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Part I

Introduction

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1 The Asia-centric coal era

Mark C. Thurber and Richard K. Morse

1.1 Introduction: coal's dominant role in the world energy mix

The world has witnessed tremendous upheaval in global energy markets in the last decade. Oil markets were roiled by war and uprisings in the Middle East, with economic expansion helping to push real oil prices to near-record high levels. Natural gas production in the United States was revolutionized with the emergence of new techniques for extracting gas from shale deposits. The extension of these techniques to oil created a surge in North American oil production that, coupled with a global economic slowdown, helped bring oil prices far down from their peak. Nuclear power appeared on the verge of a dramatic expansion before its rise was cast into doubt by the tragic disaster at Fukushima in March 2011. And renewable energy began to grow from a small contributor to world energy supplies into one of the largest sources of new electricity generation in many markets. Those narratives, for the most part, are well known. But one of the most important stories in modern energy markets remained largely untold and unappreciated, even as it reshaped the map of global energy use and the pace of climate change. That story is the story of coal's stunning growth.[1]

For more than a century, coal has been a cornerstone of the global energy supply due to its wide availability and low cost of extraction. In recent years, far from seeing its place overtaken by competing energy sources, this catalyst of the Industrial Revolution[2] has grown to have an even more pivotal role in the world's energy mix (see Figure 1.1). Over the decade to 2012, energy generation from coal grew far faster in absolute terms than any other energy source. In fact, coal served nearly as much incremental demand for primary energy as *all other forms of energy combined* (IEA 2013). As of 2011, 29% of total world energy was supplied by coal, second only to oil at 31% (IEA 2013). Most of this coal is used in the power sector, where it accounts for more than 41% of global electricity production (IEA 2013) – a larger share than any other form of energy. If

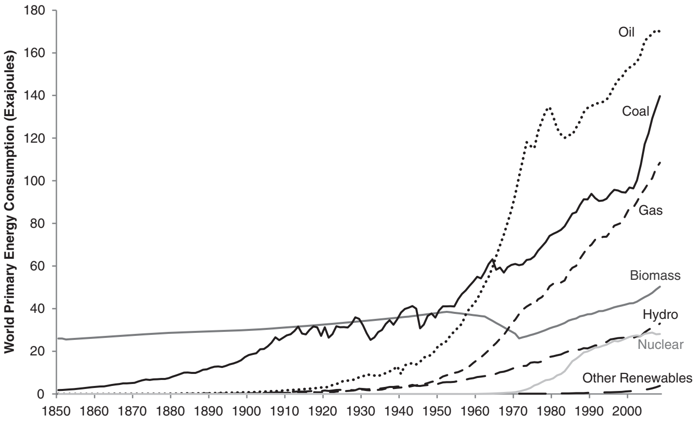

Figure 1.1 Historical trends in world primary energy consumption by energy source. Data sources: IIASA (2012); Grubler (2012).

there is no new policy action on climate change, coal is expected to be the single largest source of energy globally by the early 2020s, overtaking oil (IEA 2013, p. 58).[3]

Coal use in Europe and the United States powered the first global industrial revolution; the second coal era is centered in Asia and is intimately connected to the rise of developing economies. In its "New Policies Scenario,"[4] the International Energy Agency (IEA) projects a reduction in coal demand from developed countries of 362 million tonnes (Mt) per year by 2035, but an increase from non-OECD (Organization for Economic Cooperation and Development) countries of 1,298 Mt/year, of which demand from China, India, and ASEAN nations accounts for 90% (IEA 2013, p. 145). Coal-fired power has helped drive robust economic growth in these and other Asian countries, which in many cases see few affordable alternatives to coal.

As coal is transforming economies, it is also transforming the climate through its CO_2 emissions, and in many cases leaving local pollution problems such as acid rain and smog in its wake. Coal combustion is now responsible for more CO_2 equivalent emissions than any other fossil fuel (Figure 1.2). And while the SO_2, NO_x, particulate, and toxics emissions that degrade local air quality can be mitigated to a substantial degree through well-understood and affordable technological fixes, curtailing CO_2 emissions from coal is a much more difficult task (see Section 1.4.2 of this chapter). The IEA predicts that about half the total increase in global CO_2 emissions from fossil fuel use by 2035 will come from coal use in

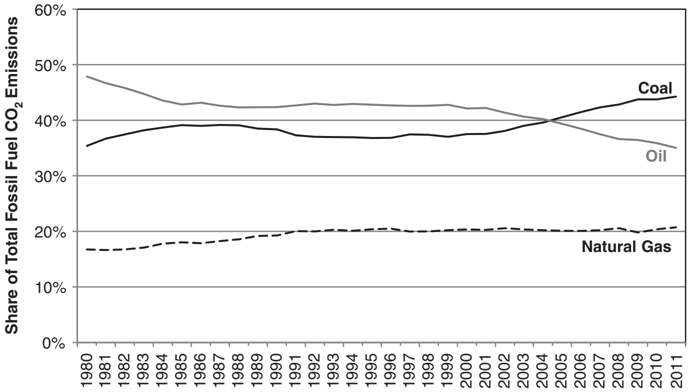

Figure 1.2 Share of total global CO_2 emissions from fossil fuels for coal, oil, and natural gas. Data source: EIA (2014).

non-OECD Asia (IEA 2013).[5] Coal appears likely to persist as the single largest cause of global warming in the coming decades.

But seeing coal solely as "climate enemy number one" misses an important point. Just as coal is the leading *cause* of climate change, so it represents a leading *opportunity* for carbon mitigation. As an illustration of this, we estimate that upgrading the average efficiency of China's fleet of coal power plants by 4%, which is ambitious but not infeasible, would contribute more to CO_2 mitigation on an annual basis than all of the world's wind, solar, tidal, and geothermal energy generation.[6] (Of course, such a reduction in emissions intensity would not be able to counter the increase in emissions if China and other countries continue to build *new* coal power plants at a rapid pace.) This suggests that emerging technologies that might reduce the environmental impact of coal are essential to the fight against climate change. There is another important reason why those who are serious about combating climate change need to understand the world's coal markets – namely, those markets play a key role in determining the competitiveness and viability of alternative energy sources. Coal-fired power represents the cheapest source of electricity in many economies.[7] Thus coal prices help determine the levelized cost of electricity against which "cleaner" generation sources have to compete in the market. Factors that cause coal prices around the world to increase or decrease will have a direct effect on the size of this cost gap, the competitiveness of alternatives to coal, and consequently global carbon emissions.

In short, no climate policy is likely to succeed without a strategy for cleaning up or displacing coal. Efforts by environmentalists to block new coal plants in the US and Europe are an implicit recognition of this fact. However, such efforts risk irrelevancy if they fail to recognize the interconnected nature of the global coal market and the central role of developing economies in determining the future of coal. Moreover, many of these emerging economies feature heavy government control and regulation of markets, necessitating a different understanding of the possible drivers of change.

One of the key objectives of this book is to understand how domestic coal markets in large developing countries will interact with and shape global coal markets. We will consider which domestic factors in key coal-producing and consuming countries have the most impact on the balance of global coal supply and demand, and thus on world prices. As one example, understanding that China, now the world's largest importer of steam coal, imports coal as a form of price arbitrage rather than because of a domestic shortage (Chapter 9) may lead to a surprising conclusion – namely, that the single largest source of incremental demand in world coal markets over the last five years is highly dependent on the particulars of domestic Chinese energy policy. As another example, whether India's domestic coal monopoly, Coal India Limited (CIL), can increase production to meet domestic demand will have major impacts on how much coal India seeks on world markets as well as on the country's CO_2 emissions. Models of the global coal trade that capture these important feedback effects between domestic and global markets are needed to better understand such effects (Chapters 9 and 10).

The China case highlights another key theme of our analysis: that heavy market intervention by governments in key coal countries means that the leverage points over coal production and use are different than in more liberalized economies.[8] For example, it is impossible to understand China's coal industry without understanding its largest, highly regulated customer, the power industry, which is majority government-owned. China's government is very concerned with maintaining low prices for electricity – both to hold down inflation and to fuel industrial development and economic growth. But as coal markets and prices have been partially liberalized over several decades to incentivize production, the power sector has not kept pace and remains dominated by state-owned firms providing electricity at fixed prices (see Chapter 2). The result today is what is known as the "coal-power conflict," in which the mismatch in industrial organization between the coal and power sectors, and the constraint of the monopoly rail network that transports coal, creates significant distortions and bottlenecks in the coal-to-power value chain – especially when coal prices go up. To illustrate how dramatic these distortions have become, for many periods between 2009 and 2012, raw coal was worth more on an energy basis than the final product, electricity, it was used to produce (see Chapter 12). This resulted in supply shortages, the imposition of price controls, and an urgent need for imports. China is looking to vertical integration as one possible solution to these problems, which have resulted from its hybrid of liberalized market and state control (Chapter 3).

We also examine the even more daunting challenges India's government faces around the performance of its coal-producing and consuming industries, which are the result in part of the ways India has involved itself in coal, rail, and power markets (Chapter 4). Due to a low-performing state coal company and rail monopoly, an unsettled legal regime around land rights, and conflict in coal-producing regions, the country's domestic production is falling far short of demand. The government has projected that India's "coal deficit" could reach around 185 Mt by 2017 and over 270 Mt by 2021–2022 (*Economic Times* 2012; Thapar 2015). However, given government control over power prices and numerous other dysfunctions of the Indian power sector, including line loss and theft, there are serious questions about whether India can generate the revenue from electricity sales that would enable it to pay for sufficient coal from the international market. How the interaction between India's power sector and its monopoly coal producer evolves may have a crucial influence on whether massive import demand from the country materializes.

We devote significant attention to major coal-exporting countries, which to varying degrees are facing supply expansion problems of their own. Australia (Chapter 6), Indonesia (Chapter 7), and South Africa (Chapter 5) have contended with challenges of different sorts in the development of new mines and/or transportation infrastructure. At times, competing priorities seem to be making it more difficult than in the past for these countries' governments to maintain a supportive policy environment for the coal export industry. Constrained supply from these key exporters would reverberate throughout the global coal market.

To gain insight into these kinds of issues – how the global coal market works and the economic and environmental implications – this book poses three fundamental questions. First, which kinds of government intervention – such as economic and environmental regulation at central and local levels of government, or direct involvement in coal-producing or consuming enterprises through state ownership – have tended to have the most significant impact on the evolution of coal production and consumption in a country? Second, how do domestic policies and stakeholder processes in key producing and consuming countries collectively impact the global coal trade and shape economic and environmental outcomes? Third, can policy or technological measures reconcile increased coal use with the imperative to reduce greenhouse gas emissions, and, if so, what will be the resulting impacts on global coal markets?

In Sections 1.2 through 1.4 of this introductory chapter, we elaborate on each of these three questions, provide relevant background, and discuss how our country case selection provides insights into these questions. Section 1.2 describes how the nature of government regulation strongly affects the character of the coal value chain and, as a result, the functioning of the coal market itself. Section 1.3 charts the historical evolution of the international coal trade and sets the stage for subsequent discussion of how this trade functions at present and will evolve going forward. Section 1.4 considers how the different instruments of international and domestic climate policy as well as emerging "clean coal" technologies might affect the coal industries of specific producing countries and the global coal market. Finally, Section 1.5 concludes with a description of how this book is structured in order to address the central questions we pose.

1.2 The coal value chain

1.2.1 A brief introduction to the coal value chain

Coal was a key driver of the Industrial Revolution that began in Great Britain in the mid-1700s. It substituted for increasingly scarce biomass in firing blast furnaces for the production of iron, was tapped as a fuel for commercial and residential heating, and, with the refinement of steam engine technology, found growing use in all applications requiring mechanical power, prominently including manufacturing, mining, and transportation (Landes 1969; Gordon 1987). By the 1920s coal had surpassed biomass as the preeminent fuel in the global energy system (Wilson and Grubler 2011).

With the sharp rise after World War II in the availability of petroleum-based fuels and electricity, which have higher energy densities and are easier to transport,[9] coal use became increasingly concentrated in power generation and iron making. In the latter application, coal has unique technological advantages. Specific kinds of low-ash, low-sulfur coals ("coking coals") are used to produce "coke," a solid fuel that meets the special chemical and physical requirements of the iron-making process (Landes 1969; Gordon 1987). Electricity generation or industrial uses do not demand coals with the exacting specifications of coking coals, explaining the characteristic differentiation of coal into "steam" and "coking" types. In this volume we focus on steam coal markets, which now represent the majority of internationally traded coal and are most consequential for today's global energy system.

Before it can be used to efficiently generate electricity, coal requires additional processing. It is typically pulverized prior to burning. It may also be screened and washed to reduce impurities. Less commonly, it is converted into a gaseous or liquid fuel by means of thermo-chemical conversion processes such as gasification and pyrolysis. Because of the required pre-combustion processing and handling, and sometimes the environmental controls that are mandated, coal power plants are significantly more capital-intensive than oil- or gas-fired alternatives. Large power plants provide economies of scale in coal processing and environmental control, making electricity generation in such facilities a preferred application for coal. But coal's only competitive advantages as a fuel for power generation relative to oil and natural gas are low cost and wide availability. In growing economies such as those of China and India, where coal is one of the relatively few domestic energy resources found in abundance, these advantages are of overriding importance.

Transportation of coal from mines to end use sites has always been a crucial link in the coal value chain. Domestic waterways played a central role in transport in early coal markets in Great Britain and the United States (Finch 1973; Miller and Sharpless 1985). The advent of steam-powered locomotives in the 1800s led railroads to assume the central role in coal transport that they maintain to this day.[10] The need to move coal was in fact an important spur to the development of both canal systems and, later, rail networks (Miller and Sharpless 1985; Garnett 2005). In theory, an alternative to barges and trains is to mix coal with water and transport the resulting slurry by pipeline, but disadvantages of this method include its water intensity and the need to dry the coal before burning. The only plant fueled with coal transported by this method, the Mohave Generation Station in Laughlin, Nevada, was shut down in 2005 (SCE 2012).

An alternative to bulk transport of coal itself is "coal by wire," in which electricity from coal-fired power plants near coal mines ("mine mouth" plants) is carried to the location where energy is consumed by high-voltage transmission lines (see, e.g., Gordon 1987; EIA 1998). The relative attractiveness of transporting coal versus electricity depends on a number of factors including the distance between coal mine and end use as well as the respective regulatory environments for coal transportation, power generation, and electricity transmission (including the relative ease of siting new rail lines as compared with new transmission lines). In the Soviet era, for example, the characteristics of Siberian lignite and their distance from population centers might have argued for electricity transmission from mine mouth plants, but underdevelopment in the region made this approach infeasible, whereas transport by rail was encouraged by low tariffs under central planning (Gordon 1987; Victor and Morse 2009).

1.2.2 Government involvement in the coal value chain

A key tenet of our approach throughout this volume is that the coal industry cannot be understood in isolation from the applications that it serves – particularly power generation – and the means by which it is transported.[11] The organization of these three linked industrial segments – coal production, coal transportation, and the electric power sector – is a function both of "natural" factors, such as geology and geography, and of how governments choose to control each respective segment. Regulation of one part of the coal value chain often has powerful effects on another part. Through comparative analysis of the different forms of government involvement along the coal-to-power value chain in these five key countries, we seek insight into which kinds of government policy and intervention have had the most significant impact on coal production and use over the past several decades.

There is significant literature addressing the interactions between coal, rail, and power sector regulation in the United States and Europe, but far less for the world's fastest growing coal markets – a gap that we seek to address in this book. The effect of market restructuring and price liberalization in the power, and sometimes rail, markets has been an important theme in the US and Europe. Effective deregulation of rail transport rates in the US by the Staggers Act of 1980 combined with barriers to entry have allowed railroads to exercise significant market power and extract a large portion of the rents in the coal value chain (Wolak and Kolstad 1988; EIA 1998; Busse and Keohane 2007). In fact, Gerking and Hamilton (2010) argue that the market power of US railroads has blunted the impact of SO_2 regulation on the US coal market, illustrating the potential policy implications of how the coal value chain is structured.

Restructuring of US electricity markets has required generators to compete and in turn to seek lower-cost supplies of coal (although in the last several years low prices for natural gas have exacted an even heavier toll on the coal industry by giving gas an economic advantage over coal in many cases). Generators also face more uncertainty about electricity prices and quantities and thus may prefer to procure coal via shorter, more flexible contracts. The uncertainties flowing from a competitive electricity market translate into risk that needs to be hedged by both coal and power producers, encouraging the creation of derivative financial contracts (EIA 1998).