Special Feature: Commodity Market Developments and Forecasts with a Focus on Recent Trends in Energy Demand

Energy prices have increased since the release of the April 2018 World Economic Outlook *(WEO), mostly driven by higher oil prices. Notwithstanding record-high US production, tight supply conditions and sustained economic activity in the first half of 2018 reduced Organisation for Economic Co-operation and Development (OECD) oil inventories rapidly, pushing up oil prices in May and June to their highest levels since November 2014. Since then, however, higher production in Saudi Arabia and Russia has rebalanced the oil market. A decline in metals demand from China and trade tensions have put downward pressure on metals prices. Agricultural market fundamentals, in contrast, remain solid and have partially offset the introduction of tariffs on some key agricultural products. This special feature includes an in-depth analysis of the long-term determinants of energy demand.*

The IMF's Primary Commodities Price Index rose 3.3 percent between February 2018 and August 2018, the reference periods for the April 2018 and current WEOs, respectively (Figure 1.SF.1, panel 1). Energy prices drove that increase, rising by 11.1 percent; food prices declined by 6.4 percent, while metals prices decreased by 11.7 percent because of trade tensions and weaker-than-expected metal demand from China. Oil prices increased to more than $76 a barrel in June, attaining their highest level since November 2014. Since July, however, oil prices have stabilized as Organization for the Petroleum Exporting Countries (OPEC) and non-OPEC oil exporters (including Russia) agreed to boost production. Coal prices increased strongly because of relatively tight supply conditions, while natural gas prices increased in part following higher oil and coal prices.

Oil Prices at the Highest Level since 2014

On June 22, 2018, OPEC agreed to increase its members' oil output by 0.7 million barrels a day (mbd) to offset declining output in Angola and especially in Venezuela, both OPEC members, and regain its origi-

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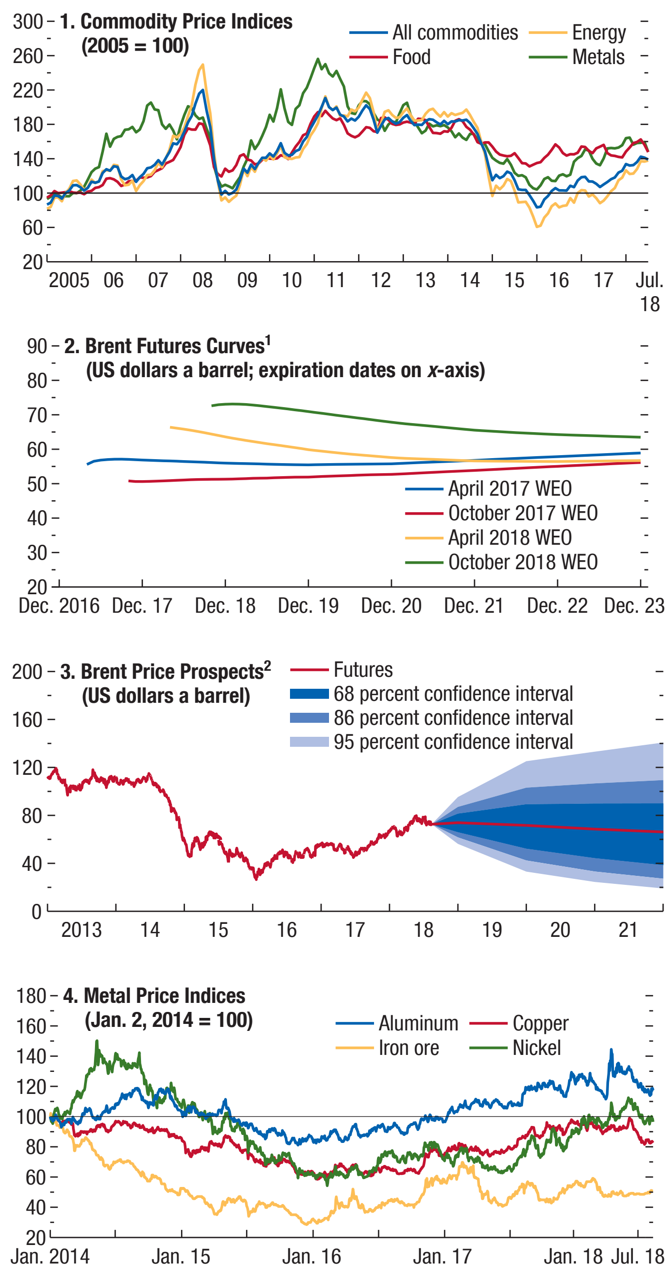
Figure 1.SF.1. Commodity Market Developments



Sources: Bloomberg Finance L.P.; Thomson Reuters Datastream; IMF, Primary Commodity Price System; and IMF staff estimates.
Note: WEO = *World Economic Outlook.*
[1]WEO futures prices are baseline assumptions for each WEO and are derived from futures prices. October 2018 WEO prices are based on August 13, 2018, closing.
[2]Derived from prices of futures options on August 13, 2018.

nal target level set in the November 2016 agreement.[1] Notwithstanding record-high US production, tight supply conditions and sustained economic activity in the first half of 2018 reduced OECD oil inventories from historically high levels to their five-year average, pushing oil prices to more than $76 a barrel in June—the highest level since November 2014. In July, however, oil prices retrenched from recent peaks and, as of August, stood at about $71 a barrel as higher Saudi and Russian production offset the effects of unplanned outages in Canada and Libya and a tougher US stance on the implementation of sanctions on Iran. Natural gas and coal prices have increased, supported by strong demand from China and India.

Oil futures contracts point to a decline of prices to about $60 a barrel in 2023 (Figure 1.SF.1, panel 2). Baseline assumptions for the IMF's average petroleum spot prices, based on futures prices, suggest average annual prices of $69.3 a barrel in 2018—an increase of 31 percent from the 2017 average—and $68.8 a barrel in 2019 (Figure 1.SF.1, panel 3). On one hand, global economic growth is expected to be relatively strong, albeit with regional differences, supporting underlying oil demand—the International Energy Agency expects oil demand to grow by 1.4 mbd and 1.5 mbd in 2018 and 2019, respectively. On the other hand, the US Energy Information Administration expects US crude production to reach 10.7 mbd in 2018 and 11.7 mbd in 2019, putting downward pressure on oil prices in the medium term. Canada's oil production is expected to grow steadily, too.

Although risks are balanced, uncertainty remains substantial around the baseline assumptions for oil prices because Saudi Arabia's spare capacity is shrinking and US sanctions against Iran will both weigh on Iran's oil production prospects in the medium term and reduce Iran's crude exports in the short term, requiring others with spare production capacity to step in. Upside risks to prices in the short term include a faster-than-expected deterioration of Venezuelan production and a larger-than-anticipated reduction in Iran's crude exports. Downside risks include higher OPEC output and stronger-than-expected Canadian and US production even though, in the short term, the United States faces bottlenecks caused by labor shortages and lack of pipeline infrastructure.

[1]The 0.7 mbd increase is the production increase necessary to bring OPEC output back to 100 percent compliance from current overcompliance (the calculations are based on International Energy Agency data).

In addition, trade tensions and other risks to global growth (highlighted in the section titled "Risks" in Chapter 1) can potentially affect global activity and its prospects, reducing, in turn, oil demand. Coal prices are expected to decline from current levels due to a rebound in supply and in line with declining oil and natural gas prices.

Metal Prices Decreasing

After peaking in February, metal prices declined by 11.7 percent between February 2018 and August 2018 because of weaker metal demand from China following stringent environmental regulations and tighter credit conditions. Global trade tensions have also added downward price pressures and substantially increased volatility in metal markets.

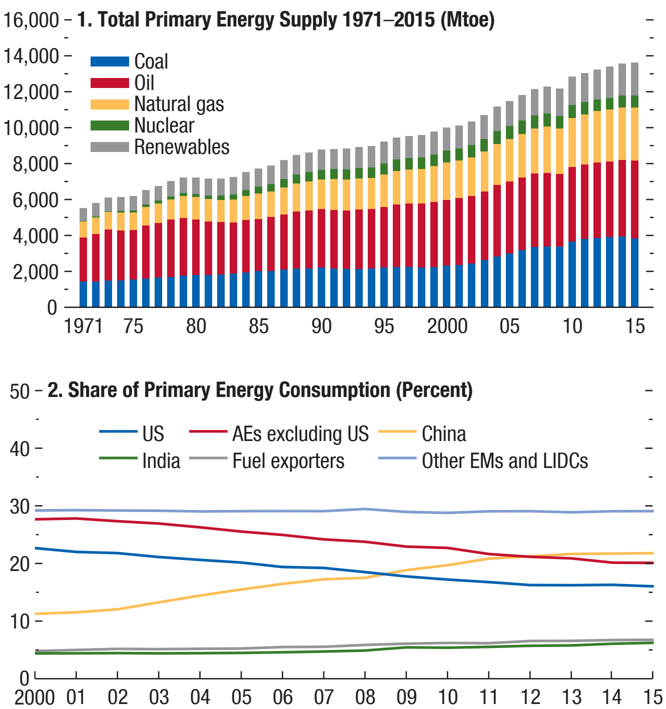
The price of iron ore, the key input in steelmaking, dropped by 12.4 percent between the reference periods because of US tariffs on steel, substitution with scrap by Chinese steelmakers, and China's production curbs across major steel mills. Copper prices declined after the fear of a strike at the world's largest copper mine in Chile faded, while aluminum prices went through a period of high volatility following US sanctions on the giant Russian aluminum and alumina producer (United Company Rusal), along with trade tensions. Nickel, the main input for stainless steel and batteries in electric vehicles, reached multiyear highs in early June 2018 and then declined to its February price on trade tensions. Zinc, mainly used to galvanize steel, dropped 28.9 percent between February and August 2018 following surging stockpiles and weak demand from China.

The IMF annual metals price index is projected to increase by 5.3 percent in 2018 (relative to its average in 2017) but to decline by 3.7 percent in 2019 from its 2018 average. Upside risks to the outlook for metal prices include sanctions against metals producers and easing environmental regulations in China. Downside risks are mounting because of trade tensions, higher-than-expected metals production in China, and a slowdown of the Chinese economy, which accounts for more than half of the world's metals consumption.

Food Prices Decreasing and Trade Risks Remain

Although agricultural market fundamentals remain solid, the IMF's agricultural price index decreased between February 2018 and August 2018

Figure 1.SF.2. Primary Energy Consumption and Supply



Sources: International Energy Agency; and IMF staff calculations.
Note: AEs = advanced economies; EMs = emerging markets; LIDCs = low-income developing countries; Fuel exporters = Algeria, Angola, Azerbaijan, Bahrain, Bolivia, Brunei Darussalam, Ecuador, Gabon, Iraq, Kazakhstan, Kuwait, Libya, Nigeria, Oman, Qatar, Saudi Arabia, United Arab Emirates, Venezuela; Mtoe = million tons of oil equivalent.

by 6.4 percent on trade tensions and concerns over global growth.

Wheat prices increased by 22.6 percent between February 2018 and August 2018 following adverse weather conditions during spring and summer in Russia and western Europe, respectively. Soybean prices fell sharply, however, in June and July after China announced a 25 percent retaliatory tariff on US soybean imports and US production numbers for 2018 were revised upward. As a result, prices stood 14.7 percent lower in August 2018 than in February 2018.

Food prices are projected to increase in 2018 by 2.3 percent, and by a further 1.7 percent in 2019. Weather disruptions are an upside risk to the forecast. As of August 9, 2018, the National Oceanic and Atmospheric Administration puts the chances of El Niño during winter 2018–19 at 70 percent. A deepening of the trade conflict between the United States—the world's largest food exporter—and several of its key trading partners constitutes a major downside risk.

Global Energy Demand

The consumption of energy services and liquid fuels is pervasive and essential in the economic system and is the major driver of demand for primary energy sources, such as fossil fuels, nuclear, and renewables. Increased energy efficiency, however, has raised the possibility of reaching a saturation point in the global demand for energy (or some of its primary energy sources), which could leave producer countries with overcapacity and stranded assets. Moreover, the use of energy, especially in the form of fossil fuels, gives rise to a multitude of environmental externalities, the severity of which, in turn, depends on the energy mix used and the technologies adopted (Stern 2006; IPCC 2014).

This section analyzes the main drivers of energy demand and the evolution of the primary energy–source mix by looking at long-term trends in energy efficiency; exploring the role of power generation in energy demand; and investigating the presence of an S-shaped relationship between energy and income that would, ultimately, induce saturation in energy demand (Wolfram, Shelef, and Gertler 2012).

Basic Facts

The demand for energy services and liquid fuels induces a direct and indirect (through power generation) demand for primary energy sources. Electricity has been a key force in the past decades: energy demand from power generation increased by nearly 300 percent between 1971 and 2015—almost twice the rate of total energy. This phenomenon, dubbed *electrification*, has sustained the demand for coal and has led to a major decline of oil as a share of total energy and to increases in natural gas usage, and, more recently, in renewables (Figure 1.SF.2, panel 1). Indeed, power generation today accounts for more than 40 percent of the demand for primary energy, and for about 55 percent if oil is excluded, which instead is mostly used in the transport sector.

Although power generation has contributed significantly to global energy demand growth, it is worth looking at contributions by country. Emerging markets, especially China and, more recently, India, have driven most of the energy demand growth of the past 15 years (Figure 1.SF.2, panel 2), while the contribution of advanced economies has been minimal, leading to a decline in their world consumption shares and raising the prospects of saturation in energy

Table 1.SF.1. Total Demand Determinants for Baseline Specification

	(1)	(2)	(3)	(4)
Population	1.079***	0.965***	0.959***	1.161***
GDP per Capita	–7.103*	–8.676**	–5.068*	–6.889***
(GDP per Capita)^2	0.843*	1.044**	0.639*	0.865***
(GDP per Capita)^3	–0.0293	–0.0378**	–0.0231	–0.0330***
Area		0.0798	0.0953*	
Oil Exporter		–0.0173	0.00523	
Gas Exporter		0.0483	–0.0478	
Coal Exporter		0.378**	0.315**	
Coal Producer		0.251*	0.132	
Latitude			0.0138***	
Static Saturation Point	401,087	179,389	323,516	82,921
Dynamic Saturation Point (1% eff. gain)	127,286	63,590	74,050	17,831
Dynamic Saturation Point (spec. eff. gain)	33,576	38,410	41,298	25,281
Inflection Point	14,447	10,039	10,184	6,204
Max Elasticity	0.9723	0.9416	0.8280	0.6660
Average Elasticity	0.9721	0.9233	0.8177	0.5888
R^2	0.95	0.96	0.97	1.00
Model	WLS	WLS	WLS	WLS – FE

Sources: International Energy Agency; World Bank, World Development Indicators database; and IMF staff calculations.
Note: Energy exporters and producers are derived from the International Energy Agency. Average elasticity is calculated at $15,000 2011 international US dollars. "eff. gain" is efficiency gain. "spec. eff. gain" is specific efficiency gain calculated using each specification's average growth of time dummies. FE = fixed effects; WLS = weighted least squares. Latitude is the absolute value of latitude in degrees for national capitals.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

demand for advanced economies (Wolfram, Shelef, and Gertler 2012). This dissimilarity suggests a relationship between stages of development and the elasticity of energy demand to income. Farrell (1954) and, more recently, Gertler and others (2016) postulate an S-shaped relationship between electricity demand and household purchases of durable goods (such as domestic appliances and automobiles). Dargay and Gately (1999) and Dargay, Gately, and Sommer (2007) find such an S-shaped relationship for car ownership. The next section tests whether such a relationship holds more generally for energy demand and income.

Energy and Income: An S-Shaped Relationship

Using an unbalanced panel of 136 countries, this analysis tests for the presence of an S-shaped relationship between energy demand and per capita income, controlling for the size of the country (that is, population and land area) and fossil fuel abundance. Time fixed effects are used to capture worldwide gains in energy efficiency and fluctuations in global economic activity and energy prices. The sample is annual and spans 1971–2015, covering two major energy price cycles. Specifically, the exercise estimates the following specification relating (log) total energy demand E to (log) population, *pop*; a third-order polynomial in (log) income per capita, *gdp*; and a vector of control variables, X:[2]

$$E_{it} = \beta_0 + \beta_1 pop_{it} + \beta_2 gdp_{it} + \beta_3 (gdp_{it})^2 + \beta_4 (gdp_{it})^3 + \beta_5 \times X_{it} + \lambda_t + \varepsilon_{it} \quad (1.1)$$

in which λ_t are year fixed effects, while X_{it} includes a time-varying energy-export and coal producer dummy, distance from the equator, and the log of land area; the indices i and t refer to countries and years, respectively.[3]

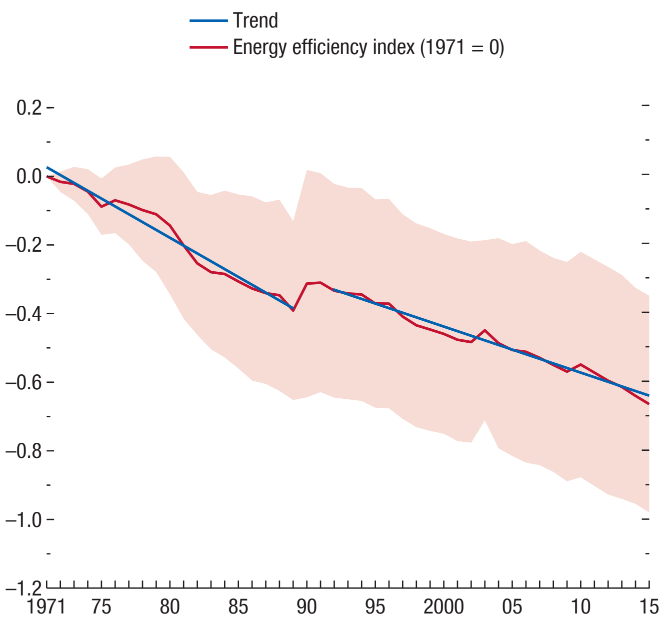
Results for the baseline specification, column (2), and robustness checks are reported in Table 1.SF.1 and in Online Annex 1.SF.1.[4] Not surprisingly, the analysis finds that energy demand moves in lockstep with population. Point estimates suggest that having a sizable land

[2]Energy demand (in million tons of oil equivalent) is the sum of electricity and primary energy supply (that is, coal, oil, natural gas, hydropower, nuclear energy, and renewables). Energy data are from the International Energy Agency; data on population, GDP per capita (in 2011 US dollars), and country area size (in square kilometers) are from the World Bank's World Development Indicators database. Latitude is from the GeoDist database by Centre d'Etudes Prospectives et d'Informations Internationales.

[3]An oil exporter is defined as having oil production exceeding consumption. A similar definition is used for natural gas and coal exporters. A coal producer is defined as having production able to satisfy between 60 percent and 100 percent of the country's coal consumption. Distance from equator is the absolute value of latitude.

[4]The annex is available online at www.imf/en/Publications/WEO.

Figure 1.SF.3. Energy Efficiency



Sources: International Energy Agency; World Bank, World Development Indicators database; and IMF staff calculations.
Note: The red line represents the time fixed effects estimated in Table 1.SF.1 column (2) with 95 percent confidence intervals (shaded area). The blue line is a linear trend estimated for the period 1971–89 (1992–2015) with a slope of 0.23 (0.13).

area, coupled with being a coal exporter (producer), increases energy demand by about 45 (33) percent.

Turning to income, the data strongly support the presence of an S-shaped relationship between per capita energy consumption and per capita income. The inflection point in the energy-income relationship (that is, the maximum income elasticity) is about $10,000 (in 2011 US dollars), which is below the global per capita income in 2015, which stood at $15,000 (2011 US dollars). Indeed, this inflection point has already been reached by many emerging markets. At that income level, the energy income elasticity is close to one.

At higher income levels, the elasticity starts to decline. Ultimately, as income keeps growing, the economy would reach a saturation point for energy demand; however, at an estimated $180,000 per capita (in 2011 US dollars) the saturation point looks, at current technology, to still be very far into the future.[5]

Energy-saving technologies, however, can lead to faster actual saturation by shifting the energy-income curve downward because the same economic activities (such as heating, cooling, and transport) require less energy. In the regression, improvements in energy efficiency globally are captured by the time dummies, which show a remarkably steady decline (Figure 1.SF.3).

Indeed, except for during 1990–92 (mostly affected by the inclusion in the sample of former Soviet Union countries, whose energy efficiency was lower), the improvement in energy efficiency has been very steady, averaging about 1 percent a year over the entire sample. If it is conservatively assumed that energy efficiency globally keeps increasing at its historical rate of 1 percent a year, the saturation point previously estimated drops to about $64,000 per capita.[6]

The estimated S-shaped energy-income relationship (Figure 1.SF.4) not only predicts energy demand growth to be highest in emerging markets but also captures the behavior of energy demand at low-income levels. Typically, in most low-income countries, energy consumption initially declines in response to income growth probably as the result of graduation from biomass (solid biofuels excluding charcoal)—an inefficient source of energy. Biomass, in fact, is an inferior good, implying that households reduce its use as income grows. The share of biomass in total primary energy supply of the country tends to decline as income grows (Figure 1.SF.5).

In conclusion, the evidence suggests that the relationship between energy demand and income follows an S-shaped curve, with an initial decline of energy demand at low levels of income followed by stages of acceleration and then saturation at middle- and high-income levels, respectively. Thus, the main driver of future energy demand hinges on the dynamics of middle-income countries. In fact, even though some advanced economies may have already reached saturation in energy demand, estimates suggest that global saturation is still far into the future. However, total energy is not all that matters. The same level of energy consumption can be the result of varying mixes of primary energy sources, which is the topic of the next section.

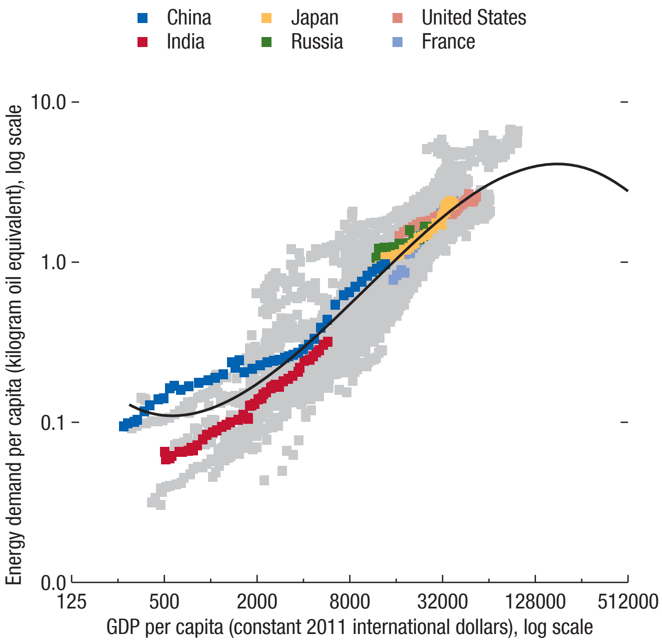
The Primary Energy Mix

The optimal energy mix in each country is the result of relative resource abundance, technology, and social

[5]An economy with a $50,000 per capita income today (for example, Germany) growing at 2 percent a year would take 65 years to reach a per capita income of $180,000.

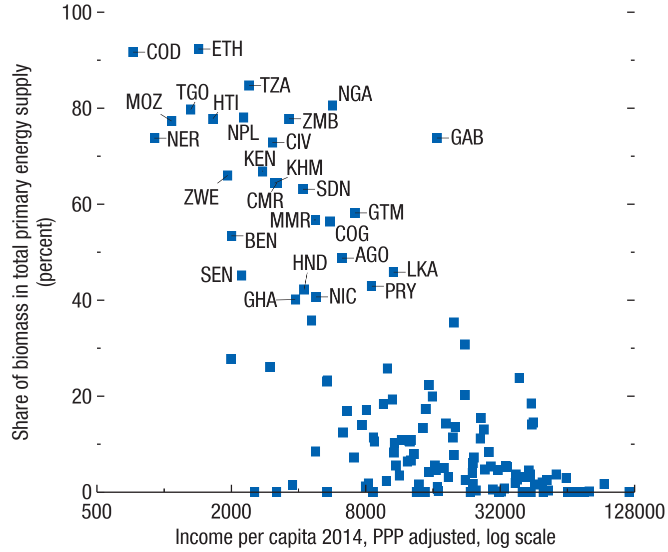
[6]An economy with a $50,000 per capita income today (for example, Germany) growing at 2 percent a year would take 13 years to reach a per capital income of $64,000.

Figure 1.SF.4. Energy Demand and GDP per Capita



Sources: International Energy Agency; World Bank, World Development Indicators database; and IMF staff calculations.
Note: Adjusted fitted values show the S-shaped energy-income relation (constructed using the cubic polynomial) while energy demand per capita is adjusted for estimated time fixed effects. Estimates are from the baseline specification.

Figure 1.SF.5. Biomass



Sources: International Energy Agency, IEA Renewables Information Statistics; World Bank, World Development Indicators database; and IMF staff calculations.
Note: Data labels for countries with biomass shares greater than 40 percent are displayed in the figure. Data labels in the figure use International Organization for Standardization (ISO) country codes. PPP = purchasing power parity.

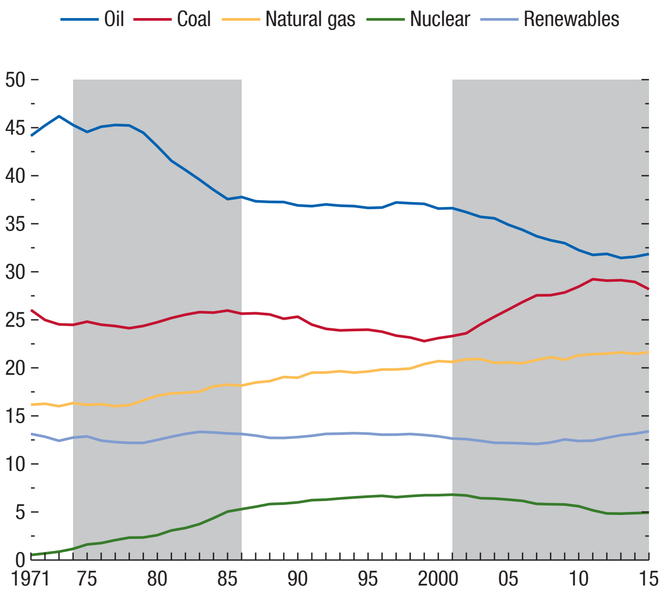
preferences. The local relative abundance or availability of an energy source determines its local costs, while the efficiency of use in production determines its desirability (that is, its marginal benefit).[7] These two factors combined help determine the relative price of an energy source. Technical substitutability across resources then determines the impact of changes in efficiency of use or relative prices on the energy mix. For example, the relative importance of oil as a primary energy source has substantially declined over time as other energy sources became cheaper (such as coal and nuclear in the early part of the sample) or more desirable to use (such as natural gas and, more recently, renewables). The link between high and volatile crude oil prices and the decline in the oil share is indeed noticeable (Figure 1.SF.6).[8] Over the long term, however, efficiency is also determined by capital investment, which allows the potential of an energy source (for example, investment in solar power or natural gas infrastructure) to be better exploited. This generates a relationship between the energy mix and the stage of development (see Online Annex 1.SF.1 for further details).

At medium- and low-income levels, the semi-elasticity of the oil share to income is positive as the transport sector expands (for example, car and truck ownership increases), but it turns negative at higher income levels when the stock of motor vehicles plateaus, fuel efficiency reduces gasoline consumption, and cleaner natural gas is preferred in heating and power generation. Regressions, indeed, suggest that peak oil demand may have already been reached for some advanced economies, given that their oil share declines while energy demand is close to saturation (see Online Annex 1.SF.1). In contrast, the share of natural gas seems mostly independent of income.

The relationship between income and the share of coal is weak because higher incomes are associated with cleaner energy sources but also with higher electrification rates (the main driver of coal consumption). At medium incomes, however, coal has proved

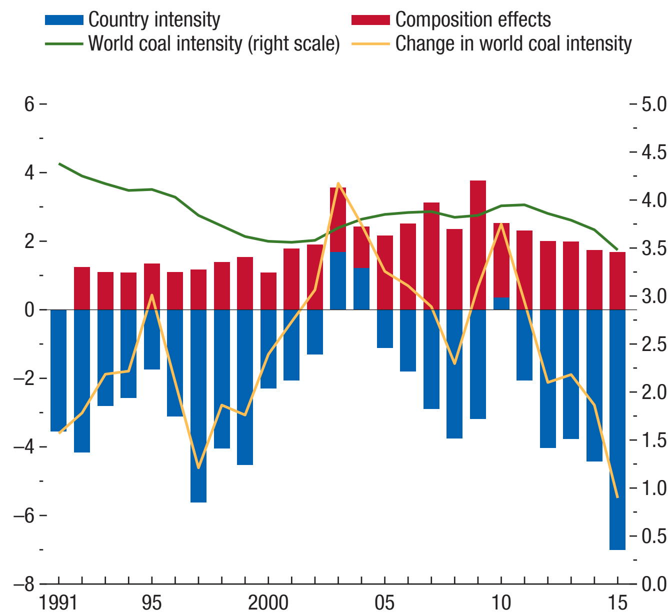
[7]It is up to policy to align private and social marginal benefits.
[8]In most advanced economies, the two oil shocks of the 1970s that generated high oil prices called into question the energy security of oil and led to a switch in the power sector, with oil being replaced by alternative sources of power generation, such as coal, natural gas, and nuclear power.

Figure 1.SF.6. Primary Energy Source Shares
(Percent)



Sources: International Energy Agency; and IMF staff calculations.
Note: Sample is International Energy Agency world aggregate; grey shaded area = high and volatile oil prices; nonshaded area = low and stable oil prices.

Figure 1.SF.7. Decomposition of Change in World Coal Intensity
(Percent)



Sources: International Energy Agency; World Bank, World Development Indicators database; and IMF staff calculations.

to be a cheap and abundant energy source able to satisfy a quickly growing demand for electricity, especially in some large, coal-abundant emerging markets, such as China and India (being a coal producer or exporter increases a country's coal share by 10 percentage points or 18 percentage points, respectively). Hence, notwithstanding a reduction of coal intensity at the country level, the legacy of high coal usage in large and fast-growing economies led to a surprise increase in global coal intensity in the mid-2000s (Figure 1.SF.7). As China and other major emerging markets develop, however, demand for cleaner fuels is expected to increase, leading to a decline in the coal share.

Although it is too early to assess the evolution of renewables, the analysis clearly points to an increase in the use of renewables in high-income countries, especially for power generation. Advanced economies, in fact, are typically highly electrified while emerging markets, as they become more urbanized and expand the electricity grid, are expected to substantially increase their electrification rate in the medium term. The projected rise of the electric car and growth in the services sector, moreover, are expected to increase the electrification rate in advanced economies, too.

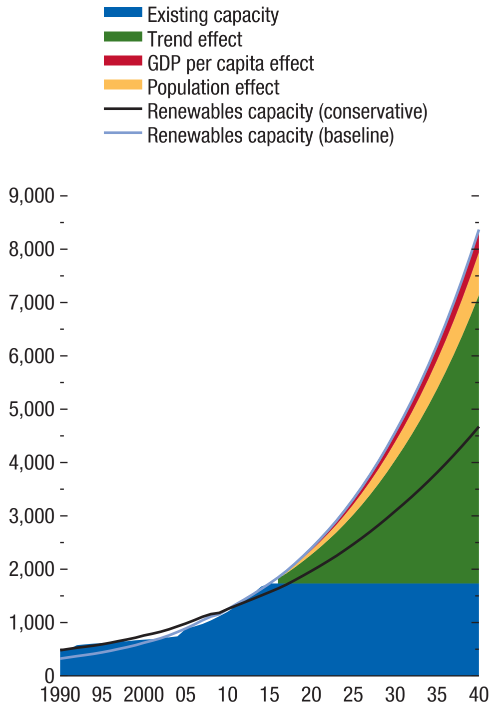
The implication of higher electrification rates is important for primary energy demand. In fact, while oil saturation will probably be reached sooner than total energy saturation (as oil's share in the mix declines), saturation for natural gas and renewables will come later. Recent sharp declines in the price of solar photovoltaic cells and government support for the development of renewables are paving the way for the rapid growth of renewables (see Box 1.SF.1). Although coal may remain attractive for some countries, local air pollution has compelled China and India, to some extent, to shift toward renewables. Thus, cost changes and environmental concerns will play a key role for the increased penetration of renewables and the saturation point for coal.

Conclusion

Most of the increase in energy consumption is expected to come from emerging markets whose energy demand is approximately at its peak income elasticity, which is about one. In contrast, that elasticity is close to zero for advanced economies, suggesting that their contribution to energy demand growth will be more modest or possibly absent. Nonetheless, emerging markets' saturation point for energy demand is still far in the future—even assuming steady gains in energy efficiency. Saturation, however, is probably much closer for some energy sources, such as coal and oil, raising the risk of stranded assets for high-cost projects, while other sources, such as natural gas and renewables, are expected to become more important in the energy mix as electrification rates increase. Even though dynamics in energy transitions and technological innovations are hard to predict, substantial long-term investment is required to change the energy infrastructure of an economic system (for example, the life of power plants and airplanes is about 40 years). Nonetheless, climate concerns, energy policies, and market forces will be key in forging future energy markets as energy regulation and prices interact to stimulate or constrain technological innovation. It is the role of policymakers to exploit these interactions to develop ecologically sustainable economies.

Box 1.SF.1. The Demand and Supply of Renewable Energy

Figure 1.SF.1.1. Renewables Capacity
(Gigawatts)



Sources: Organisation for Economic Co-operation and Development; US Energy Information Administration; World Bank, World Development Indicators database; and IMF staff calculations.

The rapid growth of renewable energy since the beginning of the 21st century (see Online Annex 1.SF.1) can be attributed to several demand- and supply-side factors. First, governments have implemented a variety of energy policies over the years that have helped countries lower their greenhouse gas emissions. Second, aided by regulatory pressure, technological innovation has reduced the cost of wind and solar energy substantially in recent years (Goldman Sachs 2015; IRENA 2017).[1]

Using a model that relates renewable energy capacity to GDP per capita, population, a set of control variables, and a trend, this box analyzes the outlook for renewable energy capacity (see Online Annex 1.SF.1). Results depend on whether the relationship is estimated over the full sample (1990–2015) or only over the most recent sample (2000–15), as the trend coefficient increases from 1.7 percent a year to 3.9 percent in the most recent sample. The rising trend reflects performance improvements and price reductions in several major renewable energy technologies, most notably solar panels and wind turbines.

An out-of-sample prediction, focusing on 45 countries for which long-term forecasts for GDP per capita and population size are available (OECD 2014), shows that, under the conservative forecast, the world will have accumulated more than 4,600 gigawatt of renewable energy-generating assets by 2040. This number increases to more than 8,400 gigawatt in the baseline scenario—a fourfold increase from 2015.

The increase in renewable energy capacity under the conservative and baseline scenarios will, respectively, deliver 732 million tons and 1,733 million tons of oil equivalent of energy to the electricity grid, equal to 50 percent and 117 percent, respectively, of all electricity generated by fossil fuels in 2015. Indeed, if the new renewable energy capacity were to displace fossil-fuel-based electricity generation, it would constitute a sizable step in reducing global greenhouse gas emissions.

Figure 1.SF.1.1. decomposes future renewable energy growth under the baseline scenario into income, population, and the trend effect. This shows that renewable energy investment is driven mostly by supply (technology) rather than demand (income and population), which is in line with the popular rationale of an energy transition led by innovations in wind, solar, and other technologies. The same dependence on a persistence in the trend factor, however, makes the outlook for renewable energy uncertain.

The authors of this box are Christian Bogmans and Lama Kiyasseh.

[1]Other factors of importance are the rate of interest; cross-country differences in endowments of human capital and raw potential for wind, solar, and hydro energy (Collier and Venables 2012); and government support for renewable industries (see Zhang and others 2013).