The Effect of Energy Shocks on National Economies

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Abstract

Energy prices rose rapidly through much of 2022. In the third quarter of that year, the price of coal from Australia was up 150 percent compared to one year earlier. Natural gas prices in Europe rose over 150 percent; globally, it rose over 115 percent. And crude oil was up over 40 percent. These increases strain households and businesses in many countries, shifting both the level and composition of consumer expenditures and production volumes. But since, as this chapter documents, the overwhelming majority of global energy use is embodied within countless non-energy goods and services, the entire supply chain must be considered to fully appreciate the scale of the impact of energy shocks. In this chapter, I explore both the direct and indirect effects of recent energy price increases and characterize the exposure of different economies to energy shocks in general. I show that over four-fifths of global energy use is not consumed directly but is instead implicitly contained within the cost of producing individual items. Combining measure of direct and indirect energy trade, I also demonstrate that energy shocks can originate from countries that are not themselves meaningful direct exporters of energy. The analysis also reveals that most European countries are susceptible to not only adverse direct energy shocks—as occurred most recently following Russia's invasion of Ukraine—but also from indirect energy shocks, especially from the Asia-Pacific region. As the world becomes increasingly uncertain, and global energy supplies more frequently disrupted, exploring ways to lower dependency on foreign energy sources may become a leading policy priority for many countries.

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Introduction

In 2022, the world experienced one of the largest energy shocks in decades. In the third quarter of that year, the price of coal from Australia was up 150 percent compared to one year earlier. Natural gas prices in Europe rose over 150 percent; globally, it rose over 115 percent. And crude oil was up over 40 percent.[1] This not only affects buyers of energy directly, but cascades through global supply chains as higher production and transportation costs are either passed through to consumers or absorbed through shrinking margins or scaled back business operations. By November 2022, overall consumer prices were up over 10.3 on average within the OECD.[2] Even Japan, which for decades has struggled with slow growth and not infrequent bouts of deflation, saw its inflation rate reach nearly 4 percent. Rising energy costs was a key driver of this, especially among European countries that faced unique challenges not only from rising global prices but also from disrupted supplies originating from Russia because of that country's invasion of Ukraine in February 2022. To be clear, there are some beneficiaries of rising energy prices. Countries that are net exporters of energy commodities will gain from significant improvements in their terms of trade. Canada, for example, saw its total exports increase 26 percent in the third quarter of 2022 compared to the same period in 2021 and energy products accounted for nearly 60 percent of the increase.[3] With such large disruptions resulting from rapid changes in energy prices, understanding the consequences of energy shocks for national economies throughout the world is increasingly important. This chapter will use the latest available data to quantify the effect of rising energy prices on consumers, producers, and economies generally.

As noted, it is not just the direct effects of rising energy prices that one must consider. Most energy use is embodied within the countless goods and services. Using data that I will describe later in the chapter, I show that over four-fifths of global energy use is not consumed directly but is instead implicitly contained within the cost of producing individual items. The whole supply chain must therefore be considered. Indeed, I estimate that most of the global energy use is embodied within inputs that are used to produce yet other goods and services. Rising energy prices can therefore affect economic competitiveness and costs even among sectors that one might not consider as particularly energy intensive. Agricultural production, for example, is more energy intensive than clothing and textile manufacturing when only direct energy used by those sectors are considered. But when the entire supply chain and all intersectoral linkages are accounted for, one sees that textiles is more energy intensive than agriculture. That is, the amount of energy embodied within an average product from the textile sector is larger (per dollar of output) than what is embodied within an average agricultural product.

Such supply chain considerations are critically important on a global scale. I show that the largest energy exporters are not just the main producers of oil, gas, and coal around the world but also include major manufacturing economies such as China. Indeed, of all energy embodied within goods and services around the world, China accounts for nearly 18 percent of all exported energy. India accounts for another 5 percent. And neither economy is a material exporter of primary energy products. Energy shocks that originate within China—even if localized within, say, domestic electricity prices—can therefore have global implications through the vast web of the global energy trade. Combining all energy products, including both primary direct energy trade and energy embodied energy trade, I will show that the energy balance for countries provides a useful measure of how exposed an economy is to adverse energy shocks. Europe, Japan, India, and China are particularly reliant on foreign sources of energy and are therefore

[1] Source: Author's calculations using World Bank (2023).
[2] Source: Author's calculations using OECD (2022a).
[3] Source: Author's calculations using Statistics Canada (2022).

heavily exposed to adverse shocks. The events of 2022 have made that clear for most economies in Europe.

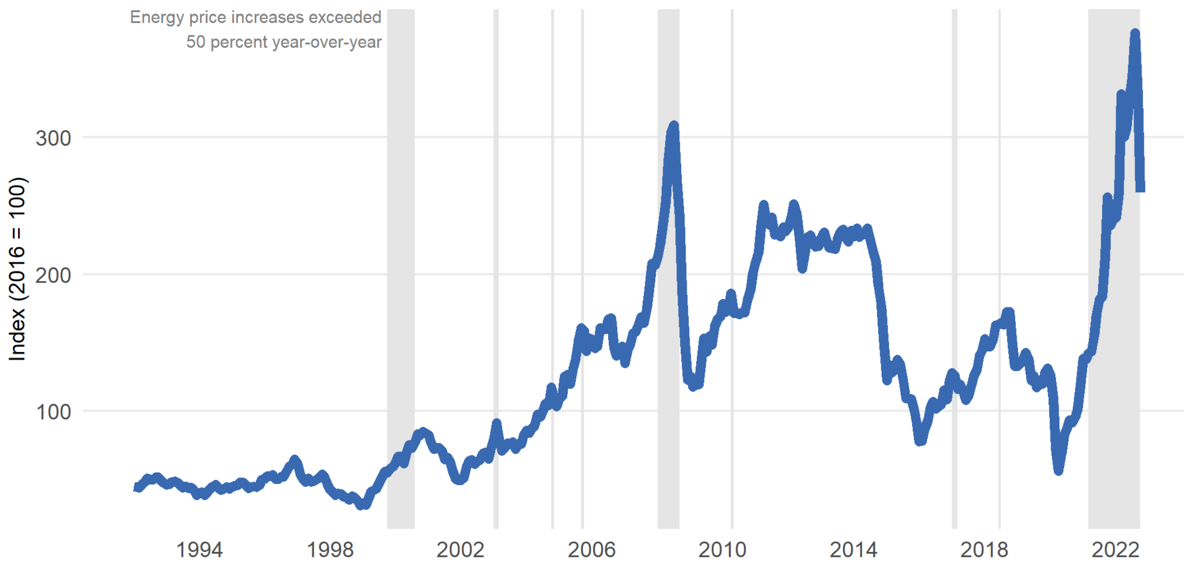
Before turning to the details of this chapter's analysis, it is worth understanding why energy shocks are not uncommon. Commodities such as energy and agriculture are unique among goods and services as their markets are dominated by buyers and sellers that are both relatively insensitive to prices. If prices increase, buyers will decrease quantities purchased only modestly and sellers will increase quantities supplied only modestly as well. This feature—inelastic demand and supply—means that small changes in demand or small changes in supply can have large effects on price. In energy markets, we see this regularly over time. In Figure 1, I display an index of global energy prices produced by the International Monetary Fund (IMF, 2022). This combines prices of the main energy products of coal, crude oil, and natural gas. The figure displays the resulting index and shades regions where price increases exceeded 50 percent compared to one year earlier.

In the past 30 years, there have been several periods of large rapid price increases and equally large rapid price decreases. The increase from 1998 to 2000, for example, saw energy prices more than double. This was followed by a subsequent decline. But between the United States' invasion of Iraq and the financial crisis, there was a large and sustained increase in prices. As this was gradual, only certain years are shaded in the graph as having exceeded 50 percent annual growth. That is, until 2007 and 2008 when prices more than doubled. Until recently, this was among the largest of energy shocks. There are numerous causes, but the rise of energy demand in China combined with relatively slow global supply growth are key contributors. But when the global financial crisis hit and demand declined, so too did prices. More recently, prices declined starting in 2014 as global supplies grew. Large production increases in the United States following the shale revolution along with increases in Russian and OPEC country production were key contributors. Finally, the increase in prices following the COVID-19 disruptions, however, was among the largest commodity price spikes in history.

Several factors have combined to generate this large and relatively long lasting energy shock from 2021 to 2022. First, the global economic recovery from COVID-19 was stronger and more robust than many anticipated. The rapid development of highly effective vaccines, combined with highly successful inoculation campaigns in many countries, were key factors increasing energy demand (and therefore prices) through 2021. There were also several adverse weather events that increased demand, such as a particularly cold winter in much of the norther hemisphere.[4] Importantly, though, this increased demand was not met by a corresponding supply response. In the short-term, as noted, energy supplies are highly inelastic. This is especially so in recent years as capital investments in oil and natural gas production declined sharply in many important producing countries since 2014. In a sense, this increases the vulnerability of energy markets to changes in demand.

[4] For a detailed description of the various demand and supply events leading to rapid increases in global energy prices in 2021, see Alvarez and Molnar (2021).

Figure 1: Global Price of Energy Index



Note: Displays an index of the global price of energy. Shaded regions represent period when annual energy price increases exceeded 50 percent.

Source: Author's calculations using IMF (2022).

These mounting pressures on global energy markets were exacerbated by Russia's invasion of Ukraine in late February 2022. Russia is a large global supplier of energy. It is the world's second-largest natural gas producer and the largest exporter. It also exports significant quantities of crude oil, mainly a medium sour blend, and in 2021 such exports were the equivalent of nearly five million barrels per day. Most of this energy flows to Europe, which as we will explore in this chapter, are particularly susceptible to adverse energy shocks. Following Russia's invasion, supply disruptions, sanctions, reduced Russian production, suspended pipeline operations, and other factors led energy prices to spike in the months following the invasion. Natural gas prices in the Europe, for example, more than tripled from late February 2022 to April 2022 (IEA, 2022a). Globally, the IMF index of energy prices increased nearly 50 percent in the months following the invasion. Although prices have eased from their summer 2022 highs, they remain high by historical standards. By the third quarter of 2022, energy prices were up over 81 percent compared to the third quarter of 2021. And the future is highly uncertain. There have been recent improvements in energy prices in Europe, for example, with natural gas prices falling to pre-invasion levels by January 2023 (Reed, 2023). But future price increases are not out of the question. Western technology and technical expertise, for example, are historically important for Russian energy development, and this may be a source of long-run supply pressures globally (Reed, 2022). Even if the effects are small, combined with rising demand and the inelastic nature of demand and supply in this market, price increases could be large.

Beyond Russia, there are material risks facing global oil supplies in several regions of the world.[5] The Persian Gulf is, of course, the largest supplier. But with its exports flowing entirely through the Strait of

[5] I summarize only a selection of potential risks that were detailed in Zeihan (2022).

Hormuz, future conflicts in the region that put this critical shipping lane at risk would have massive implications for global oil markets. To a lesser extent, this region also uses a non-trivial number of foreign energy workers. If security concerns limit the supply of such workers, then production may decline. Increased piracy activity off the coasts of west and east Africa could also risk the flow of several million barrels per day. Internal disruptions within major African producers, Nigeria in particular, could also have global implications. Whatever the source of future disruptions, energy shocks—both positive and negative—will continue to occur.

The focus on energy shocks in this chapter will not just be in the supply of primary energy sources such as coal, oil, and natural gas. Potentially just as important, though largely underappreciated, is the energy that flows between countries embodied within internationally traded goods and services. A country that does not import primary energy may still be exposed to energy shocks globally to the extent that energy is a critical input in the production of items that it may import from abroad. Indeed, as I will show later in the chapter using the latest available data, while countries in the Middle East and the Former Soviet Union are among the world's dominant energy producers and exporters, countries like China and other Asia-Pacific countries are major exporters of energy when embodied energy is included. Combined, this region accounts for over 40 percent of total exported embodied energy. China alone accounts for nearly one-fifth. Developments affecting the price of energy in those major producers of goods and services will have potentially large global implications.

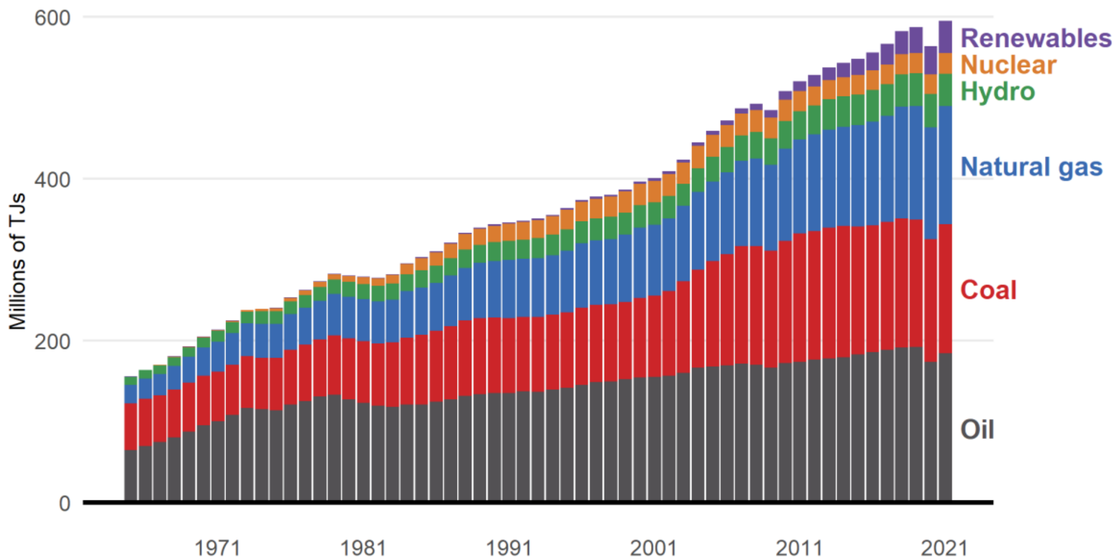
How national economies are affected by energy shocks varies considerably across the world and over time. The source of shocks matters—that is, whether prices rise because of a negative supply shock or because of a positive demand shock. The net consumption versus production position of a country also matters, since rising prices will be a net economic benefit to countries that disproportionately export energy. Policy responses matter as well. Indeed, recent improvements in monetary policy and declining energy shares of production may have made advanced economies less vulnerable to oil price shocks (Blanchard and Galí, 2010). This chapter will explore several potential indicators of a country's vulnerability, with a particular focus on the importance of foreign energy embodied within final goods and services consumed. We will see that Central Asia, Africa, and Europe (especially Eastern Europe) are disproportionately reliant on energy produced elsewhere.

World Energy Production and Consumption

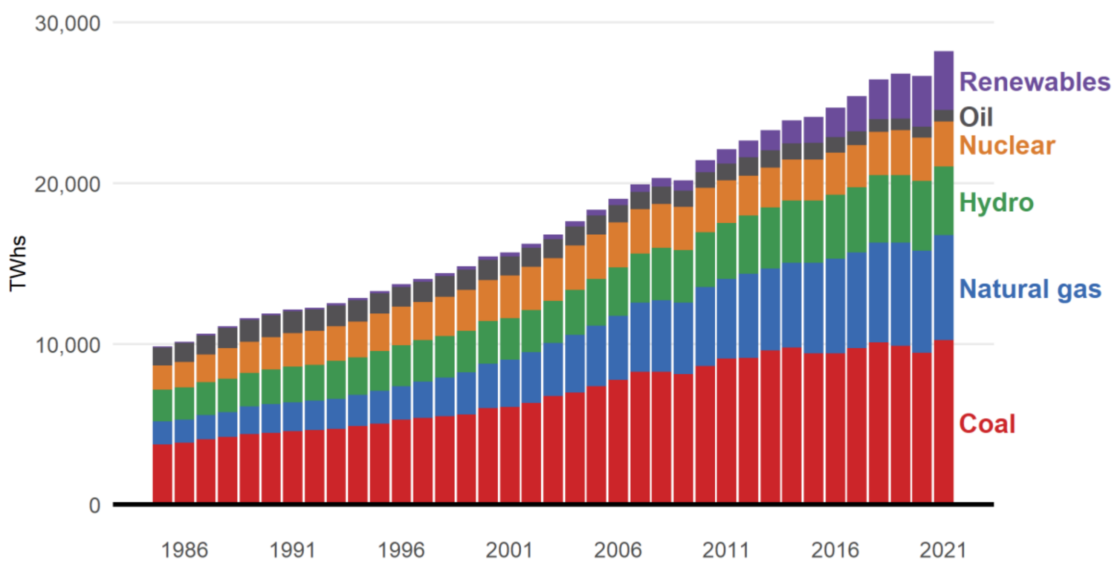
Before moving into in-depth analysis of the effect of energy shocks on national economies, it is worth first exploring the patterns of global energy production and consumption. Globally, individuals and businesses collectively consume nearly 600 million terajoules of primary energy annually—equivalent to over 75 gigajoules per person per year. And most of this energy consumption is accounted for by oil, coal, and natural gas. I display the size and composition of global primary energy consumption by fuel type over time in Figure 2 (a). In 2021, the most recent year for which this data is available, oil accounted for 31 percent of primary energy consumption (used primarily in transportation), while coal and natural gas each account for approximately one-quarter of energy consumption. This point is particularly relevant for thinking about the nature and consequences of energy shocks. Although renewables production is increasing, energy shocks will almost entirely be tied to developments in markets for natural gas, coal, and oil. These are global commodities that respond to global economic and political developments. Renewables, nuclear, and hydro energy consumption, in contrast, are more insulated.

Figure 2: Global Energy Production and Use by Fuel

(a) Primary Energy Consumption, 1965-2021



(b) Electricity Generation, 1985-2021



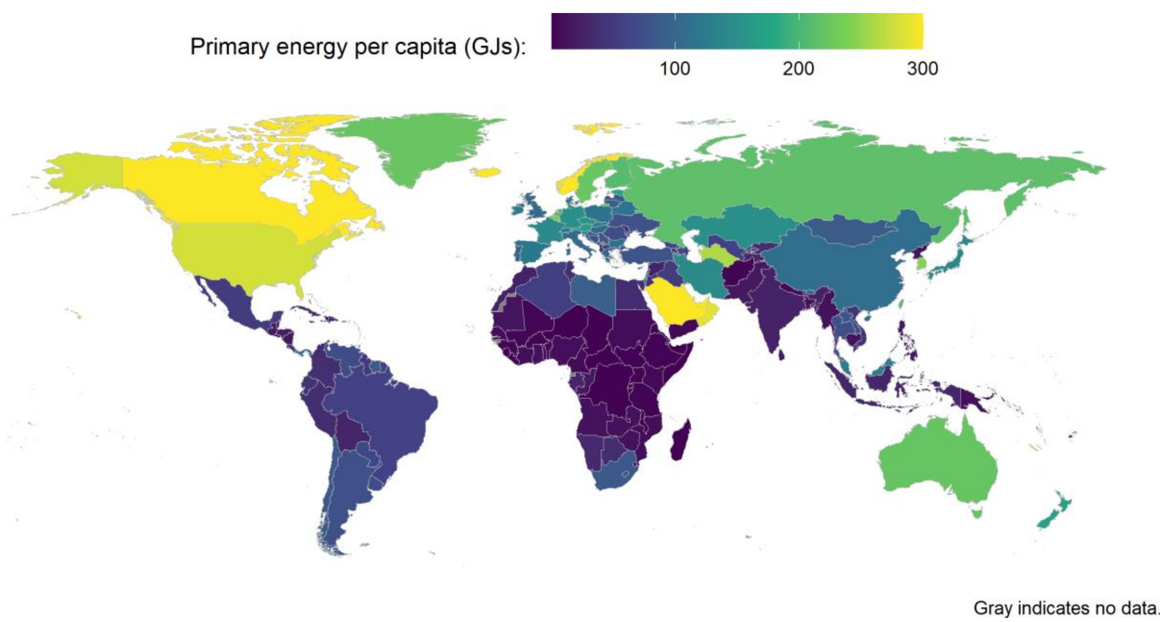
Note: Displays the world's total primary energy consumption and electricity generation, by major fuel type.

Source: Author's calculations using BP (2022).

In addition to primary energy production, secondary energy consumption is importantly dominated by electricity. But this too is tied to certain heavily traded commodities. Globally, nearly 40 percent of natural gas production flows as an input to electricity generation and over 60 percent of coal production does.[6] I display the world's electricity generation by fuel type in Figure 2 (b). In 2021, nearly 28,500 terawatt-hours of electricity was produced, with over one-third generated from coal and nearly one-quarter from natural gas. Of the growth since 2000, nearly 33 percent is accounted for by increases in natural gas generated electricity, 30 percent from coal, and 27 percent from renewables. Combined with the patterns of primary energy consumption, these data demonstrate that while renewables will continue to increase its share, globally traded oil, natural gas, and coal will dominate for some time.

While these global totals are important and informative, there is rich variation across countries and regions in production and consumption patterns. In Figure 3, I display a measure of per capita primary energy consumption, by country, for 2021. The wide variation in the intensity of energy consumption is clear. The average per capita energy consumption in North America, for example, is over 15 times higher than in Africa. And as developing and emerging markets continue to grow economically, so too will their energy consumption. This presents an important global policy challenge: how to increase energy production to facilitate economic growth among developing and emerging economies while simultaneously lower greenhouse gas emissions. This chapter will have little to say about how to best meet this long-term challenge and instead it will remain focused on short- and medium-term issue of responding to price shocks. Those countries with high levels of energy consumption per capita are potentially exposed to energy price shocks. But more important than overall consumption is whether a country produces energy in sufficient quantity to meet that consumption, or whether some or most of the energy is imported from abroad.

Figure 3: Annual Global Energy Consumption per Capita, 2021



Note: Displays the world's total primary energy consumption per capita, measured in gigajoules per year.

Source: Author's calculations using Our World in Data Energy Data Explorer, https://ourworldindata.org/energy.

[6] Source: Author's calculations using the IEA World Energy Balance, https://www.iea.org/sankey/.

To see the broad patterns of how energy production aligns with consumption, Table 1 displays the totals of each across broad regions of the world for 2021. Some regions are net producers while others are net consumers of the main primary energy fuel sources. Of the main regions, only Europe the Asia Pacific are, on the whole, net consumers of the three major energy products of oil, gas, and coal. Europe produces an amount equivalent to one-third of the region's consumption. And among European Union members, the gap is even larger: only 15 percent of consumption is served by within-region production. Asia Pacific countries, meanwhile, consume nearly 63 million TJs more than is produced in the region. While this is a larger gap than in Europe, within-region production accounts for nearly three-quarters of consumption. Europe in general, and the EU in particular, are uniquely dependent on imported oil, gas, and coal and are therefore exposed to shocks beyond its control. Regions that are net producers of energy, such as countries in North America, CIS, and the Middle East will see overall economic benefits if energy prices rise.

Table 1: Primary Energy Production and Consumption, 2021

		Oil, Gas, and Coal (Million TJs)		
Region	Per Capita Consumption (GJ per person)	Total Consumption	Total Production	Net Production
North America	227.0	90.6	100.5	42.8
South & Central America	53.7	18.7	20.5	1.9
Europe	122.0	58.1	20.3	-37.8
CIS	163.0	35.6	72.9	37.3
Middle East	143.0	37.4	82.9	45.5
Africa	14.6	18.0	30.3	12.3
Asia Pacific	63.6	231.3	168.7	-62.6

Note: Displays the regional primary energy consumption per capita and the distribution of total consumption and production across regions.

Source: Author's calculations using BP (2022).

More generally, energy exports are highly concentrated in a few countries. The value of global energy exports (as measured by HS Chapter 27 items) accounted for by the top-ten largest producers (the United States, UAE, Saudi Arabia, Russia, Canada, Norway, Australia, the Netherlands, Qatar, and India) account for nearly two-thirds of total exports. Behind the United States, the UAE, and Saudi Arabia, the fourth largest energy exporter is Russia, accounting for nearly 10 percent of total global exports.[7] Much of this flows to China, the European Union is a particularly important market. The EU-27 countries imported over 170 million tonnes of crude oil and petroleum products from Russia in 2020 and over 155 billion cubic metres of natural gas that same year. Within the EU, the top Russian crude oil importers were Germany (nearly 34.9 million tonnes), the Netherlands (27.2 million), Poland (22.2 million), Belgium (11.7 million), Finland (11.2 million) and France (10.2 million).[8] The top Russian gas importers, meanwhile, were

[7] Source: Author's calculations using UN-Comtrade for 2021.
[8] Source: Author's calculations using Eurostat data NRG_TI_OIL.

Germany (52.5 billion cubic metres, or bcm), Italy (28.7 bcm), the Netherlands (18.1 bcm), Hungary (11.6 bcm), Poland (9.6 bcm), France (7.8 bcm), and Czechia (7.6 bcm). The effect of energy price shocks on these economies will vary.

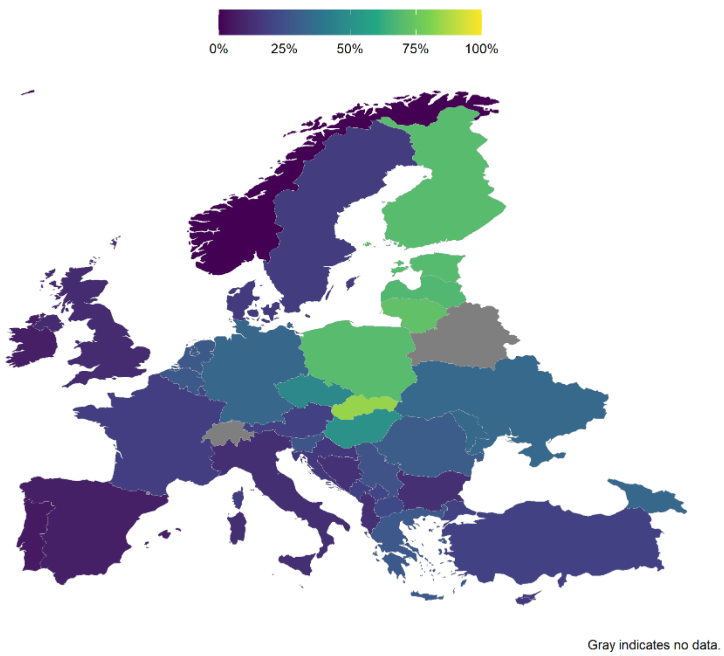
One aggregate measure starkly reveals the scale of energy dependence many European countries have on Russian imports. It is well known that Europe is highly dependent on imports for its energy needs, but the scale is uniquely large. One measure that the EU itself reports directly is the "energy dependency rate." This captures what fraction of a country's total energy needs are met with net imports (imports minus any exports). For the EU overall in 2020, the total energy dependency rate was 58 percent (Eurostat, 2022). For natural gas, this dependency rate exceeds 83 percent and for crude oil exceeds 96 percent. For some European countries, such as Norway (not in the EU), the magnitude of energy production is so large that the dependency rate is negative. In 2020, it was -623 percent. But for all EU member states the rate was positive. It varied from a low of 12 percent for Iceland to a high of nearly 98 percent for Malta. The dependence on Russia as a supplier of oil and gas is high for much of Europe. I report the Eurostat estimates of this for 2020 in Figure 4, which reflects net imports (imports less exports) relative to a country's total available energy for each of oil (panel a) and natural gas (panel b), adjusted for intermediate flows through other countries.

Energy dependence on Russian supplies varies widely across European countries. For natural gas, the dependency rate ranged from a high of 100 percent in Latvia, Czechia, and several countries in Balkans to zero percent in Ireland, Austria, Cyprus, Norway, and others. For crude oil and petroleum products, dependence on Russian supplies ranged from a high and to over 83 percent in Slovakia to zero percent in Norway. Overall, across all EU-27 countries, I estimate a Russian dependency rate of just over one-quarter for crude oil and petroleum products and nearly one-half for natural gas. Combined with information on each country's available supply of oil and gas, I estimate a combined overall dependency rate of 86 percent for Estonia, 85 percent for Slovakia, 80 percent for Latvia, and 75 percent for Hungary at the top and 7 percent for Portugal, 4 percent for Ireland, 2 percent for Iceland, and 0 for Norway at the bottom. Of the EU-27 countries, I find ten are dependent on Russian supplies for at least half of total oil and gas needs—12 for at least half of natural gas and 7 for at least half of oil and petroleum products. Disruptions to this critical supply, as we saw following Russia's invasion of Ukraine, puts tremendous short-term pressure on many countries.

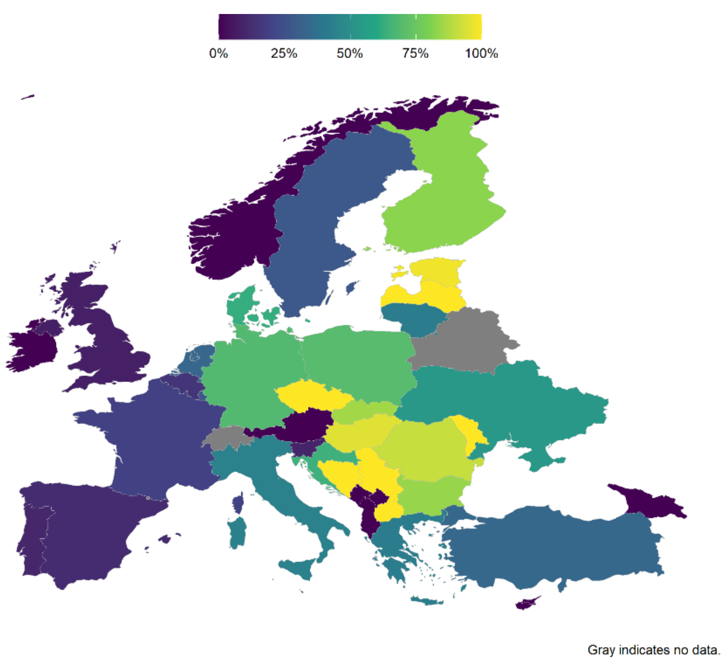
The magnitude of these imports, and the unavoidably inelastic supply from substitute sources in the short-run, means—as discussed previously—prices can rapidly increase from even relatively small changes in overall energy supply. And risks originate not only from Russian supplies. Some EU countries with relatively lower dependence on Russian oil and gas are still highly dependent on other foreign sources. Nearly 30 percent of Spain's natural gas needs are met, for example, by imports from Algeria. And 27 percent of Romania's oil and petroleum product needs are met by imports from Kazakhstan. And, to be clear, the events of 2022 have led many European governments to rapidly shift energy sourcing away from Russia. The dependency rates illustrated in the figure will therefore have changed markedly from 2020. This process of shifting energy sourcing is difficult and slow, however, as it often requires new infrastructure. The Paldiski LNG facility in Estonia is a recent example.

Figure 4: Dependence on Russian Energy for Selected European Countries, 2020 *

(a) Russian Oil Dependency Ratio



(b) Russian Gas Dependency Ratio



*Note: Displays a measure of Russian imports as a share of each country's total energy needs. Panel (a) displays this measure for crude oil and panel (b) displays this for natural gas. * Data for the United Kingdom is from 2019.*

Source: Author's calculations using Eurostat data NRG_IND_IDOGAS and NRG_IND_IDOOIL. Available at: https://ec.europa.eu/eurostat/web/energy/data/database. Accessed December 27, 2022.

Importantly, Europe is relatively unique in the world as a continent for its high degree dependency on foreign primary energy suppliers. Using IEA World Energy Statistics and Balances data for 2020 (IEA, 2022b), I estimate the dependency rate for 145 countries globally using the same approach as Eurostat. And this data can replicate the 58 percent dependency rate as the Eurostat data does for the EU-27 countries. The results for the rest of the world are strikingly different. The Americas overall have a dependency rate of -0.12, indicating they enjoy a net export position. In North America, Canada is -0.79 and United States is -0.04, although Mexico is 0.18. In Asia, overall, the dependency rate is 0.10, with China's rate at 0.22. Although 0.22 is relatively high, it is nearly two-thirds lower than the average in the European Union. India's dependency rate is 0.36, which is just above Sweden's.

While the future is uncertain, there is much we can say about the effect of rising energy prices. The next sections will explore the direct effect on consumers and producers, as well as the indirect effects on the composition of economic activity and trade.

Direct Effects of Energy Prices

Increases in the price of important energy commodities can strain individuals, raise business costs, and reallocate economic activity between sectors. And in recent years, global commodity prices have increased at a more rapid pace than any period in recent memory. The IMF global price index of all commodities, for example, increased by nearly 150 percent between the second quarter of 2020 and the second quarter of 2022.[9] Some of this was due to price declines through the first half of 2020 resulting from COVID-19 pandemic related disruptions. But even comparing the second quarter of 2022 to the second quarter of 2019 reveals an over 91 percent increase in global commodity prices. And, as noted in the introduction, the rapid rise in energy prices was a large portion of this increase. In this section, I describe several direct effects of increases in commodity prices in general and energy prices in particular, starting with the effect on consumers.

Energy and Inflation

Global inflation rose rapidly through 2022, and energy was an important driver of this. While countries differ in their specific approaches to calculating the average change in consumer prices, inflation can most intuitively be seen as a spending-weighted average change in the price of individual goods and services. That is, inflation in country i at month t is

$$\pi_{i,t} = \sum_{j=1}^{J} s_{i,t-12}^{j} \times \left(\frac{p_{i,t}^{j}}{p_{i,t-12}^{j}} - 1 \right),$$

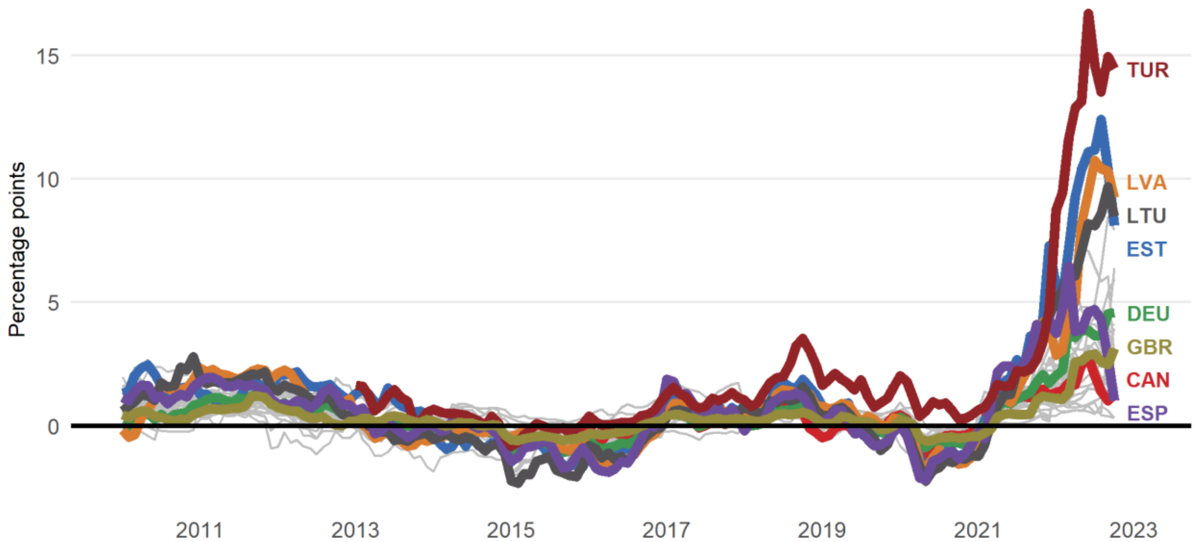
where $p_{i,t}^{j}$ is the price of item j at time t, $p_{i,t-12}^{j}$ is its price one year earlier, and $s_{i,t-12}^{j}$ is the share of total consumer spending allocated to purchasing item j one year earlier. Different price indexes will have different expressions, but intuitively if an item that accounts for 5 percent of total consumer spending rises in price by 10 percent, then measured inflation rises by 0.5 percentage points. In this way, the contribution to changes in inflation rates may be decomposed across all included goods and services.

Since 2021, energy's contribution has rapidly increased. Based on data from the OECD, I display in Figure 5 the contribution of energy to inflation in selected countries. Among all countries for which data is available and this decomposition is done, Turkey experienced the largest contribution of energy. In

[9] Source: Author's calculations using IMF (2022).

October 2022, energy contributed 14.5 percentage points to the country's overall inflation rate of 85.5 percent. This is an unusually high rate of inflation. The Baltic countries of Latvia, Lithuania, and Estonia are the EU countries with the largest energy contributions. In October 2022, energy contributed 9 percentage points to Latvia's 21.8 percent inflation rate. For Lithuania, energy contributed 8.8 percentage points out of the 23.6 percent inflation rate. And for Estonia, energy contributed 8.1 percentage points out of the 22.5 percent inflation rate. While most other European countries are not experiencing such large magnitudes, energy is contributing significantly more to rising inflation rates almost everywhere. Across the EU-27, for example, the average energy price index was one-third higher by November 2022 compared to one year earlier.[10] This strains individuals and businesses alike.

Figure 5: Energy's Contribution to Inflation in Selected Countries, January 2010 to October 2022



Note: Displays the percentage point contribution of energy to inflation rates in selected countries.

Source: Author's calculations using OECD (2022a).

Consumers are affected by rising energy prices in several important ways. First, rising energy costs is a direct—and in most countries today—significant burden on household budgets. In 2021, data compiled by the OECD finds spending on electricity, gas, and other fuels for residential homes accounted for 4.5 percent of total final consumption expenditures in the European Union. In addition, over 7 percent was accounted for by the cost of operating personal vehicles (mainly fuel).[11] Rapid increases in energy prices therefore require households either reallocate a significant share of their total expenditures, deplete their savings, or accumulate debt. Recent data from Eurostat finds that in the first half of 2022, average

[10] Source: Author's calculation using Eurostat data PRC_HICP_MIDX.
[11] Source: Author's calculation using the OECD national accounts data, Table 5. Available online at https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE5.

household gas prices are up 53 percent from the same period in 2021.[12] Electricity prices are also up by 44 percent over this same period.[13]

The large reduction in household disposable incomes after subtracting energy costs, which are typically much more inelastic (that is, more difficult to substitute away from) than other goods and services, is an important channel through which energy price spikes can affect overall economic conditions. As consumers spend less on non-energy goods and services, production, employment, profit, and so on, will contract elsewhere in the economy. This negative income effect is particularly strong when the cause of high energy prices is a rise in the price of imported energy since there will be no offsetting benefit of high prices for the incomes of labour and capital owners in domestic energy producing activities. The effect is not uniform throughout the economy, though. Some items will be more heavily affected than others. Large durable goods, such as vehicles and appliances, or other purchases that can be delayed, are likely to be affected more than necessities. Those items that themselves are energy intensive in their use, such as vehicles or transportation services, will also be more heavily affected because the direct cost of ownership or the price charged by energy-intensive service providers will rise.

Research presented by Kilian (2008) can illustrate the magnitudes of these effects. Results summarized in that paper suggests the one-year energy price elasticity of vehicles, for example, is -0.84. This means for each 1 percent increase in energy prices the consumer demand for vehicles decreases on average by 0.84 percent. For durable goods overall, the estimated elasticities are -0.47. For services and nondurables, they are roughly -0.1. Overall, these estimates suggest that total consumption expenditures decline by 0.15 percent for each 1 percent rise in energy prices. The effect also extends beyond consumption expenditures. Investment levels can be affected as well. For individuals, lower demand for housing is one, and the estimated energy price elasticity reported by Kilian (2008) is -1.02 for residential investment. While these are but one set of estimates, and other researchers and methods yield different results, these results illustrate the general principle very well. And given the scale of recent energy price increases, the consumer response will almost surely be very large. Taking the over 81 percent increase in energy prices in the third quarter of 2022 compared to one-year earlier (discussed in the introduction of this chapter), these results taken at face value suggest the current energy shock could lower total consumption expenditures by roughly 12 percent. Future research will refine these estimates, but regardless of the precise effect, it will be large.

Another way in which rising energy prices can affect individual behaviour in a way that lowers aggregate economic activity and demand for goods and services is by increasing the level of uncertainty that individuals face. Naturally, high levels of volatility or sharp changes in prices will lead individuals to increase their savings. This is called the "precautionary motive" for savings. And if individuals believe a recession may occur, then increasing savings in advance of a potential unemployment spell would be appropriate. Both lead to lower demand for goods and services and households seek to prepare for an uncertain future. Although this is difficult to measure, it does appear that 2022 saw a sharp increase in the degree of economic uncertainty as measured by the World Uncertainty Index produced by Hites Ahir and Davide Furceri of the IMF and Nick Bloom of Stanford University.[14] This measure of world uncertainty increased by nearly 50 percent from the fourth quarter of 2019 to the second quarter of 2022 following

[12] Source: Author's calculations using Eurostat data NRG_PC_202.
[13] Source: Author's calculations using Eurostat data NRG_PC_204.
[14] This data is available online at https://worlduncertaintyindex.com/.

Russia's invasion of Ukraine and the subsequent energy price spikes. To be clear, this should not all be attributed to energy price increases, but it is potentially related. In Europe, this measure of uncertain increased further in the third quarter of 2022 despite falling in most of the rest of the world. Consumer confidence indexes are also falling sharply through much of 2022, and this is especially true in Europe. The European Commission, for example, found that in September 2022 its consumer confidence index reached was less than -29, which was lower than even the lowest point recorded in the depths of the early 2020 COVID-19 disruptions (European Commission, 2022).

Changes in consumer expenditures—overall through higher savings and away from energy intensive items due to higher relative price increases—will affect economic activity, output, employment, incomes, and more, throughout the economy. The effects from consumers, however, may affect downstream producers of final goods and services most. But producers further up the supply chain will also be affected in several important ways. I turn to this issue next.

Production Costs

Producers throughout the economy are also directly affected by rising energy costs. Energy-intensive industrial activities in most countries include food and beverages manufacturing, paper manufacturing, printing activities, iron and steel manufacturing, chemicals, refining, cement, aluminum production, and more. These are particularly strained as energy prices rise. In Europe, for example, high energy prices in 2022 led roughly half of the continent's aluminum and zinc manufacturing capacity being shut down temporarily (Alderman, 2022).

To quantify the typical direct energy intensity by industry, I use global data from the UN-EORA database to estimate the GJs of energy per $1,000 (US) in total output (Lenzen et al., 2012, 2013). I discuss this data in more detail shortly, but the results are in the second column of Table 2. Utilities and transportation are, not surprisingly, the most energy intensive activities by a wide margin. Within manufacturing, the typical global energy intensities vary from 0.5 GJs per $1,000 output in transport equipment manufacturing, to 0.7 for textiles, 0.8 for electrical equipment and machinery, 1.3 for food and beverages, 2.2 for wood and paper products, 3.1 for metal products, and 5.9 for petroleum, chemicals, and minerals. A rise in energy costs will naturally tend to increase the production costs most in energy intensive sectors. In the short-term, the ability to substitute to other inputs or to change the underlying production process is typically limited.

There is a large research literature that examines the economic implications of energy price shocks on producers. The challenge to identifying the effects in data are several, but most notable is the fact that movements in energy prices are often themselves caused by changes in national or global macroeconomic conditions. When a recession occurs, for example, energy prices tend to fall. One would not want to conclude that lower energy prices cause rising unemployment and lower output in contracting sectors. It was the recession, not the fall in energy prices, that was the cause of both any observed contraction in output and the fall in energy prices. Kilian (2008) is a notable review article that surveys several higher quality empirical papers. While there is no consensus around the optimal empirical method to identify the effect, several results from different methods seem common. I discussed some previously regarding consumer responses. And overall, the effect of energy price increases on aggregate economic activity will depend on how energy intensive production is overall. Globally, the energy intensity of GDP has been systematically declining for decades. According to recent data, global energy use has declined by one-third between 1990 and 2021 (Enerdata, 2023). This should make economies less responsive to energy price changes.

There may also be offsetting positive effects on economic activity in some areas. Kilian (2008) notes that the one-year energy price elasticity of US investment expenditures in mining structures and equipment, for example, are large and positive. This is a natural supply-side response to rising prices, although one that takes considerable time to increase the overall energy supply. Given recent structural shocks that may upend the previous international flows of energy, in particular from Russia to European countries, this effect may be magnified as policy makers seek to potentially facilitate or directly subsidize the production of energy in, or to serve, countries with strong diplomatic ties. This energy "friendshoring", as some have labeled it, may be a trend that builds momentum well into the future.

Geopolitical developments aside, the potential reallocation of production and consumption activities across countries in response to rising energy prices is an important potential consequence that deserves careful attention. The sectors different countries specialize in—and generally produces more than is domestically consumed, leaving the residual for export—is determined by what is known as comparative advantage. This concept predicts countries will specialize in areas where they have lower opportunity costs of production—that is, in areas where they give up less in output of other sectors shifting resources to produce more in the sector in question. Changes in energy prices can materially change the pattern of comparative advantage across countries.

Energy Shocks and International Comparative Advantage

Changes in the price of a certain input affects some sectors more than others, depending on how intensively each uses that input. Changes in wages, for example, will affect labour intensive sectors more than capital intensive sectors. Similarly, change in the price of energy will disproportionately affect energy intensive sectors. After all, rising energy prices will increase production costs more in energy-intensive sectors than in non-intensive sectors. To the extent that producers tend to pass higher costs onto buyers through higher prices, the price of energy-intensive items will increase relative to non-intensive items. This creates a strong incentive for domestic and international buyers to shift away to substitute items, leading to a contraction in activity in energy-intensive activities. At the margin, employment and investment capital will consequently also shift away from those activities, which will also tend to lower a country's net exports of those goods. This is intuitive, but it has important implications for the composition of economic activity and trade across countries.

Recent empirical evidence suggests these effects can be large. Consider some work investigating the recent experience of the United States, which in the past two decades has enjoyed a technologically induced reduction in domestic energy prices. The US shale revolution involves new technologies that allowed for horizontal drilling techniques that inject water, chemical, and sands at high pressure to access previously inaccessible deposits of oil and gas. Arezki et al. (2017) exploit this development to investigate the affect on U.S. manufacturing and trade. They find large effects, with strong and measurable gains in energy-intensive sectors in terms of output, employment, and exports. Based on their estimates, in 2012 when the Europe-US price gap in natural gas reached $10 (US) per cubic foot caused increases in US manufacturing exports of approximately 10 percent—equivalent to 4.4 percent of *total* US exports that year. Their results also suggest that lower energy prices and the resulting expansion of energy-intensive manufacturing activity may partially help explain the relatively stronger US recovery from the financial crisis.

These results hold for a broad set of countries, and recent evidence also suggests rising energy prices in the early 2000s had large negative effects on European energy-intensive manufacturing. In recent work, for example, Chan et al. (2022) find that energy prices globally have important implications for the composition of national exports. The details behind their method is not relevant for the purposes of this chapter, but in effect they establish a strong negative correlation between a country's energy price and exports from a country's energy-intensive sectors. They explore both direct and indirect energy flows throughout the production supply chain (which I will describe in more detail in the next section). The effects are large: a one standard-deviation increase in energy prices decreases exports by 0.77 standard deviations, on average. For context, this is roughly than double the effect of wages on exports of labour-intensive sectors. And to make these results concrete, the researchers find that for the EU the observed energy price increase from 2004 to 2012 in the EU compared to the rest of the world decreased overall EU exports by 6.8 percent. The effect is substantially larger (more than double) when indirect effects of energy use are also accounted for. The implications of recent (and even more dramatic) increases in energy prices may similarly negative for the continent's manufacturing and trade activity.

Indirect Effects Through Global Supply Chains

While understanding the source of, and exposure to, energy shocks through primary energy markets matters, indirect shocks through the supply chain for countless non-energy goods and services do as well. This section describes methods to measure indirect energy flows across countries embodied within all goods and services. Using detailed data on 189 countries and over two dozen sectors, it also presents measures of foreign energy dependence that goes beyond what is normally measured.

Global Supply Chains

Global supply chains are networks of production and distribution of goods and services that start with raw materials and end with final products for consumers. These supply chains span across countries and involve multiple stages of production, often involving a range of intermediaries. Understanding these supply chains is critical since so much of global economic activity is accounted for by these intermediate stages and shocks in one country or sector can affect many others as it cascades through these interconnections.

Significant research explores the value-added by each country and sector that is traded across borders. Some service sector activities that are not themselves directly traded, for example, can account for a large share of the value of goods that are. The OECD, for example, produces rich summary statistics on trade in value-added throughout much of the world. Of the $520 billion (US) in exports from Canada reported in this database for 2018, over $145 billion was value-added upstream from the exporting sector.[15] For the whole of the OECD, approximately 42 percent of gross exports was indirect value-added of this kind. And since intermediate inputs are often imported from another country, value-added by one can facilitate the exports of another. For the OECD, roughly 8 percent of total gross exports in 2018 was accounted for by value-added in another economy that produced intermediate inputs.[16] These chains can also become long and complex. In Canada, over $1.5 billion in Canadian value-added was exported as an input into the

[15] Source: Author's calculation using OECD (2022b).
[16] Ibid.

production of another input in another country, which was subsequently returned to Canada as an input for another good or service that was exported yet again.

Similar approaches may be used to construct a mapping of the flow of energy between countries and sectors. This will reveal a complementary set of indicators that reflect how energy shocks can spread from one country and one sector to an entirely different country and sector. I will begin in the next section with some straightforward algebra to illustrate the core principles involved before turning to the data.

Embedded Energy: Algebra

This chapter will not present a comprehensive exploration of the complex algebra of global input-output linkages, but some simple intuition aided by simple expressions can help fix ideas. Interested readers in explore can see recent work by Koopman, Wang, and Wei (2014).

Consider first a simple setting where there are J sectors, but only one economy that does not trade with any other. Energy is used directly by households as a final good (such as fuel to heat homes, or gasoline to power vehicles) and is used as an input into the production of other goods and services. Total energy used in this economy will simply be the sum of the two. That is,

$$E = E^f + \sum_{j=1}^{J} e^j Y^j,$$

where e^j is the energy intensity of sector j production, Y^j is the total amount produced by sector j, and E^f is final demand for energy by households. In the absence of input-output linkages between sectors, we could end here and know how much energy each sector accounts for by just looking at $e^j Y^j$. And if we were only interested in the energy use directly accounted for by households and industries, then we could also stop here.

But if output from one sector can be used as an input by another, and we were interested in the amount of energy that each good or service was *ultimately* responsible for using, then we have to trace these intersectoral linkages. Specifically, total output of each sector will either be consumed C^j or used by another sector M^{kj} and therefore,

$$Y^j = C^j + \sum_{k=1}^{J} M^{kj}.$$

Simply put, this says that supply of goods or services (the left side of the equation) will equal the demand for those goods or services (the right side) in all sectors.

We can also trace where and when energy is used across the supply chain. If producing one unit of goods in sector 1 requires e^1 units of energy, then the total energy accounted for by final consumption of this good equals $e^1 C^1$. But if sector 1 also requires M^{12} units of inputs produced sector 2, then emissions embodied in this stage of production is $e^2 M^{12}$. And if sector 2 requires inputs produced by sector 3, then energy required to produce output in sector 3 is similarly embodied in goods produced in sector 2 and therefore also sector 1. And so on, and so on. The precise expression used to perform this accounting is somewhat more complex than this, but the results are intuitive and explored shortly.

Standard input-output tables produced by statistical agencies throughout the world, and by various international organizations and research teams, provide all the information we need to work with these two equations. If one assumes that the quantity of inputs each sector requires from each other sector is a fixed proportion of production, then one can represent M^{kj} as a function of Y^k. Specifically, define a^{kj} as the share of total input purchases by sector k allocated to items produces by sector j. Collecting these input shares within a matrix $\boldsymbol{A}$, one can re-write the above in vector form. That is,

$$\boldsymbol{Y} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{C},$$

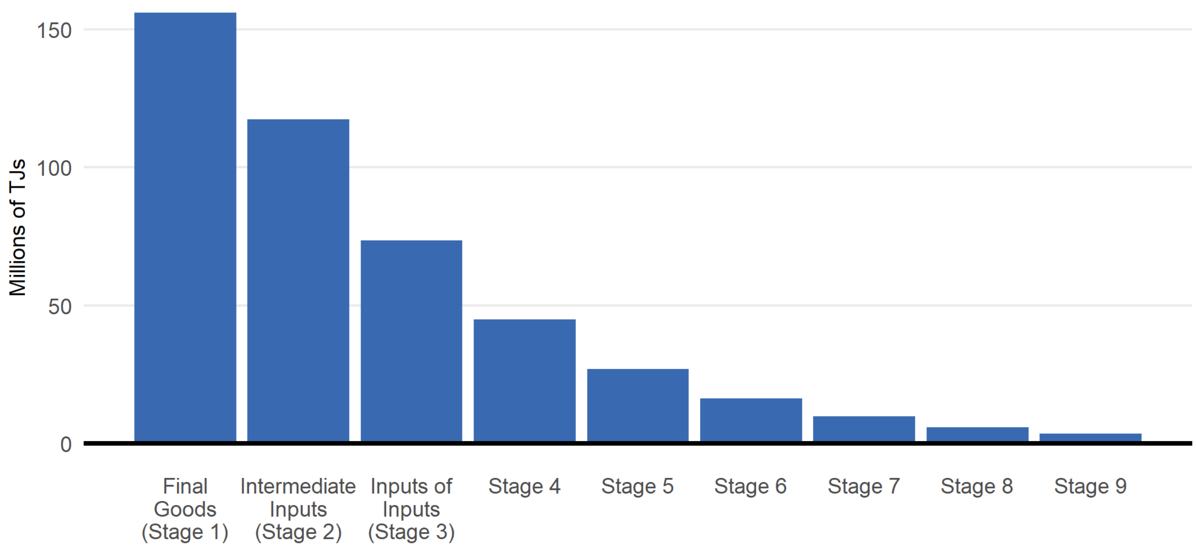
Where the vector $\boldsymbol{Y}$ collects output from each sector and $\boldsymbol{C}$ is final consumption of goods and services from sector. In effect, this expression allows one to determine what level of production in each sector is required to satisfy a particular level of final consumption. It also allows one to determine how much output of each other sector is required to satisfy consumption of any *one* sector. In this way, energy use up the supply chain can be measured. This standard algebra is well known in the economics literature, so I will not proceed further with additional detail. These expressions can also be expanded across countries without losing any intuition. I do that in all that follows.

Embedded Energy: Data

To implement the above methods to measure international embodied energy flows, I use the latest information from the UN-EORA (Environmental Operations and Resources Accounting) database (Lenzen et al., 2012, 2013). This is a comprehensive resource produced by the UN Environment Programme that aims to quantify international environmental footprints. That is, the production and consumption of greenhouse gases, water use, land use, and several other indicators. The data also includes energy use, both in total and separated by key fuel sources including coal, oil, gas, nuclear, hydro, and more. It constructs measures of international and intersectoral flows of goods and services for 26 sectors and 189 countries.

This data is ideal to measure indirect energy flows. As noted in the previous section, energy is embedded within goods and services in various ways. Energy is used to produce goods in factories, transport them to market, and provide the necessary power for their use. Many services also require energy to be delivered, such as heating and cooling buildings. The production and consumption of these goods and services result in the use of energy at various stages of the supply chain, from raw material extraction to final consumption. It is important to understand this intermediate use of energy, as it accounts for a significant portion of total energy consumption. Using the latest data from UN-EORA, I estimate that most embodied energy is used in intermediate stages of production and delivery. I display this pattern in Figure 6. This corresponds to data for 2016, the latest available at the time of writing this chapter, but while the level of energy use is higher today, the broad patterns will not have changed in a material way. I estimate that only just over one-third of embodied energy use is in the final stage of consumption. Energy used to produce intermediate inputs of these final goods accounts for just over one-quarter of total energy use. Producing inputs for those inputs accounts for just over 16 percent. And so on.

Figure 6: Global Embodied Energy Use by Stage of Production



Note: Displays energy usage by stage of production. Stage 1 is producing final goods and services, stage 2 is producing intermediate inputs for those final goods, stage 3 is producing inputs of the inputs of final goods and services, and so on.

Source: Author's calculations using UN-EORA database, following Aslam et al. (2017) for GVCs.

Since so much of energy use is embedded up the supply chain, the energy intensity of most goods and services differs widely from what one would conclude if only direct use of energy in the production process was used. In effect, I account for all the energy flows, wherever it was used in the supply chain, and apportion it to consumer final demand. I report the result of this exercise in the third column of Table 2, and contrast it directly with the energy used only the production of goods and services in column 2. Industries vary widely in their level of total (direct and indirect) energy usage. Some sectors, such as power generation or transportation, use large quantities of energy directly in their production processes. Others, such as retail trade, finance, or private household services, use very little directly. But all use considerably more energy per dollar of final demand, including many services that are not directly energy intensive. Retail trade, for example, uses 3.1 GJs of energy per $1,000 (US) in final consumption. This is as energy intensive as the direct energy used to product metal products, and more energy than directly used to produce goods in most other manufacturing sectors and more than agriculture. The largest difference in energy intensity between the two measures is in metal products, which are 11.1 GJs per $1,000 more energy intensive when the entire supply chain is accounted for than when only direct energy use is measured. Proportionally, though, construction activities are 1,500 percent more energy intensive in total than direct energy use suggests.

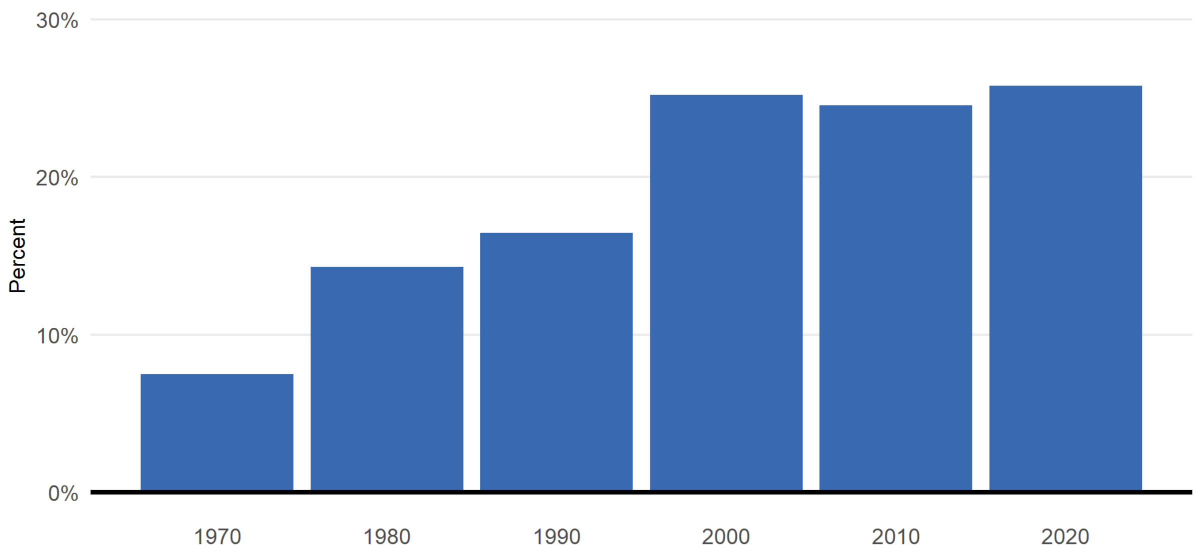
Table 2: Average Global Energy Intensity of Selected Sectors, 2016

	Energy Intensity (GJs / $1,000)	
	Gross Output	Final Demand
Agriculture	1.3	5.4
Fishing	1.3	6.0
Mining and Quarrying	4.4	11.7
Food & Beverages	1.3	6.8
Textiles and Wearing Apparel	0.7	6.8
Wood and Paper	2.2	9.1
Petroleum, Chemicals, Minerals	5.9	15.3
Metal Products	3.1	14.2
Electrical and Machinery	0.8	7.4
Transport Equipment	0.5	6.0
Other Manufacturing	2.7	9.2
Recycling	3.2	9.4
Electricity, Gas and Water	47.4	56.3
Construction	0.4	6.4
Maintenance and Repair	0.3	2.7
Wholesale Trade	0.4	2.7
Retail Trade	0.4	3.1
Hotels and Restaurants	0.5	3.4
Transport	10.2	14.9
Post and Telecommunications	0.4	2.3
Finance and Business Activities	0.3	1.9
Public Administration	0.4	3.3
Education, Health, Other Services	0.3	3.1
Private Households	0.3	1.4
Others	2.3	5.0

Source: Author's calculations using UN-EORA database, following Aslam et al. (2017) for GVCs.

One can use these data to similarly measure how much embodied energy is traded across borders within goods and services. Chinese electricity production, for example, is embodied within many consumer electronics that are assembled there but purchased throughout the world. Overall, I estimate that over one-quarter of global energy production was exported—either directly or indirectly—in 2021. This has risen considerably in recent decades, as I illustrate in Figure 7. In the 1970s, for example, far less than ten percent of total direct and indirect energy use was imported from abroad. This rose to roughly 15 percent by the 1980s and 1990s. But in 2000 and afterwards, this reached the current share of approximately one-quarter. Much of this recent increase is due to the rise of China as a manufacturing hub for the world. China alone accounts for over 18 percent of global embodied energy exports, despite only accounting for less than two percent of direct exports of primary energy products. Russia, meanwhile, accounts for just over 7.5 percent of total energy exports when all indirect flows are accounted for compared to the 10 percent share of direct primary energy product exports. Countries in the middle east are considerably less significant as exporters of total energy. The UAE, for example, accounted for just under 10 percent of primary energy product exports in 2021 but less than 1.5 percent of total exported energy. Saudi Arabia has similar shares as this.

Figure 7: Foreign Energy as a Share of Total Global Embodied Energy Usage



Note: Displays foreign the share of energy embodied in goods and services traded across international boundaries.

Source: Author's calculations using UN-EORA resource footprints database.

The indirect use of foreign energy sources varies depending on the fuel type. For the main primary energy sources, I estimate that in 2016 30 percent of embodied natural gas used globally was embedded in products that were traded to a country other than where the energy was used for production. For coal, this figure was 22 percent. Not surprisingly, China accounted for a large fraction (40 percent) of this as coal is a major fuel generating electricity in that country, which is embedded within the many goods and services it manufactures and exports. Finally, for oil, 24 percent of global embodied use was traded. Secondary energy sources were not traded as much, with 19 percent of hydro, nuclear, and wind power is embodied in products consumed in another country, and only 9 percent of solar power.

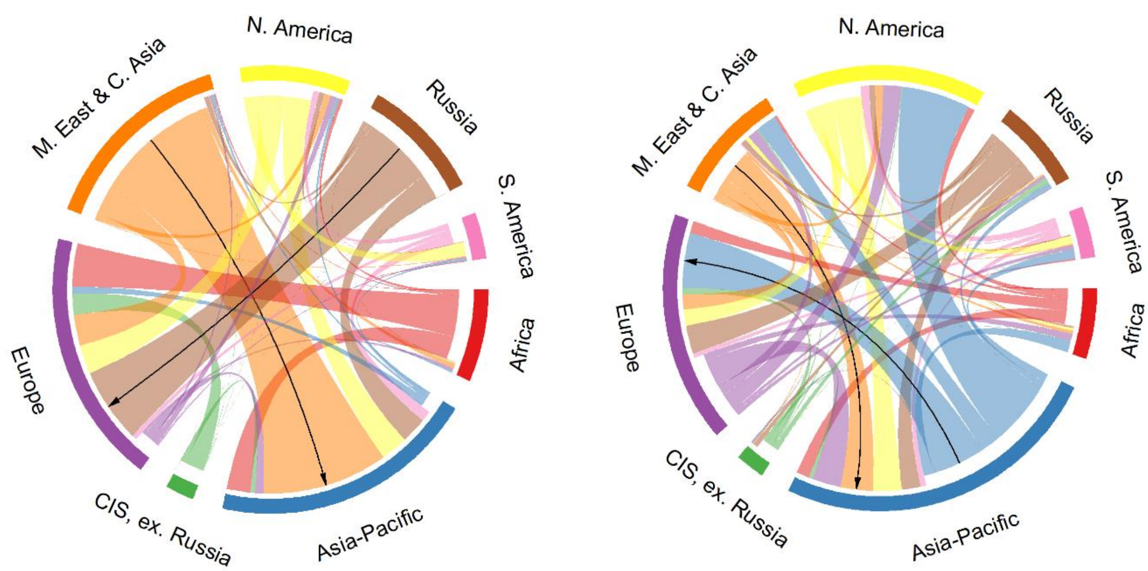
Trade Patterns and Global Energy Balances

These differences in the source of exported energy dramatically change the global picture. In Figure 8 I display the source and destination of direct primary energy products by region and compare this to the source and destination of embodied energy trade. Panel (a) reflects direct energy trade and clearly shows the dominance of the Middle East and Central Asia as a global energy supplier. Much of their production also goes to the Asia-Pacific region. Countries within the Commonwealth of Independent States, mainly Russia, are also large energy exporters with most of their flows going to Europe. But in panel (b) the embodied energy trade flows are very different. The Asia-Pacific region is the dominant energy supplier, with flows going disproportionately to Europe and North America. The importance of major primary energy exporters is also lessened dramatically when total energy is considered.

This broader pattern of the source and destination of energy flows changes where one should look for the source of international energy shocks. Of course, changes in the supply of primary energy products like coal, natural gas, and crude oil will continue to matter. But changes in the non-traded domestic price of energy (for example, domestically sourced and used fossil fuels or domestically produced renewable electricity) can have large international implications. As noted, while China is not a large supplier of primary energy it is a massive supplier of energy embodied in goods and services that it produces. Increases in the price of domestic energy in China will therefore ripple throughout the global supply chains and affect economic activity everywhere.

Figure 8: Global Trade in Energy, 2021

(a) Direct Energy Trade **(b) Embodied Energy Trade**

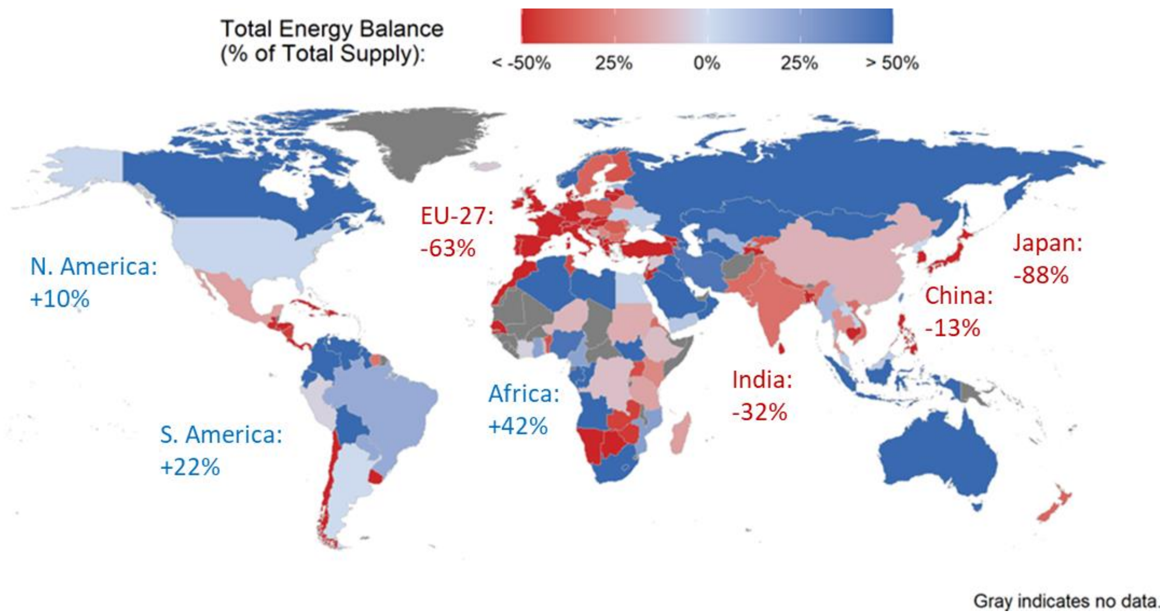


Note: Displays the source and destination of direct energy products (coal, gas, oil, and related products) and embodied energy flows including energy used to produce goods and services. The latter illustrates the source of energy and the destination that ultimately absorbed the goods and services.

Source: Author's calculations using UN-COMTRADE (HS 27 for direct flows) and UN-EORA Resource Footprints.

But the degree to which a country is exposed to energy shocks varies widely and is potentially well captured by a measure discussed previously in this chapter: the country's dependence on foreign energy sources. To illustrate this, I estimate the foreign energy embodied within final goods and services consumed in each country and compare this to the domestic energy embodied within exports of this country. The balance between these two can be positive or negative, depending on whether the country is a net exporter of embodied energy or whether it is a net importer. I find China, Russia, Taiwan, and South Africa have the largest positive balances. The United Kingdom, Hong Kong, Germany, the U.S.A., France, and Italy have the largest negative balances. I add to these measures the energy balance in primary energy products (coal, oil, and natural gas) to arrive at a total measure of energy balances for each country. I display the result in Figure 9, with energy balances expressed as a share of total energy supply available in each country. The results reveal the Americas are, on the whole, net exporters of energy. Australia, most CIS countries, and Africa as a whole, are also large net exporters. The large Asian economies of Japan, India, and to a lesser extent China, are large net importers. Japan in particular has a total energy deficit equivalent to 88 percent of total available energy supply in the country. Europe is also highly exposed to international energy shocks as, on average, the EU-27 countries overall total energy deficit is equivalent to nearly two-thirds of available supply.

Figure 9: A Measure of Foreign Energy Shock Exposure (Direct and Embodied), 2020



Note: Displays the total energy balance including both direct trade in energy products and embodied energy within all goods and services that are traded across borders. Negative values indicate more foreign energy use than domestic.

Source: Author's calculations using UN-EORA resource footprints database and the IEA (2022b).

Finally, as a concluding point for this section, how international shocks will affect domestic economies depends on one's place within the global energy trade. After all, as discussed at length in the previous section, foreign energy embodied within imported goods and services is not just consumed as final goods and services but is also embodied within intermediate inputs that may facilitate the production and export of other goods and services. Indeed, I estimate nearly three-quarters of total energy trade is accounted for by intermediate inputs traded across national borders. And nearly 14 percent are accounted for by intermediate inputs that are reexported to yet a third country following the direct import by a trade partner of the exporter. Many of these imported intermediates are used to produce exported goods by various countries. Globally, I estimate that over 44 percent of the total global energy trade is embodied within the exports of the direct importing country. For example, Canada importing an intermediate part from China that is used to produce another good for export to a third country.

A country's place within the complex web of global energy trade matters for its exposure to energy shocks. Building on the insight of the value-added trade literature, consider two measures of a country's participation in the global energy trade: forward participation and backward participation. The former is how much a country's domestically produced energy is embodied within goods and services exported to another country that is used within that country's own exports to yet some third country. Consider this country as a “supplier” of energy to another country’s exports. Backward participation, in contrast, how much foreign energy is embodied within a country’s own exports. For Canada, I estimate that 1.6 GJs per $1,000 of Canadian energy is used in the exports of another country in 2016. This is its forward participation. I also estimate that 1.8 GJs per $1,000 of foreign energy is embodied in Canada’s exports. On balance, this makes Canadian export flows slightly more dependent on foreign energy than other countries’ exports are dependent on Canadian energy. In Western Europe, that dependence is even larger. I estimate this region’s forward participation is 1.4 while its backward participation is nearly three. The exports from these countries are therefore highly dependent on foreign energy.

Conclusion

Changes in the cost of any important economic resource—whether labour, capital, or energy—will have complex and cascading effects throughout the global economy. Some sectors will expand, others will contract, and the wellbeing of individuals can also rise or fall depending on individual circumstances. In this chapter, I explored the nature and consequences of energy shocks on national economies throughout the world. The three primary sources of energy (coal, natural gas, and oil) are, by far, the dominant source of energy. And this will remain so for many years to come. Changes in global supply and demand conditions can have massive effects on the price of energy because the quantity that both buyers and sellers with to acquire and produce, respectively, are relatively insensitive to prices in the short-term. Such inelastic markets are susceptible to large price shocks even if global demand and supply change only slightly. And in 2022, price increases were indeed large. The price of Australian coal increased 150 percent in 2022 compared to 2021. The price of natural gas in Europe increased by over 150 percent. And the price of global crude oil (Brent) increased by over 40 percent.

These increases have direct effects on consumers, producers, and on the structure of an economy. There are also indirect effects throughout the supply chain, as the cost of producing inputs changes, which affects the cost of producing both other inputs and final goods. A broad view of energy use and trade is also necessary to understand which national economies are most exposed to energy shocks and how price increases affect them. Economies that are net exporters of these commodities will benefit while those that are not importers will not. Manufacturing activities that are energy intensive will contract, while others—such as upstream activities in energy producing sectors—will expand. But the picture is made more complex when energy embodied with the various goods and services that are consumed in each country are counted. Energy is exported not only directly by countries with coal, oil, or natural gas exports, but also within the goods and services a country makes. China exports significant energy around the world because it is such a large manufacturing hub. Changes in the price of energy in China, even if only domestically produced and consumed energy, can therefore have global implications as the price of goods China produces will be affected. And sectors that are indirectly energy intensive because of the inputs they require are also adversely affected. Global increases in energy prices will shift a country’s exports away from those sectors.

Combining both direct and embodied global energy flows also allow for a broad estimate of how dependent different countries are on foreign suppliers of energy. Japan, Europe, India, and China have large negative energy balances with the world while the Americas, CIS countries, and Africa have large positive balances. As the world becomes increasingly uncertain, and global energy supplies more frequently disrupted, exploring ways to lower dependency on foreign energy sources may become a leading policy priority for many countries.

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