pay the cost of shifting from fossil fuel to clean energy sources. As Figure 9-13 shows, today's wealthy economies have historically been responsible for most of the carbon dioxide emissions—and carbon dioxide alone accounts for almost 76% of all global greenhouse gas emissions. But newly emerging economies like China and India are responsible for the recent growth. Inevitably, rich countries are reluctant to pay the price of reducing emissions only to have their efforts frustrated by rapidly growing emissions from new players. But relatively poor countries like China and India consider it unfair that they should be expected to bear the burden of protecting an environment threatened by the past actions of rich nations.

FIGURE 9-13 Climate Change and Growth

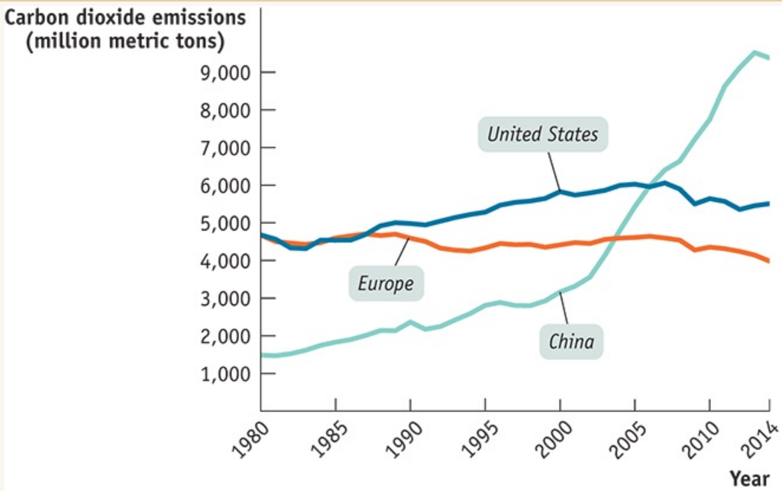


FIGURE 9-13 Krugman/Wells, *Macroeconomics*, 5e, © 2018 Worth Publishers
Data from: Energy Information Administration.

Greenhouse gas emissions are positively related to growth. As shown here by the United States and Europe, wealthy countries have historically been responsible for the great bulk of carbon dioxide emissions—which make up more than three quarters of all greenhouse gas emissions—because of their richer and faster-growing economies. As China and other emerging economies have grown, they began to emit much more carbon dioxide. China has since overtaken the United States and Europe in emissions.

In 2015, in acknowledgement of the seriousness of the problem, 196 countries came together under the **Paris Agreement**, committing to reduce their emissions of greenhouse gases in an effort to limit the rise in the earth's temperature to no more than 2 degrees centigrade. The linchpin of the agreement was cooperation between China, India, and the United States. China and India agreed to limit their emissions, and the United States, along with other rich countries, committed to develop various forms of public and private financing to help poorer countries pay the cost.

Under the **Paris Agreement** of 2015, 196 countries agreed to reduce their greenhouse gas emissions in an effort to limit the rise in the earth's temperature to no more than 2 degrees centigrade.

Is it possible to maintain long-run growth while averting the effects of climate change? The answer, according to most economists who have studied the issue, is yes. While there will be economic costs, those costs have been falling as technological innovation in clean energy sources advances. The best available estimates show that even a large reduction in greenhouse gas emissions over the next few decades would cause only a modest reduction in the long-term rise in real GDP per capita.

To achieve long-run economic growth with environmental protection, governments will need to use regulations and environmental standards, and institute policies that create market incentives to encourage individuals and firms to make the transition to clean energy sources. Finally, governments—both rich and poor—will need to continue to cooperate with one another. Getting political consensus around the necessary policies will be key.

ECONOMICS >> *in Action*

What Is the Cost of Limiting Carbon?

You may be surprised to learn that taking action against climate change in the United States doesn't necessarily require new legislation. Under U.S. law, the Environmental Protection Agency (EPA) is obliged to regulate pollutants that endanger public health, and in 2007 the Supreme Court ruled that carbon dioxide emissions meet that criterion.

iurii/Shutterstock

The answer is blowing in the wind.

So the EPA initiated a series of steps to limit carbon emissions. First, it set new fuel-efficiency standards to reduce emissions from motor vehicles. Then, it introduced rules limiting emissions from new power plants. Finally, in June 2014 it announced plans to limit emissions from existing power plants. This was a crucial step because coal-burning power plants account for a large part of carbon emissions, both in the United States and in other countries.

But how will the new rules affect the U.S. economy? Critics have argued that the EPA rules would cripple economic growth. For the most part, however, economists disagree. The EPA's own analysis suggests that by 2030 its rules would cost the U.S. economy about $9 billion annually in today's dollars—equivalent to 0.05% of the $19 trillion of goods and services produced annually—a trivial sum.

Still, the EPA's proposed rules would, at best, make a small dent in the problem of climate change. How much would a program that really deals with the problem cost? In 2014 the United Nations International Panel on Climate Change (IPCC) estimated that global measures limiting the rise in temperatures to 2 degrees centigrade would impose gradually rising costs, reaching about 5% of output by the year 2100. The impact on the world's rate of economic growth would, however, be small—a reduction of approximately 0.06 percentage points each year. The IPCC's numbers were more or less in line with other estimates. Most independent studies have found that environmental protection need not greatly reduce growth.

Why this optimism? At a fundamental level, the key insight is that given the right incentives modern economies can find many ways to reduce emissions, ranging from the use of renewable energy sources (which have grown much cheaper) to inducing consumers to choose goods with lower environmental impact. Economic growth and environmental damage don't have to go together.

>> *Check Your Understanding* 9-5

Solutions appear at back of book.

. Are economists typically more concerned about the limits to growth imposed by environmental degradation or those imposed by resource scarcity? Explain, noting the role of negative externalities (costs imposed by individuals or firms on others without the requirement to pay compensation), in your answer.

. What is the link between greenhouse gas emissions and growth? What is the expected effect on growth from emissions reduction? Why is international burden sharing of greenhouse gas emissions reduction a contentious problem?

>> *Quick Review*

- Economists generally believe that environmental degradation poses a greater challenge to **sustainable long-run economic growth** than resource scarcity. They also generally believe that modern economies can find ways to alleviate limits to growth from natural resource scarcity through the price response that promotes conservation and the creation of alternatives.
- Economic growth tends to harm the environment unless actions are taken to protect it. Local environmental degradation can be addressed through political will and resources. Global environmental degradation is harder to address because it requires cooperation across many countries.
- The accumulation of greenhouse gases, a by-product of burning fossil fuels, has led to climate change, the raising of the earth's temperature. In order to avert the impact of climate change, effective government intervention is required.
- Developed countries and large countries that are rapidly growing need to shift from a heavy reliance on fossil fuels to using clean, energy sources like solar and wind power. This will come at a modest cost to the rise in real GDP per capita, a cost that is falling as technological innovation in clean energy sources advances.
- In the **Paris Agreement** of 2015, 196 countries agreed to reduce their greenhouse gas emissions in an effort to limit the rise in the earth's temperature.

BUSINESS CASE | Raising the Bar(code)

When we think about innovation and technological progress, we tend to focus on the dramatic changes: cars replacing horses and buggies, electric light bulbs replacing gaslights, computers replacing adding machines and typewriters. However, much more progress is incremental and almost invisible to most people, yet has huge effects over time. Consider, for example, the simple bar-code scanner.

Bar codes were first used commercially in 1974, when a 10-pack of Wrigley's chewing gum was rung up with a scanner produced by the National Cash Register Corporation (now NCR Corp). Since then bar codes and their two-dimensional descendants—visual patterns that are meaningless to human eyes but are instantly recognizable by scanners and smartphones—have become ubiquitous, used to identify and route everything from shipping containers to airline passengers.

their routines. And because there are often setbacks in learning a new system, such as accidentally erasing your computer files, productivity at Multinomics may decrease for a period of time.

9-3 Check Your Understanding

. A country that has high domestic savings is able to achieve a high rate of investment spending as a percent of GDP. This, in turn, allows the country to achieve a high growth rate.

. It is likely that the United States will experience a greater pace of innovation and development of new drugs because closer links between private companies and academic research centers will lead to research and development more directly focused on producing new drugs rather than on pure research.

. It is likely that these events resulted in a fall in the country's growth rate because the lack of property rights would have dissuaded people from making investments in a productive capacity.

9-4 Check Your Understanding

. The conditional version of the convergence hypothesis says that countries grow faster, other things equal, when they start from relatively low GDP per capita. From this we can infer that they grow more slowly, other things equal, when their real GDP per capita is relatively higher. This points to lower future Asian growth. However, other things might not be equal: if Asian economies continue investing in human capital, if savings rates continue to be high, if governments invest in infrastructure, and so on, growth might continue at an accelerated pace.

. The regions of East Asia, Western Europe, and the United States support the convergence hypothesis because a comparison among them shows that the growth rate of real GDP per capita falls as real GDP per capita rises. Eastern Europe, West Asia, Latin America, and Africa do not support the hypothesis because they all have much lower real GDP per capita than the United States but have either approximately the same growth rate (West Asia and Eastern Europe) or a lower growth rate (Africa and Latin America).

. The evidence suggests that both sets of factors matter: better infrastructure is important for growth, but so is political and financial stability. Policies should try to address both areas.

9-5 Check Your Understanding

. Economists are typically more concerned about environmental degradation than resource scarcity. The reason is that in modern economies the price response tends to alleviate the limits imposed by resource scarcity through conservation and the development of alternatives. However, because environmental degradation involves a cost imposed by individuals or firms on others without the requirement to pay compensation (known as a *negative externality*), effective government intervention is required to address it. As a result, economists are more concerned about the limits to growth imposed by environmental degradation because a market response would be inadequate.

. Growth increases a country's greenhouse gas emissions. The current best estimates are that a large reduction in emissions will result in only a modest reduction in growth. The international burden sharing of greenhouse gas emissions reduction is contentious because rich countries are reluctant to pay the costs of reducing their emissions only to see newly emerging countries like China rapidly increase their emissions. Yet most of the current accumulation of gases is due to the past actions of rich countries. Poorer countries like China are equally reluctant to sacrifice their growth to pay for the past actions of rich countries.