14 Industrial Outcomes: Structural Change, Productivity Growth, Energy, and Infrastructure

During the miracle growth era, rapid growth was led by the industrial sector. Fundamental structural changes associated with this growth have reshaped industry itself, as well as the relations between industry and other sectors. This chapter presents three selected topics relating to structural change. Section 14.1 presents an overview of changes within the industrial sector, focusing primarily on manufacturing. Manufacturing grew much faster than GDP throughout the rapid growth era, and especially during the 20 years from 1991 to 2011. On closer inspection, this industrial revolution was composed of two very different sub-periods. During the first decade or so, China's industrialization consisted largely of "catch-up" industrialization, with China moving into labor-intensive manufactures usually characteristic of early stage industrialization. After the turn of the century, and especially after China's entry into the World Trade Organization (WTO) in 2001, China moved rapidly into more sophisticated industries—especially machinery—usually characteristic of later stage industrialization. Section 14.2 looks at some of the broader patterns associated with these dramatic changes. It is shown that entry and exit of firms has been rapid, and productivity growth high. Section 14.3 probes some of the implications of these patterns for China's energy supply, considering both the composition of energy supply and the prospects for energy demand. Section 14.4 concludes.

14.1 GROWTH AND STRUCTURAL CHANGE IN MANUFACTURING

Industrial growth has been rapid since the People's Republic of China was fonunded in 1949. However, during the Socialist Era, up until 1978, China's industrial development was concentrated on a few basic industrial materials. Between 1953 and 1978 per capita production of coal quintupled, that of steel increased by 11 times, and that of electricity increased by 16 times. But cloth production per capita only increased 30% over the entire 25 years, and many differentiated goods—and virtually all luxury goods—disappeared from the market altogether. By 1978, thirty-eight percent of total gross output was in the metals and machinery industry complex, yet the technological capacity of China's machinery output was extremely low, and low-quality standardized machinery was the primary product. It is only a slight exaggeration to say that Chinese industry in the late 1970s produced an iron pan and a bolt of blue cloth for each family, plus cement and machine tools for the state. Industry at this stage was hobbled by many short- comings: It was extremely capital-intensive and, as we will see in section 14.3, extremely energy-intensive as well.

After 1978, China diversified into a range of relatively low-technology, labor-intensive consumer goods that had been neglected under the planned economy. There were opportunities to produce consumer goods that required little fixed capital investment; opportunities to produce niche goods that appealed to specialized markets, even relatively low-income ones, such as buttons and thread; and opportunities to generate new employment at relatively low cost. The pattern of structural change in industry that resulted can be analyzed using the vocabulary of value chains and intersectoral linkages that we introduced in Chapters 3 and 4. In a more standard industrialization pattern we would expect a country at China's income level to primarily be "moving upstream." That is, early development having focused on light, consumer-oriented manufacturing, especially textiles and food products, the current stage of industrialization would focus on producing the intermediate goods and production machinery

needed to supply those downstream industries. This pattern (sometimes called “industrial deepening”) emerged in Japan in the 1960s and Taiwan in the 1970s. But socialist China had emulated the Soviet Union and precociously developed a few strategic upstream industries. By 1978 light and textile industries had already declined to only 27% of total output, down from 64% in the 1950s, creating the illusion that China has already passed the early, labor-intensive phase of manufacturing development. But in fact that stage had barely begun.

As a result, structural change for two decades after 1978 took on an unusual character compared to developing market economies. Instead of moving upstream, Chinese industry diversifed into previously neglected sectors, a process we might call “makeup” or “payback” industrialization. Having practiced Soviet-style “catch-up” industrialization through the 1970s, China had the opportunity to carry out “makeup” industrialization during the 1980s and 1990s. A whole range of labor-intensive, relatively low-technology sectors that had been neg- lected now presented excellent opportunities. As Table 14.1 shows, during the

Table 14.1
Real industrial growth rates, 1980–1995

Sector	Growth rate (percent)
Electronics and communication equip.	28.0
Furniture	21.9
Plastic products	20.8
Clay, stone, and other nonmetal mining	20.6
Wood and cane products	20.5
Synthetic fibers	20.4
Electric machinery	19.8
Pharmaceuticals	19.5
Leather and fur products	19.4
Metal products	19.4
Garments	19.2
Building materials	18.9
Machinery and instruments	16.9
Printing	15.9
Beverages	15.6
Paper	15.2
Ferrous metal mining	15.1
Toys, crafts, and misc.	13.7
Food proc. and products	13.3
Nonferrous metal mining	13.2
Rubber products	12.8
Tobacco products	12.8
Chemicals	12.5
Tap water	11.1
Textiles	10.2
Nonferrous metallurgy	10.2
Electricity and hot water	9.9
Ferrous metallurgy	9.3
Refining, coke, and coal gas	8.6
Coal	7.7
Oil and natural gas	4.4
Lumber	3.7

1980s and 1990s the fastest-growing sectors were typically light, labor- intensive manufacturing. Some of these previously neglected sectors were relatively high-technology, and others were decidedly “low-tech.” Electronics, plastic products, and garments all grew 20% per year or faster. In a sense, then, China has been filling in the gaps in the industrial input–output matrix. The data in Tables 14.1 and 14.2 are taken from Chinese industrial censuses. Censuses that cover industry were carried out in 1980, 1985,

1995, 2004, 2008 and 2013. THIS CHAPTER WILL BE UPDATED WITH CONSISTENT COMPARATIVE DATA THROUGH 2013. Overall industrial gross output grew at 14% annually between 1980 and 1995, when a consistent price base is used (compared with 15.7% reported in Chinese official data, using a shifting price base).

Table 14.2
Shares of total industrial output (percent)

Sector	1980	1995
Mining	12	6
Standardized products	33	26
Semistandardized	25	23
Differentiated manufactures	25	42
Utilities	5	3

Semistandardized products include chemicals, textiles, wood products, and building materials.

Table 14.2 summarizes one aspect of the data. The share of industrial output made up of differentiated final products—machinery and electronics, light manufactures, plastic products, and so on—increased by about 17 percentage points. These are sectors in which it is much more possible to create value from product design and specifications tailored to consumer needs. Raw materials and intermediate goods—especially energy and metals—declined about 15 percentage points. These changes were directly related to transition strategy. Entry of new producers was most significant in light, labor-intensive manufactures, especially in very small-scale industry. Rapid opening to foreign trade also created new industrial opportunities, which especially up through 1995 were strongly concentrated in labor-intensive manufacturing.

Around the turn of the 21st century, this pattern of "make-up" industrialization came to an end, and new patterns of structural change emerged. The detailed data for the 2013 census have not yet been published, so it is only possible to make a few tentative observations. First, the overall shift toward light manufactures came to an end after 1995. Traditional light industry products typical of the early stage of industrialization began a dramatic relative decline as a share of China's industrial output around the turn of the century. Between 1995 and 2004, food products, textiles, garments, and leather goods dropped from 24% to 17% of total industrial sales. Instead, industrial growth was concentrated in manufacturing sectors with higher technological content. These were still diversified manufactures, but ones with much greater demands on capital and technology. Electronics and telecommunications equipment were one of the first to take off, with the share increasing from 4.6% to 10.5% of total industrial sales between 1995 and 2004. Subsequently, machinery industry launched into a remarkable growth phase. Transportation equipment (especially automobiles), general purpose machinery, and office equipment began to grow rapidly after 2004. Second, there was substantial evidence of industrial "deepening," as demand for materials and energy surged in the wake of ongoing industrialization and a sustained investment effort. Already by 2004, electricity had increased its share from 4.4% to 7.1%. Ferrous and nonferrous metals initiated an extraordinary output exansion after 2004 that made China far and away the world's largest steel producer.

After about 2003, China's industrial growth accelerated, driving a new phase of high-speed economic development. Potentially even more significant, however, is that the process of structural change within industry shifted dramatically from what it had been before. China's industry rapidly moved "upstream" and produced a clear pattern of industrial deepening. The driving industries were

much more sophisticated than before, and they propelled China into a new era. Heavy industries—sometimes derided as relics of China's socialist industrialization—assumed a new vitality and increased their share of China's total industrial output. This process continued until industrial growth began to slow markedly after 2010. As the broader economy slowed, some of the industrial capacity created turned out to be excessive, and decision-makers struggled with ways to restructure and consolidate industry.

14.2 DRIVERS OF INDUSTRIAL CHANGE

A number of factors appear to underly this dramatic surge of industrialization. They include:

14.2.1 Successful Economic Reform

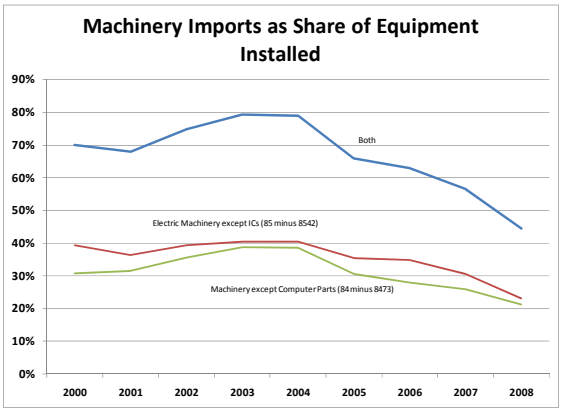
The package of economic reforms associated with Premier Zhu Rongji, carried out between 1993 and 2003, were effective in laying the groundwork for renewed growth and increased sophistication. Perhaps the clearest single indicator of the impact of these reforms is that market forces in Chinese industry were extremely strong from the late 1990s on. As Brandt, Van Biesebroeck and Zhang (2011) show in their study of firm-level productivity growth, both entry and exit were frequent and accounted for a large share of the rapid productivity growth. Between 1998 and 2006, new firms entering manufacturing account for about 15% of total firms *each year*, and nearly 10% of existing firms exit each year. As might be expected, new firms experience higher productivity growth and higher absolute productivity levels (once they have "ramped up") than existing firms, whereas exiting firms have lower-than-average productivity. These figures reflect a healthy competitive environment in manufacturing, which was the product of successful reforms.

14.2.2 Entry into the World Trade Organization (WTO)

One of the central achievements of the Zhu Rongji era of reform was China's accession into WTO, which took place on December 11, 2001. China's WTO agreement was widely seen as "locking in" the achievements of a decade of reform, but was also faced with considerable trepidation by many in China's economy. Certain manufacturing sectors (and in addition agriculture) were seen as being vulnerable to enhanced foreign competition as China's WTO commitments phased in during the years 2001-2004. Automobile manufacturing was often tagged as an especially vulnerable sector. In fact, the reality was quite different. In the first place, China's industrial firms responded effectively to increased competition. Productivity increased especially rapidly in sectors that were opened to international competition. Secondly, access to low-cost international inputs allowed Chinese manufacturers to break bottlenecks and lower costs, and increased the competitiveness of Chinese exports. As described in Chapter 16, extraordinarily rapid expansion of manufactured exports was a key feature of the period from 2003 through 2008, when they grew at over 30%.

Yet an additional aspect of China's trade during this era was perhaps equally important. As industrial growth accelerated, and China's firms were increasingly private businesses, new demands for industrial machinery and intermediate goods were created. To a surprising degree, those increased demands were met by Chinese suppliers. By contrast, during the 1990s, most of China's industrial equipment had been imported. During the 2000s, though, Chinese suppiers managed to substitute domestic production for these imports. As Figure 14.1 shows, industrial machinery imports declined from 70-80% of installed

equipment in 2003-4, to under 50% by 2008. As a result, China swung from deficit to surplus in this category of traded goods in the same time.



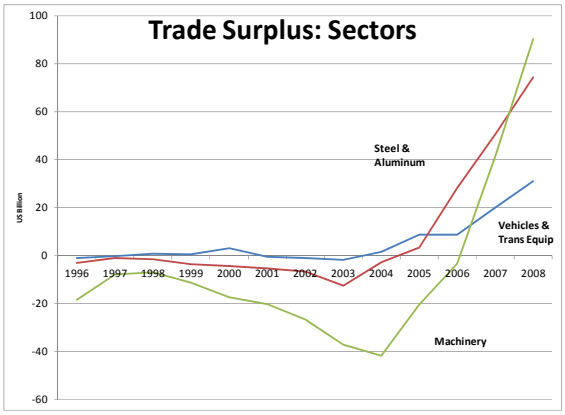


Figure 14.1 Trade in Machinery

In other words, China in the 2000s went through a process of import substitution in the machinery sectors. Here "import substitution" refers not to the trade policy (that attempts to protect domestic industry against import competition) but to an economic output driven primarily by market forces. The substitution of domestic for foreign suppliers reflected increased quality and cost competitiveness of Chinese manufacturers.[1]

14.2.3 The Housing Boom

An astonishing aspect of China's economy in the past decade has been the extraordinary expansion of housing. In this case, we find the roots of the housing boom in an economic reform policy carried out under Zhu Rongji, in this case the decision made in 1998 to distribute most enterprise-owned housing to individuals at low cost. This dramatic decision, carried out with remarkable speed, laid the foundation for the rapid expansion of the market for private housing in the 2000s. Many urban dwellers entered the new era with at least some housing in their possession, so that they could "trade up" as housing prices soared. At the same time, the ideological impact of the sudden creation of an urban (small-scale) property-owning class of over a hundred million households meant that many people had a vested interest in the new system.

ADD QUANTITATIVE SECTION:

1. Aggregate investment in housing, 1990-2015. Share of GDP; millions of m^2.
2. Increase of housing space per capita, urban households.

The housing boom created enormous derived demand for industrial production. Most immediately, the building materials industries, especially cement and steel, enjoyed steadily increasing demand from the concrete towers that sprouted up around every one of China's cities. Moreover, except for the tallest

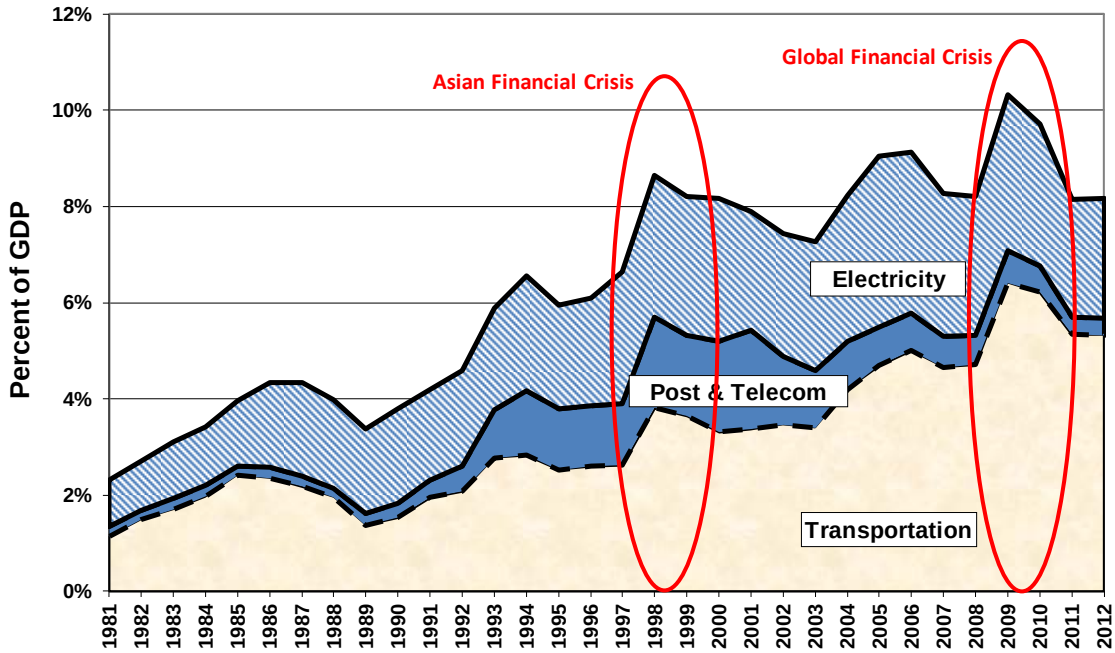
[1] This is not to deny that some protectionist policies were put in place, particularly after about 2006. However, these were not the primary drivers of the outcome.

buildings, many of these construction projects could be carried out with intermediate quality goods (especially steel) which China was well-equipped to produce. Entry barriers were low, since skills were widespread, indeed dating back to the socialist period. In a further round of derived demand, households that moved to new housing generally purchased a round of new consumer durables as well, ranging from refrigerators and televisions to air conditioners and music stereo systems.

14.2.4 The Infrastructure Boom

While the housing boom was fundamentally the outcome of individual household decisions (and of the businesses that catered to them), the Chinese government contributed to this "higher" phase of industrializatin by greatly accelerated infrastructure investment. Figure 14.2 displays the major trends in three major categories of physical infrastructure. Before 1993 the infrastructure investment effort was modest. Indeed, some development planners suggest, as a rule of thumb, that 6% of GDP needs to be invested in infrastructure to support rapid growth. By this standard, China during the 1980s was falling short, coasting on existing facili- ties. However, after 1993 investment in these three categories of physical infrastructure jumped to around 6% of GDP, and after 1998 infrastructure investment took another jump to a level around 8% of GDP. This is quite a substantial investment effort in comparative terms. Figure 14.2 also shows that surges in infrastructure investment came in 1997-99 and 2009-2010, in both cases in response to macroeconomic crises (the Asian Financial Crisis and Global Financial Crisis respectively). The pace of infrastructure investment is therefore clearly related to government stabilization efforts as well as development strategy. For our current purposes, though, the most important aspect of Figure 14.2 is simply that infrastructure investment has, since 1998, been consistently maintained at the extraordinary level of 8% of GDP.

Figure 14.2 Infrastructure Investment



Transport investment has been consistently strong, focused primarily on highway construction through most of this period, but broadening into substantial railroad construction after 2008. China has now built a national network of express highways, equivalent to that which exists in the United States. The highspeed rail network on a similar scale will be nearing completion by 2020.

Infrastructure development is the outcome of national policy-making in a number of senses. The mobilization of investment resources; requisitioning of the land; and design of the network all fall directly on policy-makers. Equally striking is that a robust institutional framework has to be in place to manage these enormous networks. Indeed, a similar institutional form has been adopted to manage development in all three of these crucial infrastructure sectors. In electricity, telecom, and most long-distance transport (trucking is a partial exception), a small group of SOEs dominate the business. Those state firms have an explicit government mandate to support infrastructure development in their sector. They also have a significant degree of profit orientation and enough market power to be able to maintain healthy profitability. No firm—with the exception of railroads—has an unambiguous monopoly, but in each sector incumbent SOEs are protected by significant market entry barriers. Much of the resulting profit is plowed back into further investment. In all these cases, China has opted to maintain state ownership of companies as an alternative to creation of a stronger regulatory framework followed by privatization. This approach has dangers, because the companies under consideration have strong economic interests and significant market power while they are subject to only limited oversight. Yet in the short run this approach has turned out to be a viable and reasonably economical solution.

Rapid infrastructure investment created additional derived demand for industrial production. Moreover, improved infrastructure drove down costs for industry, and permitted rapid productivity gains. Without doubt, rapid infrastructure build-out was a key driver of industrialization after the turn of the century.

14.2.5 Automobiles

As households enjoyed more discretionary income, the road network was built out, and housing costs pushed households out of urban centers and onto the periphery, the demand for automobiles soared. Starting from a handful of joint venture auto producers established during the 1990s, China's auto industry expanded enormously. In 2010, annual auto sales in China surpassed those in the United States, and since that time China has been the world's largest auto market.

ADD QUANTITATIVE SECTION ON AUTOS

The explosive growth of China's automobile industry seems inevitable in retrospect, but in fact the pace of growth far exceeded projections both by Chinese planners and by foreign auto companies. Auto multinationals entered China prepared for the long haul, feeling they could not neglect China's long-term potential, and were delighted to find their investments bearing fruit much earlier than they anticipated. Competition from imports was insignificant, as most multi-nationals bet instead on investments within China. With substantial investment by the automobile assemblers, the entire network of parts suppliers also set up within China, creating robust local networks and supply chains. On this basis, local Chinese firms also began to expand and grow alongside, and intertwined with, the international networks.

14.2.6 Conclusion of Restructuring Section

China thus transitioned almost seemlessly from one phase of industrialization to another after the turn of the century. Attention among industry-watchers at the time was fixed firmly on the impact of Zhu Rongji's reforms and entry in the WTO, but in the wake of these events a broader shift of industrialization occurred. The forces that drove this transformation were extraordinarily powerful: net exports grew dramatically, on the back of both rapid growth of exports and import substitution in key sectors; urban households moved into the middle class, buying housing and autos; and government invested heavily in the key infrastructure sectors. These three broad trends translated directly into high demand for industrial output. It is striking, however, how adaptable China's industry was. On the basis of the new institutions created under Zhu Rongji and native Chinese entrepreneurship, China's industry rose to meet these major new sources of demand.

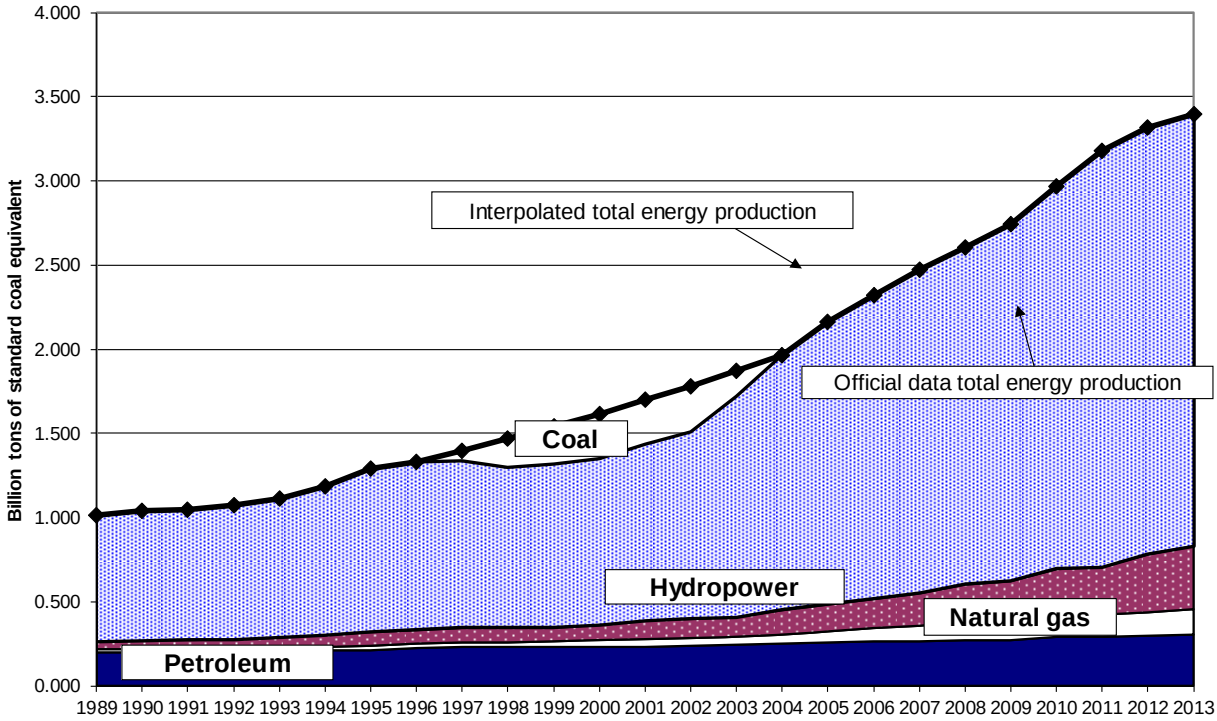
In the process of this new phase of industrialization, China enter a phase of "heavy" industrialization. Raw material industries—steel, aluminum, cement—grew rapidly to feed the construction boom, while new machinery industries, including autos, expanded to meet new industrial and consumer needs. Inevitably this heavier industrialization created new demands for energy as well.

14.3 ENERGY

China is an energy giant, but it is in many respects an immature giant. Problems relating to energy development have several times threatened to hold back China's economic development in the past. The energy crises of the past have been surmounted, but China continues to confront daunting energy challenges in the wake of rapid growth. Moreover, China's energy economy presents two huge challenges to the world as a whole: first, to integrate China's rapidly growing demand into the global energy economy; and second to mitigate the large environmental costs that China's inefficient energy industry imposes on China and the world. The stakes are high.

That China is an energy giant is easy to demonstrate. China is the world's largest consumer of energy and generator of electricity. China produced and burned over 3 billion tons of coal in 2014, far more than any other country (last-minute revelations about coal consumption not previously included in official data make this figure more than usually imprecise). Figure 14.3 shows trends in China's energy production since 1989. There are serious problems with the data between 1996 and 2003 (Box 14.1), for which we can only roughly correct, but long-run trends are clear. Between 1978 and 2005 total energy production grew at 4.5% per year, and energy consumption at 5.2% annually (Annual Report 2006). In the subsequent period, between 2005 and 2013, energy production grew at 5.8% per year and coal production nearly as fast, at 5.5% per year. Filling the gap between domestic production and demand, China shifted from being a significant oil exporter to being a net importer in 1993. In 2005 coal made up 75% of China's domestic energy production, and the share of coal has shown no tendency to decline. In fact, if we ignore the data aberrations of the late 1990s, the share of coal in energy production has been creeping upward since the early 1980s. However, since China is importing an increas- ing volume of petroleum, energy consumption has become slightly less dependent on coal.

Figure 14.3 China energy production



China Energy in Comparative Context

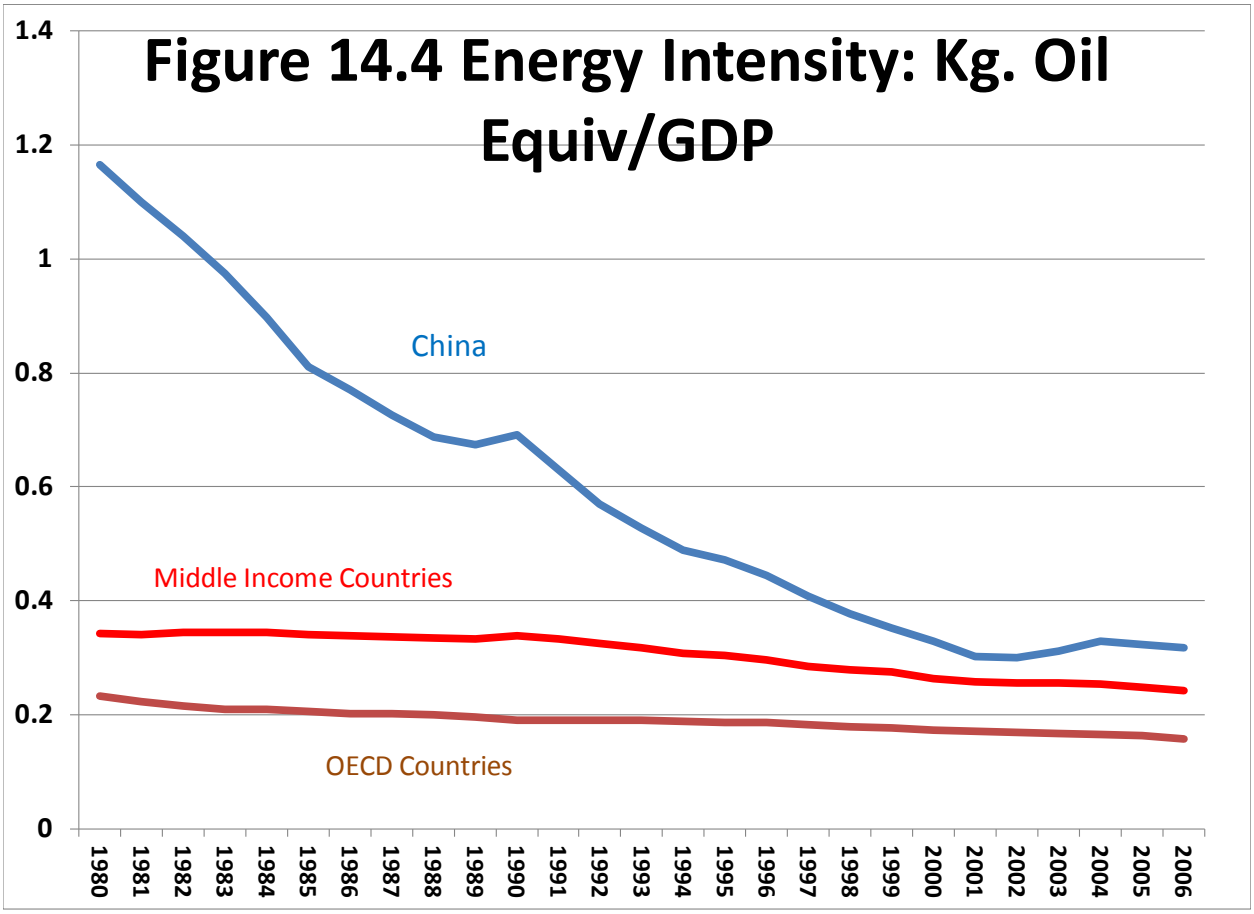
Energy consumption and its composition in the world's top-10 energy users. China's heavy reliance on coal stands out in inter- national comparison, making up 69% of consumption; only India, at 54%, is anywhere close. Petroleum now makes up 22% of consumption, and coal and petroleum together 91% of total consumption. Other large energy con- sumers have strikingly varying and diversified energy-consumption structures. The United States consumes a quarter of the world's energy, drawing large quantities of energy from all the major energy sources. France depends on nuclear power for almost 40% of its energy, while Russia draws on its huge reserves of natural gas for over 50% of its energy. The world excluding China depends much less on coal (only 21%) than China does. The biggest quanti- tative gap comes with natural gas, which made up just under 3% of China's energy use but 27% of world consumption. Gas and oil together make up only 25% of China's energy consumption but 66% of that in the world excluding China. Thus China is overwhelmingly dependent on coal for primary energy generation, while the rest of the world is predominantly dependent on oil and gas.

China's dependence on coal begins to explain the relatively low efficiency of China's energy industry, as well as the severe environmental problems that result (see Chapter 21). The sheer technical efficiency of producing electricity from coal is inevitably lower than that from natural gas, for example, and the production of by-products is much larger. Moreover, as we will discuss, reliance on coal creates a large

burden on the transportation system—since coal reserves are concentrated in the northern parts of the country—and the low technical efficiency of China's mining and power generation intensifies environmental problems. Thus the root of China's energy problems is its dependence on coal. It is also unfortu- nate that the world's two most rapidly growing economies, China and India, are both dependent on coal to power their growth.

14.3.1 Energy Efficiency of the Economy

The energy efficiency of the Chinese economy in 1978 was appallingly low; since then energy efficiency has increased substantially, but China is still a relatively inefficient user of energy (Figure 14.4). While energy consumption grew at 5.2% annually for the 27 years to 2005, real GDP grew at almost



10%, so that China today produces 10 times the real GDP it produced in 1978 with three and a half times as much energy. Even allowing for some over- statement of real GDP growth, by any reasonable accounting China's economy has become more energy efficient. Given the flaws in China's energy data, comparisons of China's energy intensity with other economies are imprecise, but still worthwhile. The World Bank World Development Indicators compare the energy consumed to produce $1 of GDP across

many countries, evaluated at purchasing power parities in 2000 prices. Adjusting China's data to correct both for the undercount of Chinese energy consumption in 2002 (using the interpolated 1995–2005 growth rate) and the revision of GDP data, it took China 0.24 kilograms of oil equivalent (koe) to produce $1 of GDP (evaluated at 999). That is a huge reduction from a staggering 0.92 kilograms back in 1978. This is similar to comparable developing countries. For example, Indonesia, Malaysia, and Korea are all at about 0.24 koe. However, Brazil and India are more efficient (at 0.15 and 0.20 koe, respectively). Developed coun- tries are generally more efficient (Japan at 0.155 and the United Kingdom at 0.14, but the United States is at 0.23). Since the PPP adjustment for China is relatively large, a comparison of energy used per unit of GDP evaluated at exchange rates would be significantly more unfavorable to China, showing China using larger amounts of energy per unit of output than any of these comparison countries.

Three interrelated factors are shaping trends in China's energy efficiency and overall energy usage. The first is structural: industry is the biggest user of energy, and Chinese industry has been growing rapidly and makes up an unusually large share of GDP. While China gained some breathing space from the shift to a lighter, less energy-intensive output mix during the 1980s and early 1990s, this shift was reversed after the turn of the century. Not only did industry become more "heavy"—and therefore more energy intensive—but in addition, as modernization proceeds, the population increases its direct consumption of energy (in the form of lighting, electricity, and air- conditioning), as well as in automobile transport. These factors are tending to push up energy consumption per unit of GDP.

The second factor is institutional. Under the planned economy, there were many reasons why energy was used inefficiently. Energy prices were controlled at low levels; planners directed energy into wasteful and inefficient projects; and incentives to conserve energy were weak to nonexistent. As the economy has undergone reform, incentives to conserve energy have greatly improved, and energy conservation policies have been implemented. Price controls have been removed on most energy products, and in sectors where prices are still regulated (such as electricity) prices have been raised to adequately reflect resource costs. Profit-oriented producers have incentives to reduce energy consumption and seek new technological solutions.

Moreover, starting in 2005, China began to get serious about energy conservation. The Eleventh Five Year Plan (2005-2010) set a binding target for reduction in energy use per unit of GDP. This quantitative target was imposed on government officials at all levels. This strong policy effort weighed against the natural structural changes in the economy to keep energy efficiency rising.

The third factor is technological. China's shift to openness has meant a sudden inflow of more- advanced technologies. Although those technologies have been selected primarily for their technological sophistication or low cost, many have had the side benefit of improving energy efficiency. The pace at which cleaner tech- nologies are implemented will depend on government policy, as well as on the cost-benefit trade-off associated with specific technologies, some of which will be discussed later. For a period, China benefited from a uniquely positive com- bination of structural, institutional, and technological factors, and this allowed a sustained improvement in overall energy efficiency in the economy. However, we cannot assume that all three factors will continue to interact in such a benevolent fashion. Rapid growth will continue to create significant challenges for the energy sector, and it will take sustained successful policy- making to adequately manage those challenges.

14.3.2 Main Energy Sectors

14.3.2.1 Coal

As China has searched for energy to feed the voracious appetite of its rapidly growing economy, it has not had the luxury of choosing among energy resources. China has been forced to rely on coal, in particular on small-scale coal mines, in order to maintain industrial growth. In that sense, China has continued to "walk on two legs," as the slogan from the GLF put it. While the national government was developing large coal mines, local governments and, increasingly, individuals have been authorized to develop small-scale coal mines, power plants, and factories. China's 1980s boom in TVEs was much in evidence in the coal sector. Exploitation of coal deposits by local village collectives and even individuals was allowed, notwithstanding the fact that resources were theoretically owned by the state. This trend combined with the highly dispersed character of China's coal resources to create a major boom in small-scale mining. Although China's large-scale coal reserves are concentrated in northern China, scattered reserves exist in much of the country. Indeed, as of 1995, coal mines were operating in 1,264 of China's 2,200 counties. After a slowdown in the late 1980s, small coal mines again began to grow rapidly in the 1990s. In 1995 there were 34,200 village- collective-run mines and 34,700 individually run mines, and these two small- scale types together accounted for 46% of total coal output, more than the big nationally run mines.

With the growth of small-scale mining, China's coal-mining sector essentially undergone technological regression. Miners in these mines work under very poor conditions. Safety measures are practically nonexistent in most small mines, and accident rates are very high. There were 6,027 accidental deaths in coal mines in 2004, mostly in small mines; accident rates in large mines are much lower. Several large, deadly accidents were publicly acknowledged in 2005, and public concern mounted. In the decade since, the total number of coal mining deaths has been brought down steadily, but is still far above those of any other country, relative to coal output, or of course in total numbers. Because property rights are not well specified, conflicts are frequent, and the "owners" of mines have little incentive to invest in long-term upkeep or environmental maintenance. As a result, many coal-mining districts are dangerous, dirty, and disreputable. Moreover, although output has increased, this growth has come primarily from mines producing lower-quality output with much higher levels of impurities. This reduces the energy efficiency of downstream units that burn coal; moreover, since the coal they produce almost never undergoes benefici- ation, it cannot be used in clean-burning power plants. Instead, most of the coal is burned in small, inefficient industrial boilers or, worse, burnt directly in furnaces and cookstoves in Chinese homes.

All these considerations influenced Zhu Rongji's 1997 decision to attempt to close down mines that were out of compliance. However, his failure to do so highlights some harsh economic realities. Small mines have survived because they have adapted production technologies to fit China's real factor proportions: since labor is cheap and capital scarce, mines that use labor- intensive, low-capital production techniques are often cost effective. Since externalities are not priced into the mine owner's profit and loss state- ment, environmental costs are ignored, and small-scale mines are profitable. Dirty and dangerous small-scale coal mines are likely to be part of China's energy balance for the foreseeable future.

14.3.2.2 Oil and Gas

China is the sixth-largest oil producer in the world, just behind Mexico. In 2004, China produced 3.6 million barrels a day (175 million tons per year). However, China's oil reserves are not large, and the ratio between verified reserves and annual production is only 13.4, compared to 40 for the world as a whole. Therefore, China is exploiting its existing reserves at a much more rapid rate than most of the other major oil producers (although the United States' and Mexico's rates are similar to China's). China's oil industry was born with the discovery of the Daqing oil field, in northeastern Heilongjiang Province, in 1959. Oil production grew very rapidly for 20 years after the discovery of Daqing, but the growth rate dropped dramatically after 1978, and it was only 2% per year through 2004. Moreover, at the end of the century the Daqing field had begun a long, irreversible decline, but was still account- ing for nearly 40% of production. China was still relying on the same small handful of oil fields as before. China has had great difficulty locating other major fields, and the costs of extracting oil from Daqing and other mature oil fields are increasing steadily. Oil is being extracted from increas- ingly difficult, distant, and dispersed locales. Under these conditions, it is remarkable that China has managed to maintain a positive growth rate at all. Most of the increased output has come from offshore oil—which, after a dis- appointing start, began to contribute significant output in the late 1990s—or from new fields in the far Northwest, especially the Tarim Basin. Extraction and transportation costs for these fields are significantly higher than the old fields.

China's demand for petroleum is growing significantly more rapidly than its domestic supply. When China first emerged into the world economy in the late 1970s, it had significant oil surpluses to sell and exported a peak of 27 million tons (about 500,000 barrels a day) in 1985. But China's petroleum surplus has steadily declined as domestic demand has grown and China became a net petroleum importer in 1993, and imports have increased steadily since. Imports in 2004 were about 2.5 million barrels a day and rising. For compari- son, Japan imports about 5 million barrels a day. China's imports are, however, set to continue a steady increase in the future. If present trends of very slow growing domestic production and rapidly rising domestic demand continue, China's imports would surpass 5 million barrels a day around 2015. With very high world oil prices in 2004–2005, concern about rising Chinese demand for oil was widespread. Such concerns should be kept in perspective. World oil markets transact 48 million barrels of oil a day. China has now surprassed the United States and become the world's largest oil importer.

14.3.2.3 Electric Power

Electricity production has grown rapidly. Unusually, however, electricity production grew less rapidly than overall industrial output during the phase of make-up industrialization, notwithstanding the conversion of many plants to electric power. Between 1980 and 1998 electricity generated grew 7.8% per year, a rate which seemed to be ample, although less rapid than overall industry and GDP (see following Table). However, beginning in 2000, electricity has grown more rapidly than GDP: the income of electricity demand after more than a decade below one (extremely unusual), suddenly shifted to the more normal pattern of being significantly above one. Planners were initially caught by surprise, therefore, when rapid increases in demand for summer power, beginning in 2003, brought widespread brownouts and power limitations in many parts of China. However, both power generated and investment in the electricity sector increased rapidly in response. Electricity output increased 11% annually between 1998 and 2004. Lying behind these quantitative trends has been a large push to upgrade the power sector and reduce the share of small-scale, relatively inefficient coal-burning plants. Relatively large-size power plants, of 300 megawatts or above, have increased their share of total

capacity from 17% in 1990, to 29% in 1996, to over 60% today. There has been a corresponding decrease in the amount of coal required to generate a kilowatt-hour of electricity, and some improvement in the volume of emissions.

Income Elasticity of Electricity Demand

Year	GDP Growth	Electricity Growth	Annual Income Elasticity	
1988	11.3%	9.6%	0.85	
1989	4.1%	7.3%	1.77	
1990	3.8%	6.2%	1.64	
1991	9.2%	9.1%	0.98	
1992	14.2%	11.3%	0.79	
1993	14.0%	11.1%	0.79	
1994	13.1%	10.8%	0.83	
1995	10.9%	8.6%	0.79	
1996	10.0%	7.2%	0.72	
1997	9.3%	5.0%	0.54	
1998	7.8%	2.8%	0.36	
1999	7.6%	6.3%	0.82	
2000	8.4%	9.4%	1.12	New Era?
2001	8.3%	8.6%	1.04	
2002	9.1%	11.5%	1.26	
2003	10.0%	16.3%	1.63	
2004	10.1%	15.3%	1.51	
2005	11.3%	12.2%	1.08	
2006	12.7%	14.4%	1.13	
2007	14.2%	14.5%	1.02	
2008	9.6%	5.6%	0.58	
2009	9.2%	7.1%	0.77	
2010	10.3%	13.3%	1.29	
2011	9.2%	11.7%	1.27	

The sheer quantitative challenge is also daunting. Electricity production has thus far generally kept pace with the economy's needs. However, per capita consumption of electricity is still in the range of a low to medium-income country. Chinese electricity consumption in 2003 was 1,464 kilowatt-hours per capita, about what it was in the United States in 1941, Japan in 1962, or Taiwan in 1975. Each of these three earlier-developing economies roughly quadrupled its per capita electricity use over about 25 years (slightly shorter in the case of Taiwan). This fact suggests that Chinese electricity output is also set to quadruple over the next 20 or so years. Given the extreme coal dependence of Chinese electricity generation today, even with significant productivity improvement a quadrupling of output almost certainly implies at least a dou- bling of coal production. It is not easy to envisage China mining and shipping something on the order of 4 billion tons of coal in the year 2030.

14.2.4 Energy Security, Diversification, and Imports

How will China address its energy challenges? It is quite clear that China will follow a conscious strategy of diversification of energy sources (Wu and Storey

2005). The domestic context of future energy strategy is the uneven geographic distribution of fossil fuel reserves within China. The northern half of China has about 90% of the gas and oil and 80% of the coal. Coal is particularly con- centrated in a three-province region of north China, comprising Shanxi, north- ern Shaanxi, and western Inner Mongolia, which accounts for almost half of total reserves. Mountainous southwestern and western China have abundant potential hydropower resources, but these require massive long-term invest- ments to be developed. The most rapidly growing part of China—the south- eastern coastal area—has very few energy resources of any kind.

In the past this distribution problem meant that a large part of the country's transport system was tied up shipping coal from the north to the south. Coal shipments, at their peak, accounted for 60% of the total weight of long- distance rail shipments in China. Coal is also shipped eastward across north- ern China and loaded onto oceangoing ships, not only for export to foreign countries, but also for shipment down the coast to China's southeast. In the future the domestic distribution problem will be addressed in conjunction with China's energy-import policy, and China is now gearing up to become a large- scale energy importer over the long term.

The most promising areas for future onshore oil and gas production are in the northwest province of Xinjiang, in the Tarim and Ordos basins. These fields are a long way from the centers of demand, however, and require expensive new infrastructure. A new natural gas pipeline, built from Xinjiang all the way to Shanghai on the east coast, began delivering gas in 2005. Development of the Northwest can be tied in with increased import of oil and/or natural gas from China's continental neighbors. Construction began in 2004 on a pipeline to carry oil from Kazakhstan to the Chinese province of Xinjiang. A long-run objective is to gain access to Russian energy resources. (China currently imports small amounts of oil from Russia by railroad.) There are ambitious plans to build a pipeline from eastern Siberia, but the project has been stalled by Russian hesitation and competition between Japan and China to be the primary pipeline destination.

The southern coast will rely most on the newest and most expensive, but also cleanest, facilities. Nuclear power will be significant along the southern coast. As of 2005, China had nine nuclear power plants in operation and plans for up to 30 more, all of them near the coast. Import of liquefied natural gas (LNG) to specialized terminals on the south coast may play a significant role. Massive LNG terminals will go into operation in Guangdong and Fujian provinces. Of course, China will also import more oil on tankers. Today about 60% of China's imported oil comes from the Middle East, and this figure is not likely to decline dramatically. One big unknown is the amount of oil off-shore in the Bohai Gulf and perhaps the East China Sea. Recently these fields have been exploited successfully, but they have not been fully explored, and disputes with Japan over mineral rights on the continental shelf are a serious problem. The emerging high degree of dependence on oil imports from the Middle East naturally pushes Chinese policy-makers to diversify supply as much as possible. China announced a strategic petroleum reserve in 2004 and aims to gradually create a stockpile equal to about one month worth of imports (compared to two months for the United States and five months for Japan). Exactly what combination of these strategies will ultimately emerge is still unclear. Given the needs and the uncertainties, China will continue to follow a multistranded approach, diversifying to reduce risk and exploiting as many different opportunities as possible.

Starting in the mid-2000s, China's demand for energy began to fundamentally shaped global energy demand, pushing up prices world-wide for coal and oil. Price relationships within China responded as

well. These trends remained strong until late 2014, when China's slowing growth finally hit world energy prices.

14.4 CONCLUSION

Dramatic changes in the pattern of industrialization have occurred over the past few decades. After the socialist economy period, China spent almost two decades opening to the outside world and engaging in "make-up" industrialization. This shows that much of the industrial plant inherited from the socialist period was of little value. But after a new century turning-point, China launched into a new phase of industrial upgrading and deepening. This may indicate a number of points:

1. Industrial reforms were successful enough to enable this transformation
2. Industrial skills inherited from the social economy period may have helped
3. The development of an urban middle class fueled a dramatic expansion in domestic demand
4. Rapid growth of net exports powered this phase
5. Government infrastructure investment provided essential support.

Even in the midst of rapid growth, China faces daunting challenges. As development proceeds, the structure of goods outputs changes in complex ways. The ability to move into labor- and skill-intensive final-goods manufacturing pres- ents the economy with exceptional opportunities. At the same time, the need to invest heavily in infrastructure to overcome inherent limitations in energy, transport, and communication poses new challenges. China's ability to sustain rapid growth depends on the success with which these problems are con- fronted and overcome. The development of a market economy in China has shaped the economy in complex and sometimes apparently contradictory directions that are far different from what a central planner would ever have envisaged. Similarly, future development will be shaped by market forces in ways that are difficult to predict at present.

The essential common feature of energy and communications is that both these sectors require large-scale investment in physical infrastructure. An essential government function—particularly critical for developing economies—is ensuring the healthy growth of infrastructure investment. In the area of infrastructure there are two major requirements. The first is that the government provide financing for infrastructure investment, either directly or indirectly; this includes direct government finance as well as the creation of a regulatory and market environment that facilitates private investment in infrastructure provision. The second requirement is that the government provide a framework for infrastructure planning, in order to resolve land-use conflicts, ensure rational allocation of resources among alternative strategies, and provide guidance to private decision-makers. China's performance in infrastructure provision has generally been good, especially recently. Despite major changes in the structure of national saving and the organization of financial institutions (see Chapter 19), China has been able to maintain a robust level of investment in infrastructure.

These common challenges faced a whole new set of changes after 2010. First, China's growth slowed for the structural reasons outlined above in Chapter 6. Then, with lower demand from China, world commodity and energy prices declined. Now, China faces a complex of industrial, macroeconomic, and energy challenges as it seeks to stabilize growth going forward.

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Table 14.2: Same as Table 14.1.

Table 14.3: BP (2005).

Figure 14.1: SYC (2005, 255). Updated with preliminary data from Annual Report (2006).

Figure 14.2: Wu and Storey (2005).

Figure 14.3: Fixed Investment (1997, 37–41); SYC (2005, 200–203).

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