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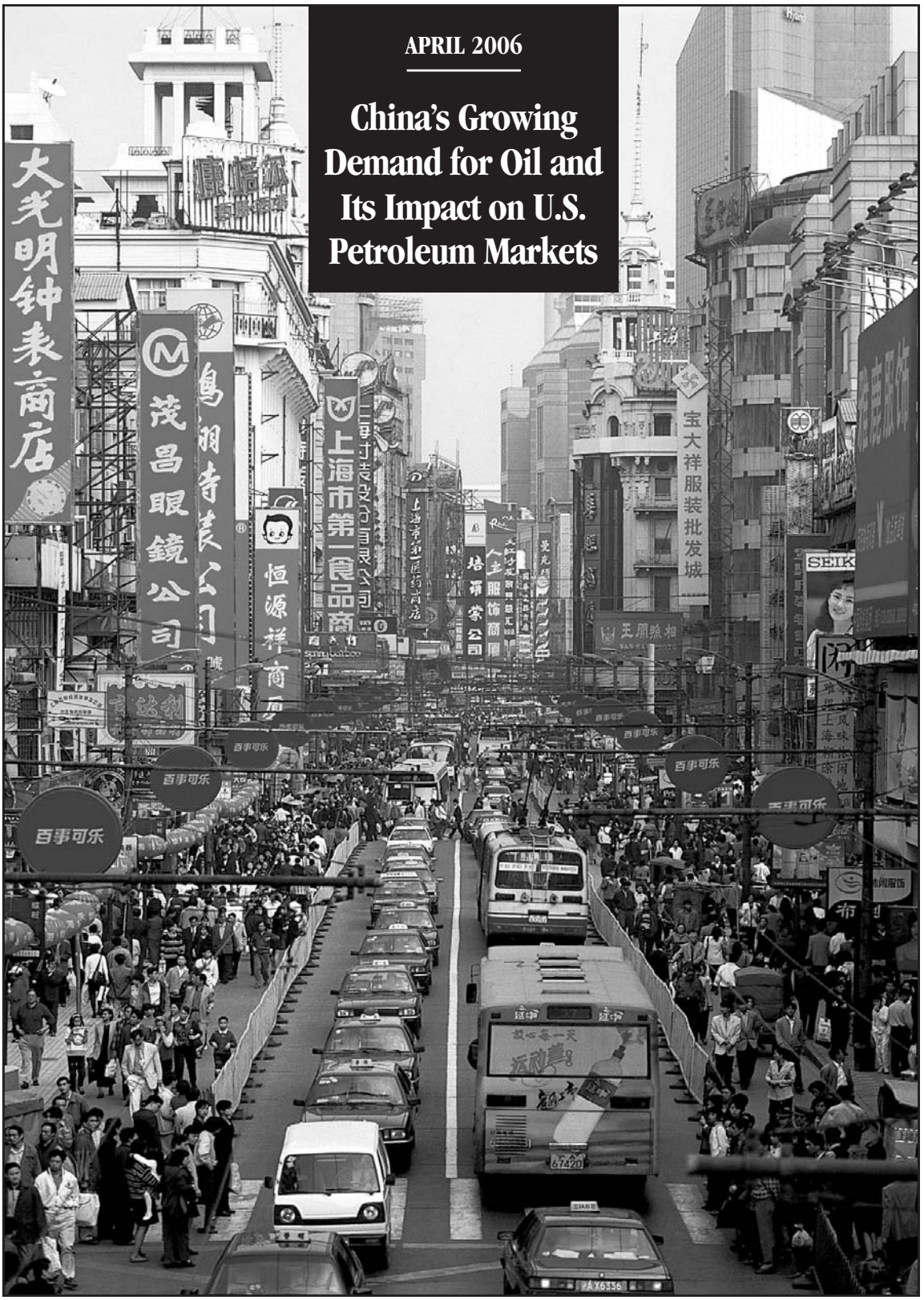
China's Growing Demand for Oil and Its Impact on U.S. Petroleum Markets



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The Congress of the United States ■ Congressional Budget Office

Preface

Strong economic growth in Asia, particularly in China, has had a significant impact on global markets in recent years, including the markets for crude oil and refined petroleum products. This Congressional Budget Office (CBO) paper reviews major developments in China's demand for crude oil and refined petroleum products over the past decade and considers the implications of those changes for motor fuel prices in the United States through 2010. The paper was prepared in response to a request from the Ranking Member of the Senate Committee on Energy and Natural Resources. In keeping with CBO's mandate to provide objective, impartial analysis, the paper makes no recommendations.

Richard D. Farmer of CBO's Microeconomic Studies Division prepared this paper under the supervision of Joseph Kile and David Moore. Robert Dennis, Matthew Goldberg, Douglas Hamilton, Arlene Holen, Juann Hung, Mark Lasky, and Thomas Woodward provided comments on a draft of the paper. Outside of CBO, James Hamilton of the University of California at San Diego, Lee Schipper of the World Resources Institute, and Phillip Tseng of the Energy Information Administration provided comments. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with CBO.)

Christine Bogusz edited the paper, and John Skeen proofread it. Angela Z. McCollough prepared the tables. Maureen Costantino prepared the paper for publication and designed the cover, and Lenny Skutnik printed copies of the paper.

Donald B. Marron
Acting Director

April 2006

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CHAPTER

1

Summary and Introduction

China's demand for crude oil and refined petroleum products has been growing over the past decade, and in 2003 and 2004, the country's demand for oil increased dramatically (see Figure 1-1), surprising many energy analysts. This paper explores the reasons for that growth and the implications for petroleum markets in the United States.

World oil prices have been rising since 2004, driven in part by the increases in China's demand for crude oil and refined petroleum products. Those increases were most prominent for the light petroleum products—gasoline and diesel—that are used primarily for transportation. Over the next five years, the pace of growth in China's demand for oil in general, and for transportation fuels in particular, could be a key factor contributing to further increases in the prices for crude oil and refined petroleum products. In the United States, those price increases could affect the demand for petroleum and influence the investment decisions of U.S. refiners.

The demand for petroleum has increased recently in other regions as well—including the United States, Middle Eastern nations, and other Asian nations—which has contributed to the higher prices. But those other markets—which are better understood than the Chinese market—are not as likely as China is to register continuing large increases in their demand for petroleum over the next five years.

A better understanding of the growing Chinese market may be difficult to come by because the Chinese economy overall is growing rapidly, economic sectors are growing at various rates, and Chinese economic data, while improving, are less reliable than those available for the United States, Europe, and Japan. Much of the analysis in this paper makes use of official Chinese data on petroleum markets and the economic and social drivers of petroleum demand—and even the data on China taken from other sources ultimately rely on those official statistics. In recent months, Chinese authorities have announced large revisions to their data on gross domestic product (GDP), which have raised questions about the quality of that data and the relationship between economic output and energy consumption. Despite those questions, the Congressional Budget Office (CBO) finds the quality of the statistics sufficiently reliable for the purposes of this analysis.

Reasons for China's Growing Demand for Petroleum

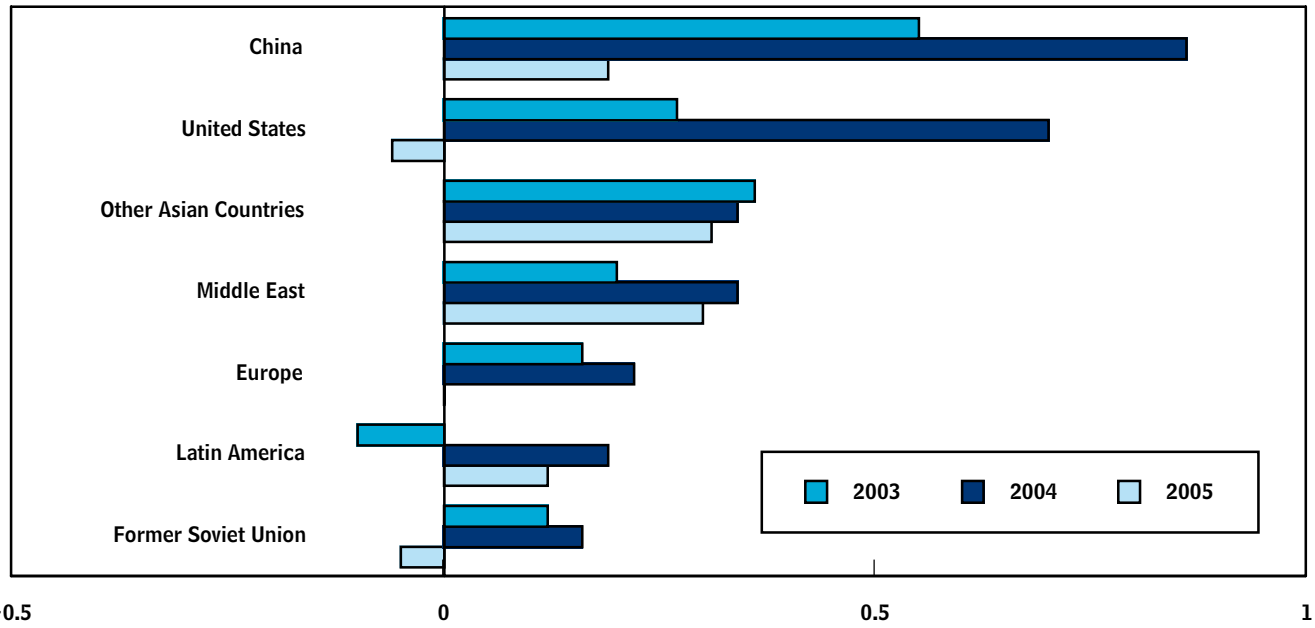
China's changing petroleum requirements are closely related to its high rates of growth in economic output and personal incomes. The growth in incomes and the accompanying changes in petroleum demand are themselves driven by an ongoing population shift from rural to urban areas. That growing urban population is demanding new vehicles and new roads, raising the demand for energy in the transportation sector (see Figure 1-2). Separately, the growth in output in the industrial sector is driving the high demand for petrochemical feedstocks, including naphtha-based petrochemicals, which are similar in composition to motor gasoline.

Those underlying factors suggest a significant momentum in China's demand for petroleum. A key concern in this analysis is not whether China's demand for petroleum will continue to grow—as it undoubtedly will—but how fast it will grow over the next five years.

Figure 1-1.

Annual Change in Global Petroleum Consumption in Selected Regions, 2003 to 2005

(Millions of barrels a day)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, *Monthly Energy Review* (January 2006), Table 3.1b (for U.S. petroleum consumption), and International Energy Agency, *Oil Market Report* (January 17, 2006), p. 4 (for other countries' petroleum consumption).

Notes: Other Asian countries comprise Japan, Australia, and Asian countries other than China that are not members of the Organization for Economic Cooperation and Development.

Europe's change in demand in 2005 was near zero.

Two Scenarios of Future Demand Growth in China

To help explain how China's oil consumption may change over the next five years, this paper presents two scenarios that encompass some of the major uncertainties underlying demand growth. The scenario of slower growth in demand is based on recent forecasts from several government and private organizations, and the scenario of faster growth in demand extrapolates from recent higher-growth trends. Each scenario has its own assumptions and implications (see Table 1-1).

In the slower-growth scenario, CBO assumes that growth in Chinese oil consumption will average 4.5 percent a year through 2010—or approximately the average growth from the published forecasts reviewed in this paper. That rate, which is half the average growth rate of 9 percent experienced in 2003 and 2004, would be consistent with several factors: some slowing in demand in response to the near doubling of worldwide oil prices since early 2004, a reduction in the temporarily high demand for oil to generate electricity, and several policy initiatives in China that are intended to slow the growth in energy demand.

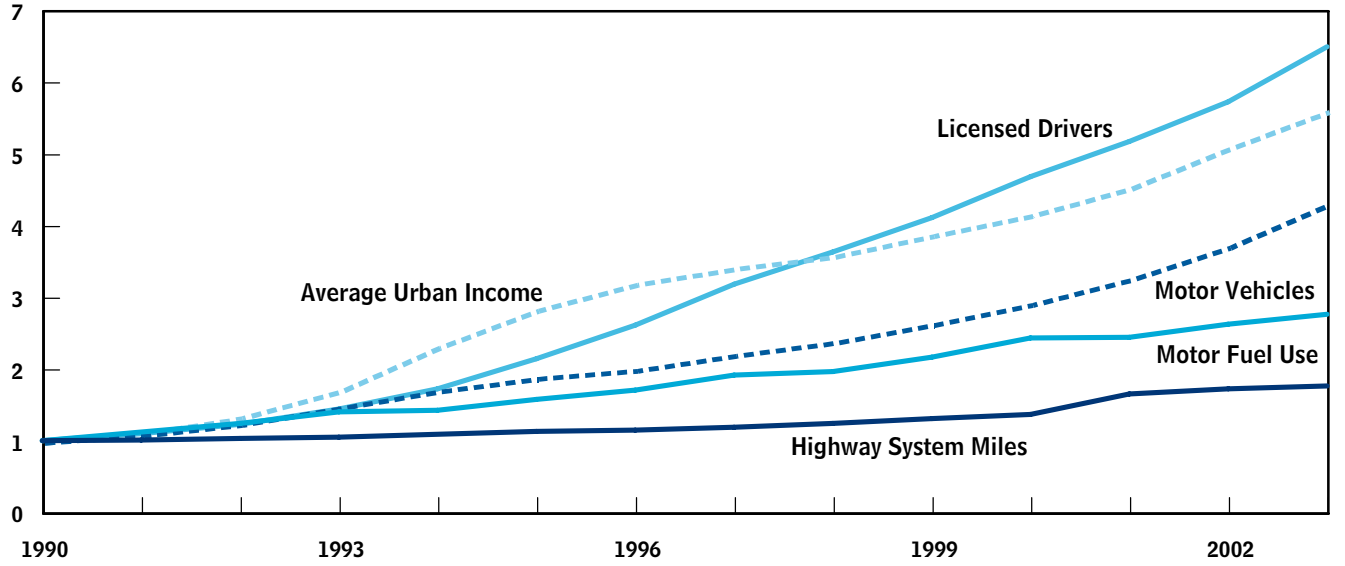
In the faster-growth scenario, CBO considers the consequences if China's petroleum use continued to grow at the high average pace of the past decade—or about 7.5 percent a year. That rate would be consistent with continued high growth in Chinese incomes, urban employment, vehicle sales, and highway construction.

In both scenarios, most of the growth in China's oil demand through 2010 is assumed to be in the form of light petroleum products—including motor fuels and some

Figure 1-2.

Change in Motor Fuel Use and Key Determinants of Oil Demand in China, 1990 to 2003

(Index, 1990 = 1.00)



Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook* 2004 (Beijing: China Statistics Press, September 22, 2004), Tables 7-11 (consumption of gasoline and diesel oil), 10-2 (average urban income), 16-4 (highway miles), and 16-28 (civil motor vehicles and licensed drivers); and British Petroleum, *Statistical Review of World Energy* (June 2005), for consumption of gasoline and middle distillates.

petrochemicals—which is consistent with other forecasts and recent trends.

Consequences of Slower and Faster Growth in Demand

In the near term, both scenarios of demand growth in China are likely to affect U.S. oil markets by causing higher crude oil prices, higher costs to refine that oil, and greater price volatility. The combined changes in crude oil costs and costs of refining could add from about 19 cents to 38 cents to the cost of a gallon of gasoline or diesel fuel in the United States in the next five years (in 2005 dollars).

The biggest part of those potential increases would result from higher prices for crude oil. The scenarios about future growth in Chinese demand could lead to increased crude oil costs that, by themselves, would result in gasoline prices that were 16 cents to 33 cents a gallon higher than what they would be otherwise. If worldwide oil supplies were more responsive to increased oil prices than is generally assumed to be the case (an assumption underlying several published forecasts of oil prices), then the impact of higher Chinese demand on prices could be smaller than the estimates given here. Conversely, if the recent restraints on oil production in Saudi Arabia, Russia, and elsewhere did not loosen, the effect of higher demand on prices could be greater yet. Those sensitivities for worldwide supply conditions are discussed but not evaluated in this paper.

Another factor contributing to potentially higher motor fuel prices in the United States would be higher worldwide costs of refining crude oil. Those costs could rise over the next five years because of the increasing relative demand within China for motor fuels and naphtha-based petrochemicals, light products that are especially costly to produce from crude oil because they require additional equipment for processing and handling. (Alternatively, refiners can at higher cost acquire more of the premium-grade crude oils that can be more easily refined into light

Table 1-1.

Implications and Assumptions of CBO's Scenarios for Slower and Faster Growth in China's Demand for Oil

	Slower Growth in Demand	Faster Growth in Demand
Implications of Scenarios for U.S. Markets		
Increase in U.S. motor fuel prices by 2010 (in 2005 dollars)	19 cents a gallon (16 cents from oil price changes and 3 cents from changes in costs of refining)	38 cents a gallon (33 cents from oil price changes and 5 cents from changes in costs of refining)
Key Assumptions of Scenarios		
Growth in China's demand for oil through 2010	4.5 percent annually (Average of published growth forecasts)	7.5 percent annually (Average growth of past decade)
Increase in demand by 2010	Two million barrels a day (Most of the increase for motor fuels and other light products)	Four million barrels a day (Most of the increase for motor fuels and other light products)
Economic growth	Decline in growth from recent rates	Continued high rates of growth
Other assumptions	Significant decrease in oil demand in response to current high oil prices; correction of problems in the electricity sector; impact from new fuel economy standards and possible new fuel taxes	Continued increases in personal income, continued urban migration, large increases in the stock of vehicles, and expansion of the highway system

Source: Congressional Budget Office.

products.) Those additional costs for petroleum refining could further boost the prices for gasoline and diesel fuel in the United States by nearly three cents a gallon in CBO's slower-growth scenario or about five cents a gallon in its faster-growth scenario (in 2005 dollars). Those impacts assume that China's policies guiding how much and what kind of refinery capacity to build do not significantly distort worldwide trade patterns.

The two scenarios examined in this paper do not span the full range of possible outcomes. Demand growth in China could turn out to be below that envisioned in CBO's slower-growth scenario (as, from preliminary data, appears to have been the case in 2005) or above that estimated in CBO's faster-growth scenario (as it was in 2003 and 2004). In neither case are the consequences of China's growing energy demand likely to appreciably dampen U.S. oil use or economic growth. Moreover, there are likely to be net benefits to the U.S. economy from China's economic growth and world trade activities that this analysis does not address.

CHAPTER

2

Recent Changes in China's Oil Markets

China's petroleum markets have undergone profound changes in the past decade as demand for a wide range of petroleum products has grown much more rapidly than many analysts expected and as growth in the country's domestic oil production has slowed sharply. The increase in demand for oil has been greatest in the country's transportation and industrial sectors, causing the mix of products demanded in China to shift away from heavy fuel oil and toward lighter fuels—diesel, gasoline, and petrochemical feedstocks. Demand in the transportation sector in particular has been pushed by high growth in incomes and demographic changes that are expanding the potential population of drivers. Along with high levels of motor vehicle sales and highway construction, those changes are laying a groundwork for future demand growth. To help manage those changes, while complying with national policies to preserve energy independence and protect the environment, the Chinese government is restructuring its oil industry.

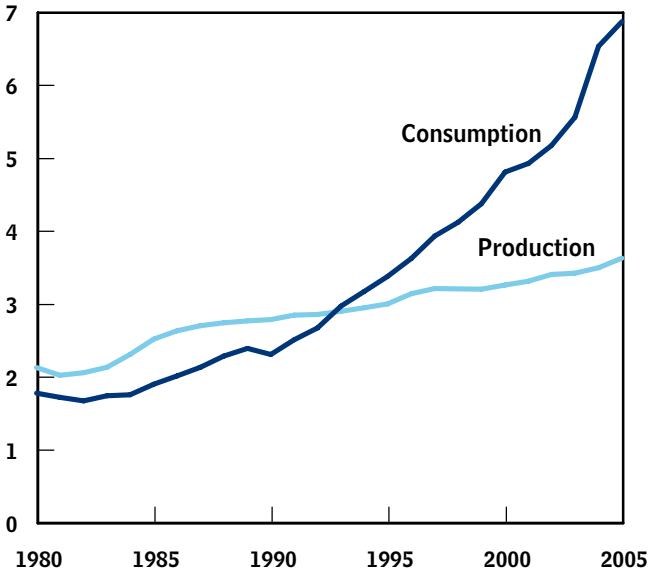
China's Total Petroleum Use

In 2004, China became the second largest consumer of petroleum, behind the United States. In that year, worldwide petroleum demand increased by 3.3 percent, more than twice the annual rate of increase over the past decade.[1] Nearly 30 percent of that additional demand originated in China, where demand grew at an annual rate of 15 percent. In the first three quarters of 2005, growth in China's demand slowed, but preliminary data for the fourth quarter indicate that growth has again accelerated. Because China now consumes so much oil—nearly 6.7 million barrels a day in 2004—even a modest percentage growth in petroleum demand translates into a great deal of new oil each year.

Figure 2-1.

Petroleum Consumption and Domestic Oil Production in China, 1980 to 2005

(Millions of barrels a day)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, "China," EIA Country Analysis Briefs (August 2005), available at www.eia.doe.gov/emeu/cabs/china.html.

Note: Data for 2005 are preliminary.

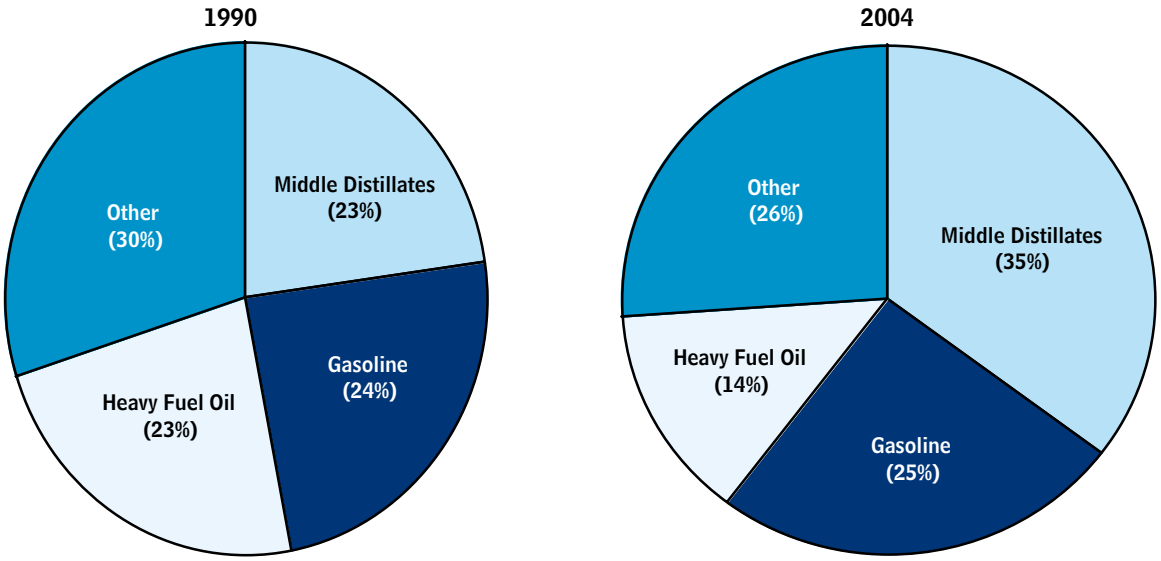
China first emerged as a net importer of crude oil in the early 1990s. The country was largely self-sufficient in oil resources until 1992 (see Figure 2-1 and Table A-1). Utilizing the resources of its western regions and coastal waters, China's state-owned oil businesses had been able for many years to boost production in line with growing demand. But production growth slowed in the mid-1990s, and came close to a halt in 2004, with output at about

1. Changes calculated from data on world oil consumption and prices reported in Department of Energy, Energy Information Administration, *Monthly Energy Review*, DOE/EIA-0025 (July 2005), Tables 9.1 and 11.2. Oil prices are the costs for U.S. refiners to acquire imported oil.

Figure 2-2.

China's Petroleum Consumption, by Type of Product, 1990 and 2004

(Percent)



Source: Congressional Budget Office based on data from British Petroleum, *Statistical Review of World Energy* (June 2005).

Note: "Middle distillates" are diesel fuel, heating oil, kerosene, and jet fuel. "Gasoline" means motor gasoline and naphtha used as feedstock for petrochemicals. "Heavy fuel oil" comprises residual fuel oil and bunker fuel. "Other" includes petrochemicals besides naphtha, liquefied petroleum gases such as propane, lubricating oils, asphalt, and waxes.

3.5 million barrels a day. By 2004, in little more than a decade, China's net imports of petroleum (including crude oil and refined products) had increased to about 3.0 million barrels a day—compared with 11.9 million barrels a day imported by the United States.[2]

A Shift in Demand Toward Light Petroleum Products

The recent growth across sectors of the Chinese economy has not been even, and the result has been a major shift in the mix of petroleum products consumed in China. A decade ago, fuel oil (in particular, heavy fuel oil for steam boilers) was an important part of that demand mix. Since then, demand growth has come from motor fuels—diesel fuel and gasoline—and from petrochemical feedstocks, including naphtha and liquefied petroleum gases.[3]

Middle distillates are the most important petroleum products consumed in China today (by volume) and have experienced the most growth in recent years (see Figure 2-2 and Table A-2). "Middle distillates" in the Chinese data comprise diesel fuel, heating oil, kerosene, and jet fuel. Middle distillates and gasoline together—with diesel being the dominant fuel—accounted for over 60 percent of petroleum consumption in China in 2004. (By comparison, in the United States, gasoline is the dominant product, and middle distillates and gasoline

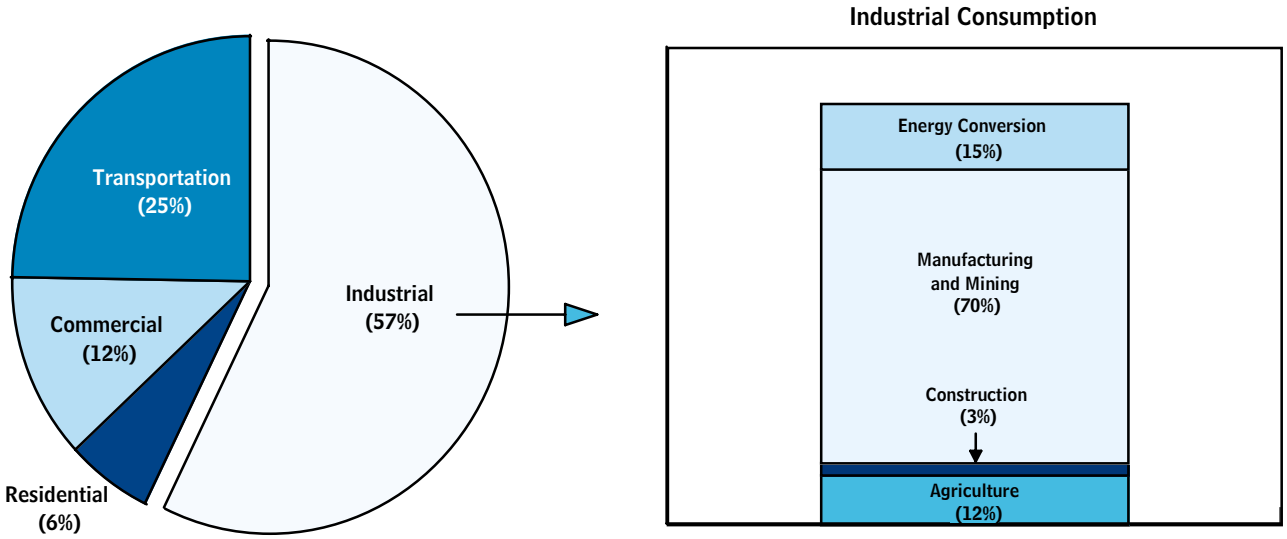
2. Net imports are estimated as the difference between reported total consumption of petroleum products and domestic production of crude oil. Data on net imports are from British Petroleum, *Statistical Review of World Energy* (June 2005). Data on changes in petroleum inventories in China are generally not available. If additions to stocks were positive in 2004, as is likely, imports for that year could have been higher than what is reported here.

3. The shift away from heavy fuel consumption may be greater than even those data indicate, since some heavy fuel oil reportedly is processed by petroleum refineries as a substitute for crude oil, not burned as fuel.

Figure 2-3.

China's Petroleum Consumption, by Economic Sector, 2002

(Percent)



Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 7-4 and 7-9.

together account for nearly 75 percent of total petroleum consumption.[4])

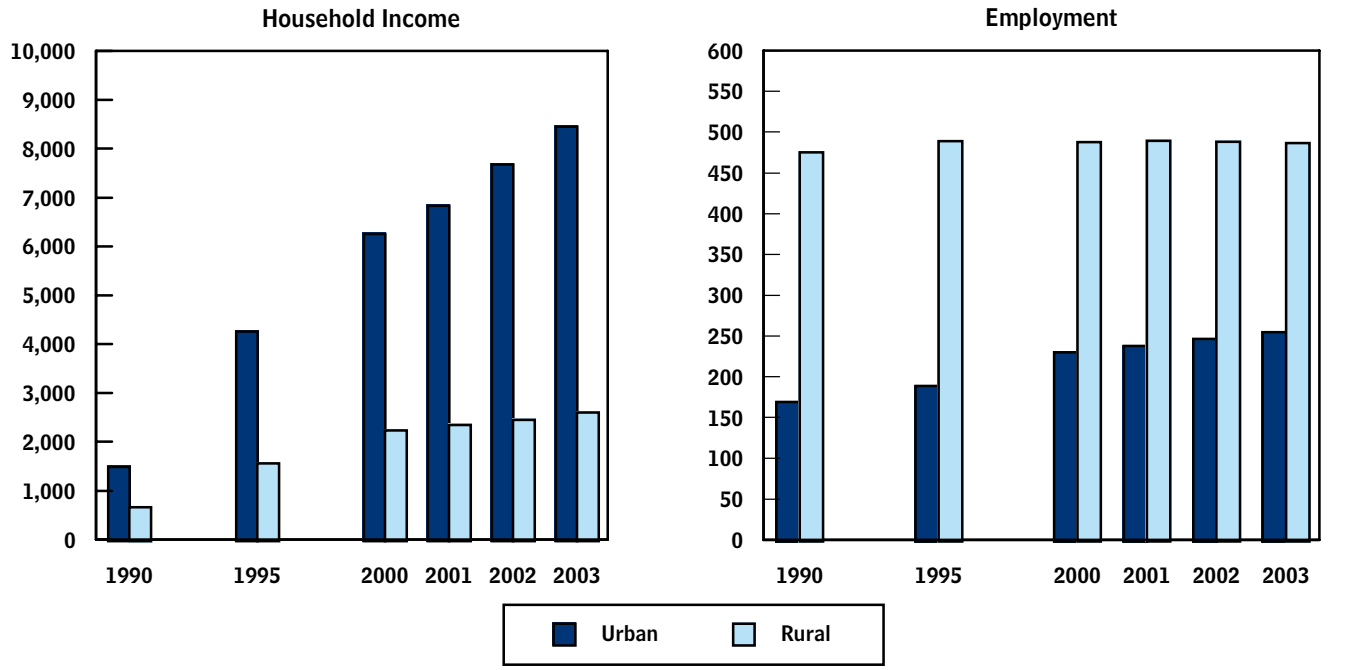
Much of the growth in petroleum consumption and the relative growth of particular fuels can be traced directly to growth in output of the major sectors of the Chinese economy—industrial, transportation, residential, and commercial. Changes in the efficiency of energy use in different sectors, which also can help to explain consumption trends, are less important than total economic activity in the short run.

Activity in the industrial and transportation sectors, which together account for over 80 percent of all petroleum use in China, explains much of the increase in demand for diesel fuel and gasoline. In 2002, the industrial sector accounted for over half of China's total demand for petroleum (see Figure 2-3 and Table A-3). That sector includes manufacturing, agriculture, and energy conversion activities, such as petroleum refining and electricity production (see Table A-4). Manufacturing concerns—many of them involving foreign investors from the United States, Japan, and South Asia—use refined petroleum products such as heavy oil and diesel fuel to operate equipment and to heat and cool their facilities and use products such as naphtha and liquified petroleum gases to produce petrochemicals. In agriculture, petroleum demand is strongest for diesel fuel, which is used to power China's 15 million tractors and 22 million small rural vehicles. The bulk of China's electricity comes from coal, hydroelectric power, and nuclear power, but limits on the ability to rapidly expand that capacity in the face of recent growth in electricity demand have steered increased usage to older power plants burning heavy fuel oil and newer small-scale generators burning diesel fuel. As with petroleum demand in general, industrial demand is growing fastest in China's urban centers.

4. Calculated from data on annual petroleum consumption in 2004 from Department of Energy, Energy Information Administration, *Monthly Energy Review,* Tables 3.1b, 3.4, 3.5, and 3.7. For consistency with Chinese data, "middle distillates" include distillates and kerosene-type jet fuel.

Figure 2-4.

Average Annual Nominal Income and Employment of Urban and Rural Households in China, Selected Years from 1990 to 2003



Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 5-4 and 10-2.

Note: Income is not corrected for changing prices, which generally were falling from 1990 to 1999 and constant thereafter, according to Table 9-5 in the *China Statistical Yearbook*.

About 25 percent of China's petroleum consumption is for transportation, including moving passengers and freight by road, water, rail, and air.[5] The growing demand in the transportation sector reflects the new personal wealth in China, as well as the transport requirements of industrial and commercial activity in the urban centers of the eastern provinces. The major fuels for transport are diesel, gasoline, heavy oil (used as bunker fuel in shipping), and jet fuel. Diesel is by far the most important, accounting for nearly twice as much consumption as gasoline.

Key Determinants of Motor Fuel Use

The key factors pushing the demand for oil in the transportation sector in China are the rising incomes of workers and the growing numbers of workers living in big cities. The cities are where the jobs requiring increased road travel are and where the road infrastructure supporting that travel is being built. That growing transportation infrastructure in turn supports further economic growth and attracts migrants to the cities. Signs of high activity in China's transportation sector include increases in per capita income, urban populations (and potential driver populations), vehicle sales, and highway construction.

Growth in incomes in China and in the size of the potential driving population has exceeded growth in the Chinese economy. Although real GDP growth in China has averaged about 9.2 percent annually since 1990, the per capita incomes of urban households grew by 13.3 percent over that same period (see Figure 2-4 and Table A-5). Moreover, although the Chinese authorities do not report

5. For background information on the rise of China's transportation sector, see Lee Schipper and Wei-Shiuen Ng, "Rapid Motorization in China," World Resources Institute, October 18, 2004 (a paper commissioned for the ADB-JBIC-World Bank East Asia and Pacific Infrastructure Flagship Study), available at www.cleanairnet.org/asia/1412/articles-60209_china.pdf.

data on inflation-adjusted incomes, separate data on consumer prices in China indicate that prices have fallen in the past decade, suggesting that the increase in real per capita incomes was even higher than 13.3 percent.[6] (Those statistics predate the upward revisions to Chinese data on GDP and growth in December 2005—as do all the data on energy consumption and sectoral activity that were used for this report.)

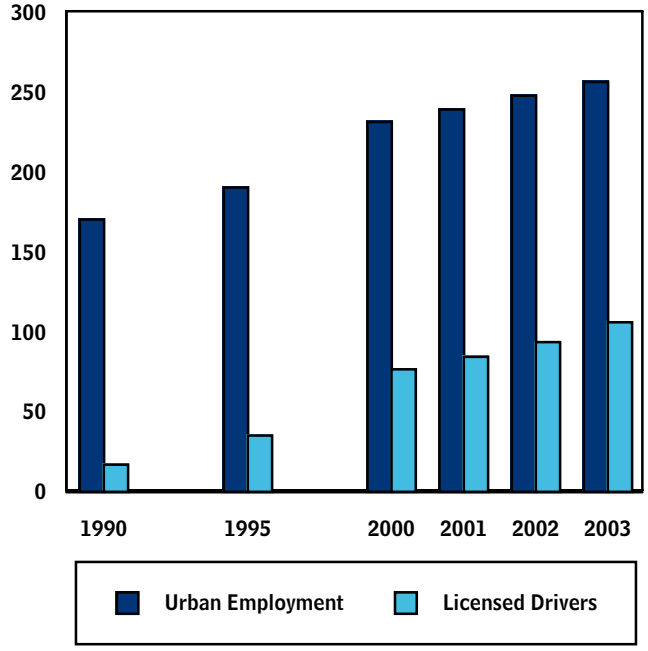
Because of the large shift in China's population from the rural areas to the cities, the number of potential drivers has been growing rapidly. From 1990 to 2003, as China's total population expanded by about 149 million, migration from the countryside helped the urban population to grow by nearly 220 million (see Table A-6). The migration to the cities is all the more important for transportation demand because the employment levels and average incomes of city dwellers have been growing relative to the levels for dwellers in rural areas. Urban employment grew by 3.1 percent a year over the 1990-2003 period, compared with a growth rate for the total population of only 0.9 percent. From some accounts, it appears that even more people are moving into the urban labor force than the total number moving to the cities would indicate—for example, as more women enter the paid workforce and as people shift from working for state-operated businesses in which they had been largely underemployed. Within those high-income urban areas, the sector of the Chinese population ages 15 to 64—the prime age for being drivers—grew by 170 million, or about 4.7 percent a year.

With the impetus from migration, employment, and earnings, the number of licensed drivers in China grew by nearly 90 million over the 1990-2003 period, or by more than 14 percent a year (see Figure 2-5 and Table A-6). That is, the rate of growth in the number of licensed drivers in China is more than four times the rate for employed urban people (the potential population of drivers), underscoring the consequences for transportation demand of the country's economic expansion. (By way of comparison, the number of drivers in the United States in 2003 totaled 196 million.[7])

Figure 2-5.

Urban Employment and Licensed Drivers in China, Selected Years from 1990 to 2003

(Millions of people)



Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 5-44 and 16-28.

The transportation requirements of the labor force (for commuting, business travel, and intracity and intercity road freight) and the means afforded by their increased incomes are, in turn, reflected in the growing demand for motor vehicles (see Figure 2-6 and Tables A-7 and A-8). In 2003, there were nearly 24 million vehicles available for civil uses, including about 15 million passenger vehicles (cars and buses) and 9 million trucks. That total number was up from about 5.5 million vehicles in 1990, indicating average annual growth over those years of 11 percent. A growing share of the country's motor vehicles are privately owned, too—including over 8 million cars and nearly 4 million trucks in 2003. (Vehicles owned by governments and businesses—mainly fleet vehicles and some vehicles assigned for personal use—account for

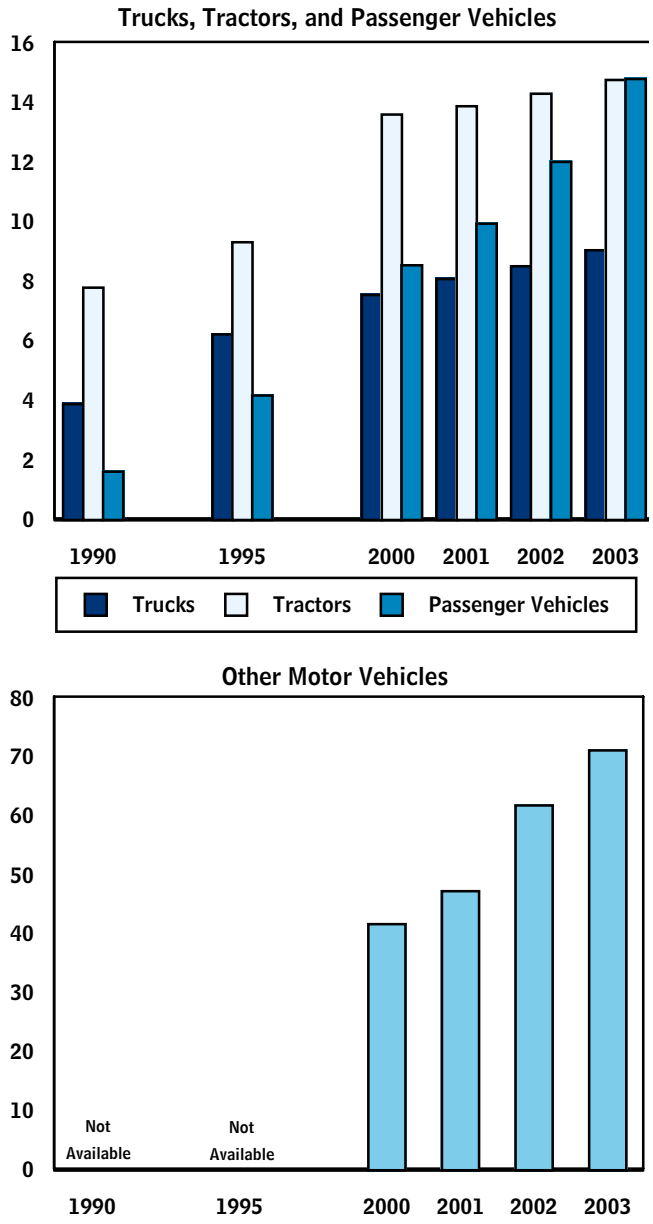
6. In the decade from 1994 to 2003, China's consumer price index declined by nearly 20 percent, from 124.1 to 101.2. See National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Table 9-5. The average price declines in urban and rural areas were similar.

7. Federal Highway Administration, *Federal Highway Statistics 2003* (November 2004).

Figure 2-6.

China's Stock of Vehicles, Selected Years from 1990 to 2003

(Millions of units)



Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 13-7 (tractors), 16-2 (other motor vehicles), and 16-28 (passenger vehicles and trucks).

Note: "Passenger vehicles" includes cars and buses. "Trucks" includes a small number of vehicles (for example, 0.5 million in 2003) described only as "other civil" vehicles. "Other motor vehicles" includes motorcycles and some off-road vehicles; data for that category are not available for 1990 and 1995.

most of the rest of the stock.) Annual sales of new cars and trucks in 2003 were about 4.3 million.

On top of those numbers—and often overlooked by studies of transportation demand in China—are government data indicating that there are 71 million motorcycles and other small off-road vehicles, with annual sales of over 13 million (despite government efforts to discourage their use in large cities). By way of comparison, there were 231 million motor vehicles registered in the United States in 2003, including only about 5 million motorcycles.[8] Other vehicles in China include a large number of agricultural vehicles that can be used on roads (with over 8 million "tire" tractors in 2001, the last year for which data are available). And research suggests that the number of rural vehicles (small three- and four-wheeled diesel-powered vehicles manufactured for use in small cities and rural areas) may be as high as 22 million—although those vehicles may be grouped with "motorcycles" in government statistics.[9]

In conjunction with growth in the driving population and vehicle stock, China is spending nearly $29 billion annually on new highway construction and expansion.[10] In 2003, the full highway system—not just expressways and first-class highways—grew by 28,000 miles, and all highways and expressways in China extended for 1.1 million miles (see Table A-9). Over the 1990-2003 period, China's highway system grew by 4.4 percent annually. And by 2000, over 98 percent of China's towns and townships had highway connections.[11] Because much of that investment removed local bottlenecks and helped to reduce travel times, the actual capacity of the highway system to move people and freight was increasing even faster than the number of lane-miles. (In comparison, the

8. Federal Highway Administration, "State Motor-Vehicle Registrations—2003" (October 2004), available at www.fhwa.dot.gov/policy/ohim/hs03/htm/mv1.htm.

9. The estimate of the number of rural vehicles comes from Dan Sperling, Zhenhong Lin, and Peter Hamilton, "Chinese Rural Vehicles: An Explanatory Analysis of Technology, Economics, Industrial Organization, Energy Use, Emissions, and Policy," Institute of Transportation Studies, UCD-ITSRR-04-01 (2004).

10. Estimated by the Congressional Budget Office from the 241 billion yuan (nominal) reported for new highway construction and highway expansion in the *Chinese Statistical Yearbook 2004,* Table 6-9, using an exchange rate in that year of 8.28 yuan per U.S. dollar. The exchange rate in late 2005 was about 8.10 yuan per dollar.

11. China News and Report, "Development of China's Transport Network," June 2001.

Box 2-1.

Ownership of China's Oil Businesses

The term "state-owned" as used in this paper means that the state holds the majority of shares in a firm. But the details of that ownership are not simple, and it is often difficult to discern private ownership from state ownership. On paper, there generally is an arm's-length relationship between the government agency that controls those shares and the firm's management.

The mechanisms for establishing state ownership are diverse. Businesses operating in China are registered under a number of categories. The three major groups are domestic-funded enterprises; enterprises with funds from Hong Kong, Macao, and Taiwan; and foreign-funded enterprises. The largest group of registered businesses are the domestic-funded enterprises, accounting for nearly 70 percent of China's industrial output in 2003.[1] Those businesses in turn include state-owned industry, collective-owned industry, cooperative-owned industry, limited liability corporations, shareholding enterprises, and private enterprises.

Actual ownership of a firm is even more complicated because the state and the diverse domestic and foreign groups may become partners through various financial arrangements. All together, within the three main categories of registered businesses, state-owned and state holding enterprises account for about 35 percent of China's industrial output.

The three large businesses that produce, import, refine, and market most of China's oil are controlled by state holding companies, which conduct their endeavors through a great many wholly owned and joint-stock subsidiaries. The partners in the joint subsidiaries may be domestic-funded enterprises; Hong Kong-, Macao-, or Taiwan-funded enterprises; other foreign-funded enterprises; or individuals (if public stock has been sold).

1. National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Table 14-1.

U.S. National Highway System comprises about 162,000 miles, including 47,000 miles of interstate highways.[12] The total U.S. system, including state highways, extends for about 4 million miles.)

Much of China's highway infrastructure is concentrated in the coastal provinces that include the country's largest cities—the same regions that are experiencing high growth in population and employment (see Table A-9). That is the area from Guangdong province in the south (on the mainland, near Hong Kong) to Liaoning province in the north (above Beijing). Of the nation's total 37,000 miles of expressways and first-class highways at the end of 2003, nearly 60 percent of those miles were in those coastal provinces and the large coastal cities of Shanghai, Beijing, and Tianjin.

12. Federal Highway Administration, *Federal Highway Statistics 2003*.

The Changing Structure of the Chinese Oil Industry

Three state-owned companies dominate all stages of the petroleum industry in China (see Box 2-1).[13] CNPC (the China National Petroleum Corporation) is a vertically integrated business, involved in oil and gas production, refining, pipelines, and retail outlets. It generally operates in the North and West of the country. A CNPC subsidiary, PetroChina, is the country's largest producer of oil and gas from onshore regions, and it operates China's largest pipeline complex. CNPC also holds oil and gas assets worldwide.

Sinopec (the China Petroleum and Chemical Corporation) is a second vertically integrated business, involved in oil and gas production, refining, pipelines, and retail

13. For background information, see Melissa Murphy, "An Overview of China's Energy Sector," Freeman Briefings, Center for Strategic and International Studies (November 2004).

outlets. Generally operating in the South and East of the country, Sinopec is China's largest petroleum refiner and largest retailer of petroleum products. The company produces crude oil domestically but imports most of the oil it refines. Like CNPC, Sinopec also holds oil and gas assets worldwide. Together, the two companies control 95 percent of the petroleum refinery capacity in the country.

The third large company—CNOOC (the China National Offshore Oil Corporation)—is involved in the production of oil and gas, liquefied natural gas, and petrochemicals.[14] It is the largest producer of oil and gas in China's offshore areas, it operates China's largest petrochemical complex, and it holds oil and gas resources throughout the Pacific and in Southwest Asia.

The government has a direct stake in the financial performance of all of those businesses. In addition to taxes on income, the government receives a share of the profits from those businesses (it holds a majority of the shares in each one). Government interests are behind the industry's push to develop oil resources in countries around the world. By providing low-cost capital and a supportive foreign policy, the government has enabled the national oil companies to sign long-term supply contracts, establish equity positions in foreign oil developments, and establish bilateral trade with those potential suppliers. Moreover, as stated in a directive, the government intends to consolidate the nation's oil businesses into a handful of large, leaner companies (shedding excess capacity and employees) capable of pooling technical resources and competing directly with the largest international oil companies.

The Chinese government has also sought to restructure its oil industry in other ways. In response to recent concerns about growing oil demand and oil imports, it has implemented efforts to make businesses more energy-efficient, diversify the sources of energy supply, and curb growth in oil demand.

In the "upstream" sector of the oil business (crude oil production), securing access to crude oil abroad is part of the government's broad strategy to diversify the country's sources of energy. That strategy includes the construction of oil and natural gas pipelines from Kazakhstan and Russia and the construction of new port facilities for the importation of liquified natural gas—as well as efforts to promote the development of alternative fuels. The effort to improve efficiency and profitability has driven a major consolidation of businesses and an opening of oil and gas activities to foreign investment.[15]

In the "downstream" sector (refining and distribution), concerns about the technical inefficiency of many small companies and about air quality have led to further consolidation in ownership. One result was the closure of many of the smallest refineries. A related potential motivation for the restructuring was the opening of the petroleum industry and other industries to direct foreign investment, as required by China's accession to the World Trade Organization. China's refinery businesses have been opened to foreign investment on several occasions to help provide financing and technical expertise for the effort to expand capacity. The industry, however, is not yet fully open to foreign capital. For example, the government has stipulated that only CNPC and Sinopec can open new retail outlets, so foreign investors must partner with those firms to gain entry to the motor fuel market.

Government Programs That Affect the Demand for Petroleum

Further change in China's oil markets is coming from regulations and programs to improve environmental quality and constrain growth in oil consumption. Noteworthy among the conservation efforts is the recent program to establish fuel economy standards for new motor vehicles. Other programs that have the potential to affect oil use are price controls on petroleum products and taxes affecting the cost of vehicle ownership and use.

The actual effect of those programs is unclear. For example, fuel economy standards are unlikely to have much impact in the near term, since new cars can only affect the average fuel economy of all vehicles over time. Retail price controls on motor fuels, which in the short run

14. In 2005, CNOOC made a bid to acquire the U.S. firm Unocal.

15. For a discussion of foreign investment in China's crude oil production and refinery industries, see Department of Energy, Energy Information Administration, *Privatization and the Globalization of Energy Markets* (October 1996), Chapter 4; and the Organization for Economic Cooperation and Development, *Foreign Direct Investment and Importance of the "Go West" Strategy in China's Energy Sector* (Paris: OECD, March 2002). A discussion from the Chinese perspective appears in China E-News, "China Slowly Reforming Refineries and Petchem Industry," available at www.pnl.gov/china/sinopec.htm.

could encourage gasoline use, have been eased. And motor fuel taxes that may appear low by international standards—and which, on their own, would seem not to discourage oil use—do not appear so low when all types of taxes on transportation are considered. As a general caveat to this discussion of government programs, there are concerns about how well China, as a still-developing country, is able to enforce those programs. In particular, institutional problems could cause fuel economy standards or other environmental policies to fall short of the government's stated goals.

Environmental Regulation

Urbanization, motor vehicle use, and industrial activity tend to degrade air and water quality in China. New environmental programs targeting emissions and waste disposal are responsible for the growing adoption of clean technologies and practices in all sectors of the petroleum industry—although the success of those relatively recent efforts cannot yet be assessed. The government's efforts to consolidate ownership in petroleum refining and fossil fuel production in China was motivated in part by the interest in closing down small unregulated businesses that were contributing to environmental problems. Among the changes that could specifically affect petroleum refinery operations are new laws to eliminate lead from gasoline and restrict the sulfur content of gasoline and diesel fuel.

Fuel Economy Standards

China's fuel economy standards for new vehicles began in 2005, with a second, more-stringent, phase taking effect in 2008. The weight-based standards impose separate minimum requirements for fuel efficiency on 16 different classes of vehicles, ranging from 38 miles per gallon (mpg) for the lightest vehicles to 19 mpg for the heaviest. (In 2008, the requirements increase to 43 mpg and 21 mpg, respectively.) The biggest improvements would be required of the heaviest vehicles.[16]

Price Controls

Expressed in U.S. dollars, gasoline and diesel prices in China are much lower than in other countries. Until recently, China's system of price controls shielded Chinese consumers from the price of oil in world markets. The controls originally based prices for refined petroleum products on average costs to the oil companies—costs that included the controlled price for domestic crude oil. The effect of those controls was to convey a subsidy from producers to consumers of refined products.

In 2001, however, Chinese policymakers began moving away from price controls on energy products by tying retail prices for gasoline and diesel to a weighted average of futures prices for those commodities in Singapore, Rotterdam, and New York.[17] The government—specifically, the National Development and Reform Commission, or NDRC—establishes a national benchmark for retail prices for all but the largest petroleum marketers. The government allows Sinopec and CNPC's PetroChina to set their own retail prices, in accordance with the principle of revising prices only when foreign prices change. For smaller marketers, local governments have the immediate responsibility for carrying out the central government's guidelines, with additional discretion to alter prices within a 5 percent band around the national benchmark.

The NRDC was to revise those prices every few months, whenever wholesale prices moved by more than 8 percent, up or down. In March 2006, the commission adopted its first major price changes in eight months, increasing pump prices in Beijing to nearly $2.20 a gallon for premium grade gasoline and about $1.90 a gallon for diesel.[18] With worldwide prices for crude oil and refined products rising steadily, the time lags in adjusting retail prices had created a periodic loss of profits for China's refiners, prompting the most recent revision in prices.

As a result of China's policy changes, gasoline and diesel prices in China now tend to reflect the marginal costs of supplying those fuels over time, without conveying as significant a subsidy to petroleum consumers. But because prices still are not completely free to respond to market conditions, the current system may be responsible for

16. For a description of China's fuel economy standards, see Amanda Sauer and Fred Wellington, "Taking the High (Fuel Economy) Road—What Do the New Chinese Fuel Economy Standards Mean for Foreign Automakers?" (Washington, D.C.: World Resources Institute, November 2004).

17. A discussion of Chinese price controls and some of the problems associated with them appears in "Trend or Glitch," *Beijing Review* (2005), available at www.bjreview.com.cn/En-2005/05-26-e/bus-5.htm.

18. *China Daily*, "Preparation Prevents Higher Oil Price Pain," March 28, 2006, available at www.chinadaily.com.cn/opinion/2006-03/28/content_553748.htm. Prices in yuan per liter were converted to dollars per gallon using 0.264 liters per gallon and 8.10 yuan per dollar.

some problems with investment and marketing. Unless time lags in adjusting retail prices are completely eliminated, there will be periodic incentives to export products if the benchmark price falls below the market value or to import them if the market value falls below the benchmark price. Prices that lag behind costs can undermine profitability and discourage domestic investment in refining and distribution capacity. Also, with a national benchmark, if prices are not completely free to vary across regions, profit incentives may not be sufficient to encourage suppliers to keep pace with demand in the fast-growing urban areas.

Energy Taxes

Direct taxes on motor fuels in China are low, compared with the levels in most industrialized countries, but additional taxes on vehicle ownership and operation (including extensive road tolls) can add greatly to the cost of travel and influence decisions about the fuel economy of new vehicles. A full consideration of the effects of taxes on motor fuel consumption in China needs to consider all of those taxes.

China's transportation costs reflect the basic costs to oil businesses of several taxes assessed by the central government:

- A 17 percent value-added tax (or VAT, the main source of revenue for the central government),
- An income tax on large enterprises,
- A "consumption" tax on luxury items, and
- A vehicle purchase tax.

The VAT and the enterprise income tax are common to all businesses, with numerous exemptions or reductions depending on the product, the technology of production, the age of the operation, and the location of the activity. For example, China has a reduced VAT—13 percent—on sales of propane, natural gas, and residential energy services. And there are many free-trade zones and foreign firms producing for export that pay lower tax rates. The consumption tax, assessed on producers of gasoline and diesel, is the only direct tax per unit of fuel. Currently, that tax is fixed at 117.6 yuan per metric ton for gasoline (about six cents a gallon) and 277 yuan per ton for diesel (about 10.5 cents a gallon).[19] The central government's tax on vehicle purchases depends on the size of the engine, varying from 3 percent for the smallest vehicles to 20 percent for the largest.[20] Only the VAT and the consumption tax directly affect fuel prices and the current cost of travel. But the tax on vehicle purchases can indirectly affect the cost of travel over time by influencing buyers' decisions about the fuel economy of new cars.

Estimating the actual costs imposed by the VAT is difficult because an up-to-date history for gasoline and diesel prices in China is not readily available. However, information on Beijing prices in March 2006 can help to clarify the impact of those taxes. With prices for premium grade gasoline at that time at 4.65 yuan per liter (or about $2.20 a gallon), the combined VAT and consumption tax included in that price was about 39 cents a gallon.[21] For comparison, the average price in the United States in that month was about $2.50, including a combined federal and state tax on gasoline of about 44 cents, on average. (If growing crude oil costs were passed through to consumers or if the yuan was revalued—many analysts believe it is priced too low relative to the dollar—the Chinese tax in cents per gallon would increase.)

Local Chinese governments also impose taxes and fees. Additional costs to consumers come from local assessments related to vehicle purchases, driver permits, vehicle licenses, and road maintenance fees, and from private tolls on expressways and bridges. Road maintenance fees and tolls, which together finance much of the country's road construction, are especially costly. Almost all of China's new expressways are toll roads.[22] Road maintenance fees are assessed annually, generally on the basis of vehicle size—so that owners of larger, less-fuel-efficient vehicles have higher costs of ownership.

19. Converted to cents per gallon using 8.53 42-gallon barrels of gasoline per metric ton, 7.46 42-gallon barrels of diesel per metric ton, and 8.10 yuan per dollar.

20. China Daily, "Buyers of Big Cars Have To Pay More Tax," March 23, 2006, available at www.chinadaily.com.cn/china/2006-03/23/content_549959.htm.

21. Converted using the factors listed in footnote 17.

22. Alfred Nickesen and others, "Toll Road Securitization in China," The World Bank Group, Roads & Highways Note RH-3 (February 2000).

It is not clear how much those local charges are costing Chinese drivers. But it is possible to get a general idea of the revenues required by looking at the country's annual spending on highway construction (which the road maintenance fees and tolls finance) and its consumption of gasoline and diesel. An assessment equivalent to nearly $1 a gallon on gasoline and diesel fuel would be needed to fully fund China's annual spending on highway construction of about $29 billion in 2003, assuming (for illustrative purposes) on-highway fuel use of about 2 million barrels a day.[23]

23. In 2004, gasoline consumption in China was 1.6 million barrels a day, which was largely for road use. It is not known how much of diesel consumption was for road use. See British Petroleum, *Statistical Review of World Energy.*

    CBO has no information on how the maintenance of roads in China is financed. Some of the toll collections could go toward that purpose. Maintenance in the United States is generally a local concern, funded in part by state motor fuel taxes.

CHAPTER

3

Scenarios of Future Demand Growth in China

This chapter examines two alternative scenarios of how rapidly the demand for petroleum in China will grow over the next five years. On the one hand, demand may be restrained by slower growth in the Chinese economy overall, high oil prices, an easing of some pressures that temporarily increased demand, and policies put in place by the Chinese government that may reduce petroleum consumption.[1] On the other hand, demand may be accelerated by the reinforcing trends of growing urban populations and incomes and more vehicles and drivers with an expanding road system on which to travel.

The growth in China's total oil consumption in the next five years is important for the United States because any addition to worldwide oil demand could put upward pressure on worldwide oil prices. The economic circumstances that would make the faster-growth scenario feasible are perhaps of most interest to policymakers, since that scenario is associated with the largest increases in worldwide oil prices. But this paper does not present either scenario as more likely than the other. Circumstances may exist in which demand growth in China turns out to be below the slower-growth case (as, from preliminary data, appears to have happened in 2005) or above the faster-growth case (as happened in 2003 and 2004).

In neither case are the consequences of China's growing energy demand likely to appreciably dampen U.S. oil use or economic growth. Most likely, the net benefits to the U.S. economy from China's economic growth and China's contribution to the world's economy—which this analysis does not address—will be positive. Furthermore, in neither scenario will the price for crude oil in 2010 necessarily be higher than it is today. Each of the forecast reports reviewed here projects a different path for prices, consistent with its views on the global growth in worldwide oil demand, not just the growth in China, and the changes in worldwide oil supply. But regardless of where oil prices are headed—whether up or down—the additional demand from China alone will add something to that price. It is those price increments attributable to changes in the Chinese market that are of interest in this analysis.

Major Oil Market Forecasts

Several government and private groups publish forecasts of worldwide energy use through 2010 and beyond. The reports examined here, all published in 2004 and 2005 and prepared before the final data for those years were available, come from the Energy Information Administration (EIA), the International Energy Agency (IEA), the International Monetary Fund (IMF), the Organization of Petroleum Exporting Countries (OPEC), and Global Insight (GI).[2] (Updates to the IEA outlook were released in November 2005, but they exclude detailed forecasts for China. Other major studies of the worldwide energy market exist but are not publicly available—such as the

1. Some analysts point to the possibility that new conservation policies, such as the promotion of alternative fuels and increased efficiency of buildings, could help to slow growth in demand. However, many of those policies are unlikely to yield significant savings in the next five years, so they are not considered in this analysis. For example, in one alternative scenario, the International Energy Agency discusses measures that might yield total oil savings of 13 percent by 2030. See International Energy Agency, *World Energy Outlook 2004* (October 2004), pp. 391 and 393. Among the policies the IEA evaluated are new standards for fuel economy, plans for increased research and tax credits to promote the use of clean vehicles, and plans for expanding China's intracity and intercity railway networks. For the other major forecasts of future energy demand in China, the potential contribution, if any, from recent conservation programs is not known.

2. See Department of Energy, Energy Information Administration, *International Energy Outlook 2005* (July 2005); International Energy Agency, *World Energy Outlook 2004*; International Monetary Fund, *World Economic Outlook* (April 2005); Organization of Petroleum Exporting Countries, *Oil Outlook to 2025* (September 2004); and Global Insight, *Global Petroleum Outlook* (Winter 2004-2005).

Table 3-1.

Forecasts of Annual Growth in Gross Domestic Product in China and the World

(Percent)

	China		World	
Source of Forecast	2004 (Preliminary)	Average Annual Growth, 2005–2010	2004 (Preliminary)	Average Annual Growth, 2005–2010
Energy Information Administration[a]	8.6	6.4	4.9	3.9
International Energy Agency[b]	7.0	6.4	n.a.	3.7
International Monetary Fund[c]	9.5	8.0	5.1	4.4
Organization of Petroleum Exporting Countries[d]	8.0	6.8	3.9	3.8
Global Insight[e]	8.7	6.8	3.8	3.1

Source: Congressional Budget Office based on information from the Department of Energy, Energy Information Administration, *International Energy Outlook 2005* (July 2005), Table 2; International Energy Agency, *World Energy Outlook 2004* (2005), Table 1.1 and p. 43; International Monetary Fund, *World Economic Outlook* (April 2005), Table 1.1 and p. 163; Organization of Petroleum Exporting Countries, *Oil Outlook to 2025* (2004), Table 1; and Global Insight, *Global Petroleum Outlook* (Winter 2004-2005), Table 12.

Notes: Growth rates are reported as purchasing-power adjusted rates, which generally are lower in each report than forecasts of market rates.

n.a. = not available.

a. Forecast horizon is 2005 to 2015.

b. Forecast horizon is 2002 to 2010.

c. Base-year forecast is for 2006; forecast horizon for world growth is 2003 to 2030.

d. Base-year forecast is based on average growth from 2003 to 2005; forecast horizon is 2006 to 2010.

e. Forecast horizon is 2005 to 2010.

Global Energy Watch by Cambridge Energy Research Associates.)

The forecasts are in relatively close agreement on the prospect of continued high growth in the Chinese economy. All of the forecasts reflect a slowing in the growth of oil demand, with total oil consumption growing more slowly than overall economic output. But each forecast has demand for oil in the transportation sector growing faster than economic output—and, as a consequence, demand for oil in other sectors growing much more slowly. As a result, the forecasts show transportation fuels as accounting for an increasing share of total oil consumption in China.

Recent mid-term forecasts of annual growth in China's gross domestic product through 2010 span a range of 6.4 percent (from EIA and IEA) to 8 percent (from IMF) (see Table 3-1). The 8 percent figure from the International Monetary Fund matches the target established in China's *11th Five-Year Plan*, issued in 2006.[3] It is likely that Chinese policies over the next five years will be oriented toward achieving growth that is at least that high. With China's real GDP currently growing at close to 10 percent a year, even that 8 percent level would represent a significant slowdown from the trend of the past five years. (The historical growth rates for GDP that this paper cites were prepared before the statistical revisions announced by the Chinese government in December 2005.[4] The revisions reflect new information on service-sector activity. As a consequence, in January 2006, the Chinese government increased its estimate of GDP growth in 2004 from 9.5 percent to 10.1 percent. The current estimate for growth in 2005 is 9.8 percent.)

Behind the projections of some slowing in economic growth is a view that China cannot continue its rapid pace of capital investment without risking inflation or

3. See Government of the People's Republic of China, *11th Five-Year Plan for National Economic and Social Development* (March 2006). The plan covers the 2006-2010 period.

4. The revisions were widely discussed in the press. See, for example, "China Says It Grew Faster Than First Thought," *New York Times*, December 20, 2005, p. C4; and "China Raises Growth Figures for Recent Years," *Wall Street Journal*, January 10, 2006, p. A12.

Table 3-2.

Forecasts of Total Oil Consumption in China and the World

(Millions of barrels per day)

	China			World		
Source of Forecast	2004 (Preliminary)	2010	Average Annual Growth (Percent)	2004 (Preliminary)	2010	Average Annual Growth (Percent)
Energy Information Administration	6.5	9.2	5.8	82.5	94.6	2.3
International Energy Agency	6.4	7.9	3.5	82.5	90.4	1.5
International Monetary Fund	6.4	8.6	4.9	82.4	92.0	1.8
Organization of Petroleum Exporting Countries[a]	6.0	7.6	3.9	81.0	88.7	1.5
Global Insight	6.7	8.8	4.5	82.4	92.2	1.9

Source: Congressional Budget Office based on information from the Department of Energy, Energy Information Administration, *International Petroleum Monthly* (June 2005), Table 2.4, and *International Energy Outlook 2005* (July 2005), Table A4; International Energy Agency, *Monthly Oil Market Report* (April 12, 2005) and *World Energy Outlook 2004* (2005), Table 3.1; International Monetary Fund, *World Economic Outlook* (April 2005), Table 4.2; Organization of Petroleum Exporting Countries, *Oil Outlook to 2025* (2004), Table 3; and Global Insight, *Global Petroleum Outlook* (Winter 2004-2005), Table 2.

a. Values for 2004 were not available; estimates shown for that year are forecasts reported for 2005.

stressing the country's financial institutions. For those reasons, many analysts agree that China's government will continue its efforts to restrain the pace of economic expansion. Moreover, China's growing current-account surplus may exert upward pressure on the value of its currency. A stronger yuan would decrease China's net exports and help to moderate its GDP growth, at least in the short run.

In each forecast, growth in total oil consumption in China through 2010 is lower than the projected growth in GDP and below the growth in oil consumption over the past decade (see Tables 3-1 and 3-2). The forecast growth rates for China's total oil use range from 3.5 percent a year (IEA) to 5.8 percent (EIA)—below the average growth of 7.5 percent a year from 1995 to 2004. The ratios of projected growth in total oil consumption to growth in GDP—described as the income elasticity of oil demand—range from 0.55 (IEA) to 0.91 (EIA).[5] (For comparison, total oil consumption in the United States and other mature economies generally grows at about half the pace of the economy, reflecting an income elasticity of oil demand equal to about 0.5.[6])

There is greater agreement among forecasters about the demand for oil in the transportation sector than about total oil use in China (see Table 3-3). The forecast growth in demand for oil consumed for transportation from 2004 to 2010 ranges from 6.0 percent a year (IEA) to 8.0 percent (OPEC). That compares with annual growth of 10.8 percent for oil consumption in China's transportation sector over the past decade and 8.4 percent for consumption of gasoline and middle distillates, including

5. Those ratios summarize the short-term relationship between changes in oil use and economic output—or income. The additional effects of changing oil prices on demand are included in the elasticity by way of their indirect effect on economic activity.

6. The income elasticity for mature market economies was calculated from Department of Energy, Energy Information Administration, *International Energy Outlook 2005*, on the basis of growth in transportation oil use described in Table 3 and GDP growth described in Table A3. Separately, the International Monetary Fund assumes an income elasticity of demand for transportation fuels that is 0.32 for OECD countries and the newly industrialized Asian economies and 0.85 for other non-OECD countries; see International Monetary Fund, *World Economic Outlook*, Table 4.3. In the past decade, oil consumption has grown at an average annual rate of 1.8 percent, while real GDP has grown at 3.3 percent.

Table 3-3.

Forecasts of Oil Use for Transportation in China and the World

(Millions of barrels a day)

	China			World		
Source of Basis for Forecast	2004 (Preliminary)	2010	Average Annual Growth (Percent)	2004 (Preliminary)	2010	Average Annual Growth (Percent)
Energy Information Administration—All Transport Energy[a]	1.9	3.4	7.2	39.1	48.3	2.5
International Energy Agency[b]						
All transport oil	1.7	2.7	6.0	36.6	44.7	2.5
Road transport oil	1.1	1.9	6.3	n.a.	n.a.	n.a.
International Monetary Fund—All Transport Oil[c]	n.a.	n.a.	n.a.	46.3	54.3	2.3
Organization of Petroleum Exporting Countries—Road Transport Oil[d]	0.9	2.0	8.0	28.2	33.6	1.8
Global Insight—All Transport Oil[e]	2.0	3.3	6.5	39.4	48.3	2.5

Source: Congressional Budget Office based on information from the Department of Energy, Energy Information Administration, *International Energy Outlook 2005* (July 2005), Table 3 and p. 23; International Energy Agency, *World Energy Outlook 2004* (2005); International Monetary Fund, *World Economic Outlook* (April 2005), Table 4.2 and p. 165; Organization of Petroleum Exporting Countries, *Oil Outlook to 2025* (2004), Table 8; and Global Insight, *Global Petroleum Outlook* (Winter 2004-2005), Tables 14 and 40.

Note: n.a. = not available.

a. Growth rate is for 2002 to 2015. China's level in 2010 is calculated from the 2002 level and forecast growth rate for China; see International Energy Agency, *International Energy Outlook 2005,* p. 23. Estimates in quadrillion Btus converted using 5.98 million Btus per barrel (the average heat content of imported crude oil to the United States).

b. Growth rate is for 2002 to 2010. Data for all transport oil from Appendix A of the *World Energy Outlook 2004,* Reference Scenario World and Reference Scenario China. Data for road transport oil from Figure 8.13, p. 266. Data in metric tons of oil equivalent (mtoe) converted using 7.7 barrels per ton, for consistency between forecasts in mtoe and barrels from Table 3.1.

c. Base year is 2003. Growth rate is for 2003 to 2015. Estimate for 2010 is calculated using forecast for GDP growth in 2010 from the *World Economic Outlook,* Table 4.2. The International Monetary Fund (IMF) expects the use of oil for transportation to be 60 percent of the increase in total oil use by 2030. IMF estimates the income elasticity for transportation oil use in China to be 0.55, so the annual growth can be imputed from IMF's GDP growth rate for China.

d. Base year is 2000. Growth rate is for 2000 to 2010.

e. Converted from metric tons of oil equivalent using 7.6 barrels per ton to preserve consistency with other Global Insight forecasts that are reported in barrels.

uses of those fuels in other sectors (see Tables A-1 and A-3). In contrast to total oil use, consumption for transportation in those forecasts generally is projected to keep pace with growth in the overall economy through 2010. Combining the forecast results, the ratios of growth in transportation demand to growth in GDP range from about 0.93 (OPEC) to about 1.13 (EIA). (Some of the difference may be attributable to different concepts of consumption for transportation, relying variously on total energy, total oil, and total oil for road use.)

Forecasts for the Chinese transportation sector reflect much higher growth than those for the U.S. transportation sector. Transportation demand in the United States (which dominates total U.S. oil demand) has been growing over the past decade at about 1.8 percent a year. That is half the rate of growth in the general economy (3.3 percent) but more than twice the rate of growth of the total population (0.8 percent).

Complementing the published forecasts of high growth in transportation use are generally low forecasts for growth in oil consumption by other sectors of the Chinese economy. The combined forecasts for oil consumed in the residential, commercial, and industrial sectors indicate annual growth through 2010 that ranges from 1.6 percent (OPEC) to 3.9 percent (EIA).[7] Those rates show expansion in the demand for oil by homes and businesses (for space heating, machine operations, processing of raw materials, and so forth) that is from one-fifth to one-half the rate of expansion in the general economy. The rates are slower than the 4.9 percent pace of growth for those sectors from 1995 to 2002 (the most recent year for which sectoral data are available) and the 6.4 percent growth for fuels other than gasoline and middle distillates from 1995 through 2004.

The forecasts also indicate a general consensus that transportation fuels will make up an increasing share of the total mix of petroleum products consumed in China in the future. Whereas the forecasts for total oil demand are important for worldwide oil prices, the forecasts for the relative demand for transportation fuels are important for the future costs of refining petroleum products.

The Case for Slower Growth in Demand

The slower-demand-growth scenario presented here assumes that total Chinese oil use will continue to grow at the rates that had been projected in the reports by the government and private organizations reviewed in this paper. Taking the average of those forecasts, the growth in this scenario would be 4.5 percent a year, resulting in total oil demand by 2010 of about 8.5 million barrels a day—an increase of about 2 million barrels a day over the current level. Based on those forecasts and recent growth, most of that additional demand is expected to be for light petroleum products—especially motor fuels in the transportation sector.

Consistent with that view, at the end of last year (before final data were available), growth in the demand for oil in 2005 indeed appears to have slowed. Based on data available through September 2005, IEA expects that China's demand for oil in 2005 will be only about 2.9 percent higher than in the previous year.[8]

That scenario also is consistent with the view that the temporary market conditions of the past couple of years have eased and that new initiatives to restrain growth will succeed. Some support for that result comes from analyses concerned with structural weaknesses in China's financial sector and with its ability to sustain high levels of capital investment in the near future.[9]

Demand Response to High Oil Prices

The major forecasts reviewed here were prepared before the big increase in worldwide oil prices in 2005. Some change in demand in response to those increased prices may have contributed to a slowdown in the growth of oil consumption in China that year. If oil prices remain high or rise further, that dampening effect will probably continue. Consistent with the view that consumers may have responded to the sharp increases in petroleum prices by buying less gasoline, oil consumption in the United States in 2005 was flat, too—even before the gasoline price hikes that followed Hurricanes Katrina and Rita.

It is difficult to assess precisely how demand will respond to changing prices in China. Prices for petroleum were controlled until 2001, so there has not been much statistical evidence of price and consumption changes to evaluate. Also, as discussed in this paper, so many other factors that determine the demand for oil were changing at the same time. In both the short and the long terms, prices are generally less important for predicting oil consumption than are population and income—both of which were adding to demand in China even as oil prices rose.

Reversal of Some Temporary Demand

One circumstance that may have contributed to the high demand for oil of the past few years has been China's problems in generating and delivering enough electricity to support its growing cities and industries. A part of that added demand may have been for heavy fuel oil, consumed by the electric utilities in central generating plants. (In 2002, utilities in China generated about 79 percent of their electricity from coal, 17 percent from hydropower, 2 percent from heavy fuel oil, and 2 percent from nuclear

7. Total consumption by other sectors was estimated by subtracting transportation consumption from total consumption.

8. International Energy Agency, *Oil Market Report* (January 17, 2006), p. 4.

9. An important discussion of that point appears in Morris Goldstein and Nicholas Lardy, "What Kind of Landing for the Chinese Economy?" Institute for International Economics, Policy Briefs in International Economics, No. PB04-7 (November 2004).

power.[10]) But, according to that explanation, problems with the reliability of the supply of electricity also caused many businesses and building owners to install small diesel-powered generators of their own—known as distributed generation—to meet their individual needs. So as the country continued to add central generating plants (largely powered by coal and nuclear energy) and to expand the transmission and distribution networks in 2005, some of the demand for diesel fuel would have eased.

It is difficult to know to what extent a shift toward distributed generation has increased the demand for diesel fuel in China. The electricity produced by those small diesel-powered generators is not counted with the data on the electricity sector, and whatever diesel fuel is used for that purpose is included (but not distinguished) in the total fuel consumed by manufacturing, commercial businesses, and residences. However, it is known that the consumption of middle distillates (including diesel) and heavy fuel oil each grew by an average of 15 percent a year in 2003 and 2004, compared with annual growth for gasoline of about 10 percent in the same period. As a first approximation, if diesel consumption for transportation had been growing at the same 10 percent pace as gasoline consumption, then some of the additional demand for middle distillates could have been for diesel to use in distributed generators. That possibility points to a maximum increment of diesel demand for power generation in 2004 and 2005 combined of only about 0.20 million barrels a day—or less than 4 percent of China's total oil use.

Government Efforts to Restrict Consumer Credit and New Car Sales

Another factor that may contribute to a slowdown in oil use relates to efforts by the Chinese government beginning in 2004 to curb automobile sales through a general tightening of consumer credit. The effects would be somewhat limited because a big part of vehicle sales is to state-owned businesses and government agencies, not to individuals. Those sales would more likely depend on the size of government- and state-owned businesses' budgets than on credit conditions. (Those cars and trucks are classified as "transport vehicles" in the Chinese transportation statistics, as distinct from "privately owned" vehicles; see Table A-7.) Moreover, it has been reported that only 1 in 10 car sales to private parties is financed by loans.[11]

Higher interest rates notwithstanding, separate changes in lending practices in China that are reducing the cost and time necessary for making loans are likely to increase car sales over the next five years. In particular, foreign automakers in China are working to create the financial information systems that will help them confirm credit histories for individuals and speed up the process of making personal loans. Consistent with those developments, "passenger cars for private use" is the fastest growing category of vehicle sales in China.

New Fuel Economy Standards and Easing of Limits on Small Car Use

China's central government recently initiated a program to raise the fuel economy of new passenger vehicles. And, in a separate action, it directed local governments to lift a number of local restrictions on the use of small cars in cities.

The goal of China's new standards for automobile fuel efficiency, commencing in 2005 and ratcheting up in 2008, is to curb the growth in motor fuel consumption. That program could save some oil, but it is important to recognize its limitations in the short term. According to the World Resources Institute, only 66 percent of the cars sold in China in 2004 would meet the 2005 standards, and only 4 percent of the SUVs and minivans sold in 2004 would meet those standards. The impact of the program would be further limited in the next five years because fuel savings can only grow with cumulative vehicle sales of more-efficient vehicles. Moreover, some analysts have raised questions about the effectiveness of the standards, and any fuel savings could be even smaller than policymakers might expect.

In particular, the program is likely to face the same problems as those seen in implementing corporate average fuel economy, or CAFE, standards in the United States.[12] Commercial vehicles and light trucks in China are not

10. Based on 2002 data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 7-4, 7-5, and 7-6.

11. Shai Oster, "DaimlerChrysler Offers Financing in China," *Washington Post*, November 2, 2005, p. D5.

12. For background information on the U.S. program, see Congressional Budget Office, *The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax* (December 2003).

subject to the fuel economy standards, and there is nothing to keep the mix of vehicles from shifting toward the heavier, less-efficient models. In the United States, the average fuel economy of new vehicles has been declining since 1987, because the standard for light trucks is lower than that for passenger cars and automakers have been able to produce more SUVs and vans—vehicles that are classified as light trucks but that compete directly with passenger cars. With 16 classes of vehicles in China's program, that type of shifting between models may be even easier. The standards are stringent, however, and the biggest improvements will be required of the heaviest vehicles covered by the program.

Beginning in March 2006, the government also has eased restrictions on the use of the smallest vehicles in certain urban areas.[13] Many of those vehicles—with engine sizes of 1 liter or less—had until then been banned from more than 80 cities because of unsafe designs and local government concerns about the possibility that great numbers of very small vehicles—like bicycles a few years ago—projected an image of low economic development. With design improvements, some of those concerns have eased. This change could promote sales of these mainly Chinese-made vehicles as well as improve average fuel economy. However, it is not known whether that policy change is simply acknowledging the existing popularity of such vehicles or what fuel savings could result.

Possible Future Increases in Fuel Taxes

China currently is debating whether to impose a national fuel tax in its effort to consolidate and streamline the collection and management of the government revenues related to vehicle ownership and use. Proponents of such a tax point to the potential benefits from reduced fuel consumption. Unlike policy measures that restrict vehicle sales or call for improved fuel economy, the full impact of a fuel tax could be immediate. Without knowing the details of a new tax, however, determining the impact on demand for motor fuels is not possible.

Aside from the fact that demand for gasoline and diesel fuel in general is not very responsive to small changes in price—especially in China, where so many vehicles are state-owned—there are many questions about how effectively such a tax could be implemented. One question concerns exemptions. If the fuel consumed by agricultural vehicles was exempt—as it is in the United States—then the impact of the tax would be small, because the exemption would apply to millions of small rural vehicles in the Chinese countryside that use diesel fuel for road travel. Moreover, if such a tax only replaced road maintenance fees (a variable cost of travel), the ultimate effect on the total cost of driving might be nil.

The Case for Faster Growth in Demand

The faster-demand-growth scenario assumes that total Chinese oil use will continue to grow at the past decade's average pace of about 7.5 percent a year, with total oil demand by 2010 of just over 10 million barrels a day, or about 4 million barrels a day higher than China's consumption in 2004. Underlying this construct is the idea that the structural changes under way in China will persist—specifically, that rising urban populations and incomes will continue to push up the numbers of drivers and vehicles using an expanding road system—and will result in greater consumption of transportation fuel.

Faster growth would require that those factors not be significantly altered in the near term by business downturns or dampened by the Chinese government's efforts to rein in economic growth and inflation by restricting consumer demand and investment. Consistent with recent trends in the basic determinants of petroleum demand and with recent demand growth, most of that additional demand is assumed to be for light products—including motor fuels in the transportation sector and diesel fuel and petrochemicals in the industrial sector.[14]

Despite the sustained high growth in oil consumption over the past decade, continued growth is not certain. In 2005, preliminary data on oil consumption indicated slowing growth into the fall. However, the early indicators at year's end were that growth would return to the rates experienced in 2003 and 2004. In September 2005, total oil consumption was growing at an annual pace of

13. See "China to Remove Restrictions on Smallest Cars," *Wall Street Journal*, January 5, 2006, p. A12.

14. In contrast, the slower-growth scenario assumes that all of the increase is for the light products consumed in the transportation sector, consistent with forecasts that indicated relatively weak growth in nontransportation sectors of the economy. The faster-growth scenario assumes that demand for diesel and petrochemicals in the industrial sector will be part of the total demand growth through 2010. However, for the purposes of estimating the impact of the growing demand for light products on refineries' costs, this analysis assumes that the relative mix of transportation fuels and light industrial fuels and feedstocks does not matter.

8.6 percent, gasoline consumption at 14.4 percent, and new car sales at 31 percent.[15]

Income Growth

Some analysts believe that the Chinese government will not be successful in restraining capital spending and export growth, in which case the continuation of high growth in output and personal income—and oil consumption—would be likely. As a matter of political concern in China, future economic expansion may be necessary to prevent unemployment from rising as the influx of people to the cities continues. Not surprisingly, a number of economists not directly involved with energy forecasting support an outlook for continued economic growth—at the rate of 8 percent or higher—in China.[16] But the faster-growth scenario could hold true even if demand for oil in the residential, commercial, and industrial sectors was to lag, because continued high growth in the transportation sector is likely.

Migration to the Cities

The potential population of drivers and general economic activity, which are key determinants of motor fuel demand, have been growing in China at a pace greater than motor fuel use. The continuing steady growth in the urban population and urban employment in China give further impetus to the idea that high growth in transportation demand is likely to persist (see Tables A-5 and A-6). The faster-growth scenario suggests that much of the new demand for motor fuels is closely related to changing demographics that will add to the demand for transportation fuel, independently of the pace of overall economic activity.

The migration to the cities and the social changes that are increasing the relative numbers of individuals of prime age in the population both have great momentum. The thrust of Chinese policy is to accommodate that movement by providing employment and housing opportunities rather than acting to slow the growth of the cities. No studies reviewed by CBO suggest that the Chinese government will reverse the tide of people moving to the cities or that the age pyramid will be altered in the next few years.

Further evidence for the potential for continued migration may come from a comparison with urbanization in the United States. In the decade after 1900, when urban residents made up nearly 40 percent of the U.S. population, the urban population was growing at nearly twice the rate of the total population.[17] In China's most recent census (2000), the country's urban population was up to a similar 35 percent of the total population, but the urban population was growing by 4.3 percent a year, or nearly four times the rate of growth for the total population.

The Growing Vehicle Stock

The potential demand for motor fuels is most directly indicated by changes in the numbers of motor vehicles and licensed drivers. In recent years, the number of drivers in China has been growing faster than the overall stock of cars and trucks and faster yet than the demand for motor fuel (see Figure 1-2 on page 3).

The rate of growth in demand for vehicles appears to be increasing. Over the 2000-2003 period, annual growth in the number of passenger vehicles (including buses) averaged 13.7 percent, trucks averaged 4.4 percent, and motorcycles and other unregistered vehicles, 13.3 percent. Data on the composition of that stock, available only for 2003 and 2004, indicate that the number of the largest and the smallest vehicles registered for highway use was essentially unchanged. But the number of medium-sized and small cars (which account for three-fourths of all passenger vehicles) grew in that short period by nearly 27 percent, and the number of middle-sized and light trucks (which account for three-fourths of all trucks) grew by almost 10 percent. "Other" motor vehicles (mainly motorcycles) increased in 2004 by 15 percent, or 10 million units. Separate data indicate that annual motorcycle sales currently are over 13 million units and that the total

15. International Energy Agency, *Oil Market Report* (November 10, 2005), p. 11.

16. For example, see Michael Mussa, "Global Economic Prospects: Slower But Still Solid Growth in 2005; Worries About Growth and Inflation for 2006," Institute for International Economics (April 2005), available at www.iie.com/publications/papers/mussa0405.pdf.

17. U.S. population data for 1900 and 1910 are from Bureau of the Census, "Mini Historical Statistics: Population Characteristics (Sex, Race, Urban, Rural)," available at www.census.gov/statab/www/minihs.html. Chinese population data for 1990 and 2000 are from the National Bureau of Statistics of China, *China Statistical Yearbook 2004*, Table 4-4.

number registered by the end of 2005 was going to be in the range of 95 million to 100 million.[18]

Many analysts expect growth in the country's stock of passenger cars, trucks, motorcycles, and small rural vehicles to remain high. In one study, the sales of cars and trucks alone are forecast to grow from 4.4 million new units in 2003 to 7 million by 2010.[19] At that higher level, China would be the second largest automobile market in the world (after the United States, but ahead of Japan). That private forecast is broadly consistent with the International Energy Agency's outlook for the total stock of civil vehicles to grow by nearly 20 million in China from 2002 to 2010.[20] Under an assumption of a 5 percent rate of attrition for old vehicles each year, those new sales would take the total car and truck stock from 23.8 million units in 2003 to 52 million in 2010.

Some observers find support for growth in China's current low levels of vehicle intensity per capita. In 2003, there were only about 11 registered passenger vehicles (including buses) and seven trucks per 1,000 people (see Tables A-5 and A-7 for data on population and vehicle stock, which were used to compute vehicle intensity). By 2010, with 0.5 percent population growth and a rate of sales that boosts the vehicle stock to 52 million units by that year, China would still have only 38 vehicles per 1,000 people. That projection compares with a 2003 rate of over 800 vehicles per 1,000 people in the United States, which includes nearly 500 automobiles per 1,000 people.[21]

Those small figures on vehicle concentrations may overstate the potential for future growth in vehicle ownership, travel, and, hence, fuel consumption. Despite relatively few cars, China has an extensive public transportation system, the number of motorcycles is large, and there are many small rural vehicles that are not counted in either the data on civil motor vehicles or motorcycles. Taxis and buses are reportedly used much more intensely than similar vehicles in the United States. Moreover, the current stock of vehicles is concentrated in the urban areas, where there were about 14 automobiles and 240 motorcycles per 1,000 households in 2003.[22] In Beijing, the average was 66 automobiles per 1,000 households.

18. Jialing, Inc., "China Rolls Out Motorcycles," reprinted from the *American Journal of Transportation* (April 14, 2004), available at www.jialing.co.za/news%202.htm.

19. FOURIN China Auto Weekly, "2010 China Automotive Market Forecast," available at www.fourin.com/chinaautoweekly/2010CAMF.html.

20. The IEA's forecast of the vehicle stock in 2002 and 2010 comes from its *World Energy Outlook 2004,* Figure 8.13. Detailed data were confirmed in a private communication with the IEA's Economics Analysis Division: 24.07 million vehicles in 2002, and 43.06 million in 2010.

21. U.S. vehicle statistics are from Federal Highway Administration, "State Motor-Vehicle Registrations—2003," available at www.fhwa.dot.gov/policy/ohim/hs03/htm/mv1.htm.

22. See National Bureau of Statistics of China, *China Statistical Yearbook 2004*, Table 10-17.

CHAPTER

4

Consequences for Motor Fuel Markets in the United States

This chapter examines the potential impact of China's economic growth on future oil prices and oil refining costs according to the scenarios of slower and faster demand growth developed in Chapter 3. Over the next five years, the likely impacts of economic growth in China on oil markets in the United States all relate to prices: increased crude oil prices, greater costs to refine oil, and, as a result, higher prices for gasoline and diesel fuel. The combined changes in crude oil costs and costs to refine it could add a total of 19 cents to 38 cents to the cost of a gallon of gasoline or diesel fuel in the United States in the next five years (in 2005 dollars).

The growing total demand for oil products in China will add pressure on worldwide crude oil prices over the next five years. And the growing relative demand for motor fuels and other light products within China will add pressure on costs to refine oil worldwide and in the United States. The potential for increased price volatility, attributable to China's contribution to growing worldwide demand and increasingly tight market conditions, is addressed in this analysis but not estimated.

The possible changes in worldwide oil prices over the next five years are calculated using an estimate of the price elasticity of the net supply of oil. Changes in costs to refine oil are calculated using the statistical relationship over the past decade between refinery margins and light product yields, and controlling for the effect of changing product inventories. The task of estimating the effects of China's economic growth on oil prices is complicated because the markets for crude oil and motor fuels are world markets, which will also be affected by changes in oil demand and refinery investments elsewhere in the world. If the world oil supply is more responsive to price changes than assumed here, the effects on world prices of growing demand for oil in China will be smaller than what is shown.

A number of additional factors bear on potential market effects. One is the policy choices that China will make about how much to invest in its domestic capacity for refining crude oil. Others are pressures on motor fuel prices that may come from changes in the environmental rules that affect product quality or refinery operations, changes in the quality of crude oils available to refineries, and changes in the mix of light products demanded—especially with diesel use growing faster than gasoline use in China and around the world.

General Consequences for Prices and Price Volatility

In the near term, growing oil demand and the changing mix of products in China are likely to push up prices for crude oil (and price premiums for lighter oils) in the United States, boost prices for motor fuels, and increase the volatility of prices.

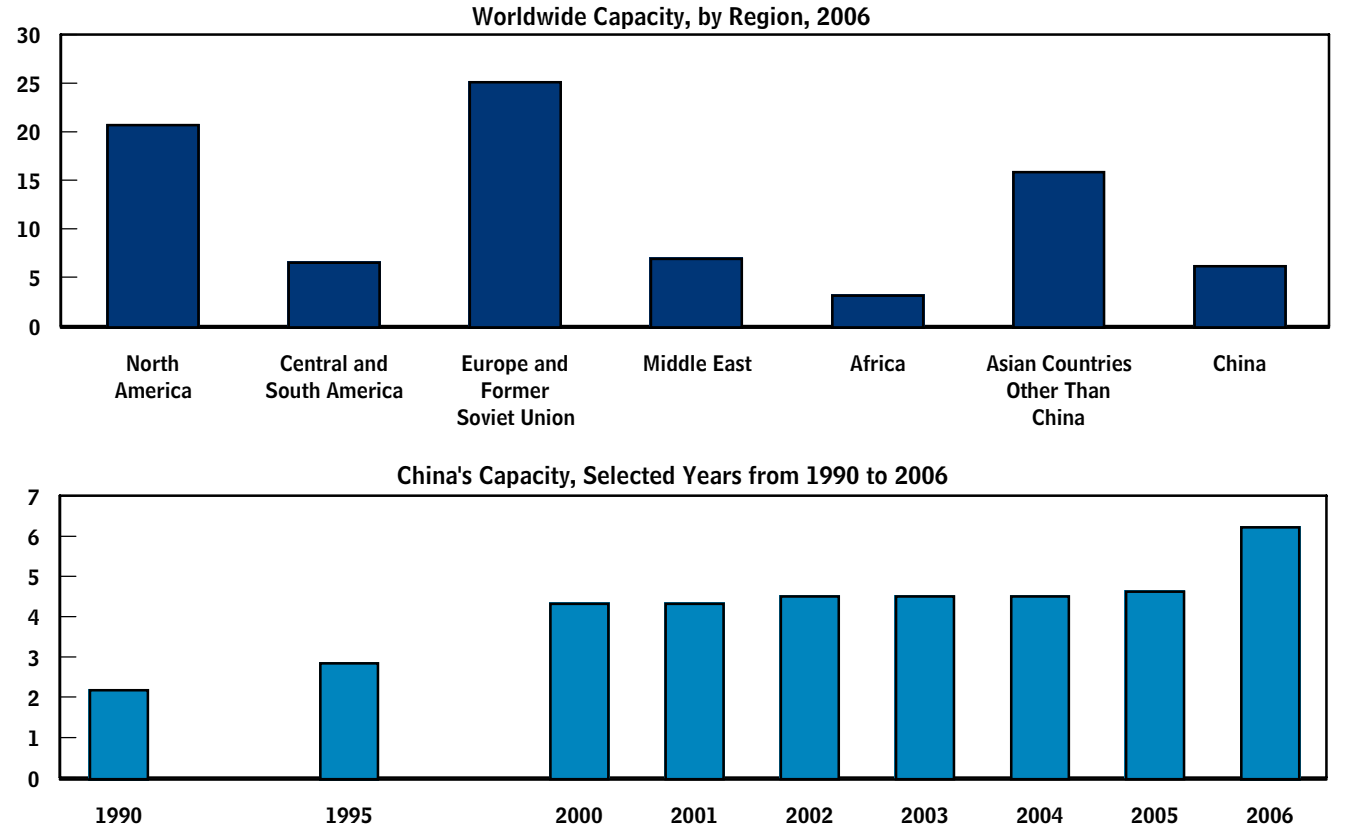
Crude Oil Prices and Costs of Refining

Rising oil demand in China will increase the price of crude oil in the United States and around the world, which will be passed on to prices for all petroleum products—including gasoline and diesel fuel. Less clear is how the growing relative demand for motor fuels within China could further contribute to increased prices for those fuels in the United States. Projections from the Energy Information Administration made in 2005 indicate that Asia, with recent investment activity in China, is moving toward becoming the biggest center for petro-

Figure 4-1.

Refinery Capacity in China and Other Selected Regions

(Millions of barrels a day)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, *International Energy Annual 2003* (July 2005), Table 3.6, and the data file supporting the report, available at www.eia.doe.gov/pub/international/iealf/table36.xls.

Note: "Capacity" is crude oil distillation capacity, measured at the beginning of year.

leum refining in the world.[1] All together, Asian countries already have about as much refinery capacity as North America or Europe (see Figure 4-1). As China becomes a growing presence in the worldwide refining industry, developments in its domestic petroleum markets will become increasingly important for costs of refining worldwide.

The growing relative preference of the Chinese market for light products such as diesel fuel, gasoline, and petrochemical feedstocks increases the price for premium grades of crude oil and adds to refiners' costs for processing low-quality oils. The market for premium crude oils is seeing some of that effect on prices (see Figure 4-2). Light, sweet crude oils have high natural yields of light distillates and low levels of sulfur. China, like many other countries, is competing more and more with the United States in the world oil markets for the types of crude oil that are most easily refined into motor fuels, especially gasoline and diesel that will satisfy increasingly stringent environmental standards for sulfur emissions.

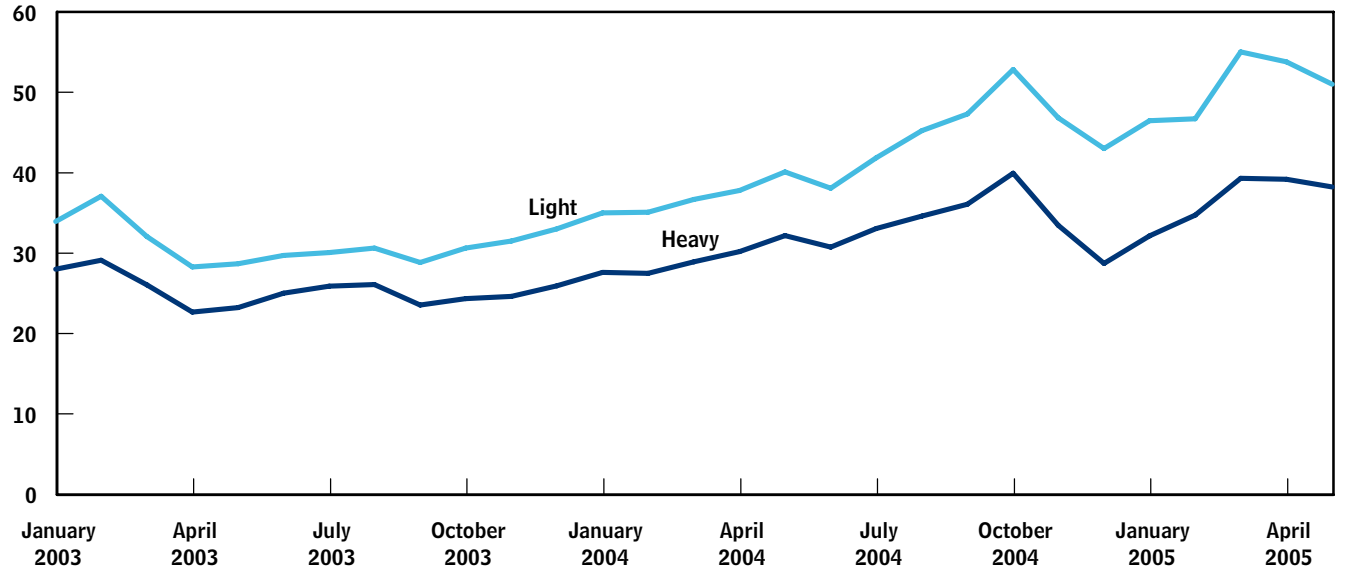
To boost the percentage yield of light products, one alternative to processing additional volumes of light, sweet oils is to invest in additional refinery capacity to process more of the less-valuable heavy, sour oils. Among the key refinery investments needed are catalytic cracking, hydrocracking, and coking units for boosting the yield of gasoline and diesel components from heavier oils and

1. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2005* (February 2005), Figure 97.

Figure 4-2.

Prices for Light and Heavy Crude Oils, 2003 to 2005

(Nominal dollars a barrel)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, *Petroleum Marketing Monthly* (August 2005), Table 27.

Note: Prices are "landed" costs (including insurance and transportation to port) of imported crude oil. The industry standard established by the American Petroleum Institute for measuring the specific gravity of crude oil is "degrees API." Light crude oils are those with 40 degrees to 45 degrees API gravity. Heavy crude oils are those with 20 degrees to 25 degrees API gravity.

hydrotreating units for removing sulfur from sour oils (see Box 4-1). Current indications are that the Chinese are interested in making such investments. For example, the Chinese refining industry has recently partnered with ExxonMobil and the Saudi Aramco to build a new refinery that would be capable of handling the heavier grades of Saudi crude oil.[2]

At a basic level, the shift in worldwide demand to motor fuels means an increase in the necessary yield of those products from crude oil and, hence, an increase in the costs of producing motor fuels. However, the magnitude of that cost increase would depend on the location and design of new refining capacity. New capacity that yielded a mix of products that did not match relative demand would generally add further to refiners' costs and possibly to transportation costs. (There is a lowest-cost configuration of refinery processes for producing any particular mix of finished products, and costs increase sharply with efforts to push the yield of particular products beyond the optimal yield for a given configuration.) In the current example, to meet the growing demand for motor fuels, that prospect of further cost increases would be true whether the incremental refinery yield of light products was too low (raising the need to import additional motor fuels as well as placing additional demand on refineries elsewhere) or too high.

Price Volatility

A part of the current concern about the impact of China's growing energy demand on oil price volatility relates to the fact that the available buffer of excess production capacity in the world market is already very slim (see Figure 4-3). Without that buffer—crude oil that is available on short notice at a relatively constant cost—any increase in demand must be met from costly incremental sources. The ability of crude oil producers worldwide to boost output in response to supply disruptions or demand surges is likely to remain limited or even diminish further for the next few years, until Saudi Arabia and per-

2. See "Exxon, Partners to Start Work on Oil Refinery Project in China," *Washington Post*, July 1, 2005, p. A8.

Box 4-1.

Basic Processes of Petroleum Refining

A petroleum refinery is a collection of processing units, usually starting with an atmospheric distillation unit that separates crude oil into its naturally occurring components, or fractions, some of which are light and some heavy. From that point, however, different refineries will add different mixes of other types of units, with the overall design depending on the quality of crude oil they want to process and the final mix of products they want to sell.

Five basic refinery processes can increase the yield of light, high-quality products from crude oil or sustain the yield of light products from crude oils of diminishing quality. The processes—from the most basic to the most complex—are as follows.

- **Topping,** which occurs in an atmospheric distillation unit, separates the crude oil into its natural components. Depending on the properties of the oil, a topping refinery can produce naphtha (the basic blending component of finished gasoline) and other light distillates, but they generally are of insufficient quality to be sold as finished products.
- **Hydroskimming,** which requires the addition of a catalytic reforming unit, upgrades the naphtha from distillation (for blending with gasoline) and produces hydrogen (for use in hydrotreating units to remove sulfur from diesel and other products).
- **Catalytic cracking,** in a vacuum distillation unit, augments the hydroskimming to pull out additional fractions of heavy distillates from the crude oil and, in a fluid catalytic cracking unit, breaks the heavy products from distillation into gasoline and light distillates (including diesel fuel and kerosene).
- **Hydrocracking**, done in a unit that adds to or replaces the catalytic cracking unit, further increases the yields of gasoline and diesel fuel. That process requires more hydrogen than the catalytic reformer produced from the original crude oil feedstock, so the hydrocracking refinery must also produce or purchase hydrogen from another source. (An important raw material for hydrogen production is natural gas.)
- **Coking**, accomplished in a unit added to the hydrocracking refinery, provides the fullest conversion of heavy oils into distillates, with petroleum coke (a combustible solid) produced as a by-product.

haps a few other countries meet their stated goals of attaining substantial levels of excess capacity.

The strategic inventories of crude oil held by the United States and several other countries may be able to augment that slim buffer of excess current production capacity. Efforts by China to develop its own strategic inventory may be important in that context, although that inventory will not be completed within the next five years (see Box 4-2). Currently, the United States and other members of the International Energy Agency are committed to maintaining a 90-day emergency supply of oil and oil products (or an equivalent capability to restrict consumption). However, it is difficult to know how well a release of those strategic inventories (or conservation measures) would help to moderate the price impact of a disruption, since the impact would depend on the timing and magnitude of such a response.[3] China currently is not a member of IEA, and it is not known if or how it would coordinate its stock withdrawals with other countries'. Over the next few years, as China works to fill its reserve, those additional oil purchases could make worldwide oil markets tighter than they already are.

3. For a critique of the emergency response in the 1990 Gulf War, see Congressional Budget Office, *Rethinking Emergency Energy Policy* (December 1994).

Box 4-2.

China's Strategic Petroleum Reserve

In general, few oil companies want to store oil for the remote possibility of a politically motivated disruption of oil supplies or a major accident of unprecedented scope, especially if those companies would not have control over decisions to build up that reserve or release the oil. The costs of holding such stocks tend to outweigh the private benefits from their expected use. The Chinese central government, however, has taken a longer term view of such supply disruptions in working to construct a strategic inventory of crude oil. (The United States and Japan already maintain such government-owned stockpiles of oil, and several other countries belonging to the International Energy Agency require private companies to hold a certain number of days of oil supply for emergency use.)

China is currently working to construct storage facilities and acquire oil for its strategic inventory. In the next five years, the biggest impact of China's strategic inventory program may come through the purchases of oil necessary to fill the inventory, because that demand for oil will put additional upward pressure on worldwide oil prices. The magnitude of that effect is uncertain, though, because China is still building its strategic reserves and has not yet begun to fill them.

The Chinese government's stated goal—delineated in its *10th Five-Year Plan for National Economic and Social Development*—is to build up by 2008 enough holdings to cover a 35-day supply of crude oil. The plan calls for developing four sites of storage tanks, capable of holding a total of 101.9 million barrels of oil. At current rates of oil consumption, however, that reserve would be enough to meet all domestic demand for less than 20 days. Although filling of the reserve may commence by late 2005, only one storage site—a 33-million-barrel tank farm in Zhejiang province—is currently under construction, and a second site (in Shangdong province) is not scheduled for completion until 2007.

The Impact of Rising Total Oil Demand on Worldwide Crude Oil Prices

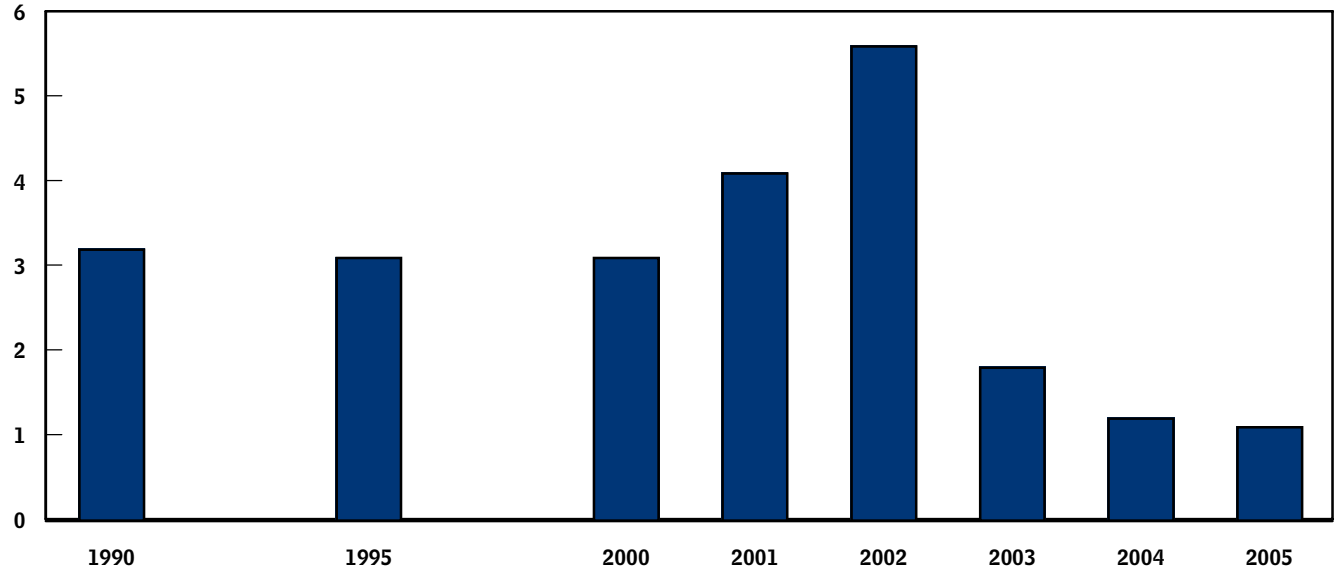
Depending on whether growth is slower or faster, CBO estimates that the increase in China's total demand for petroleum in the next five years could cause oil prices to be as much as $7 to $14 a barrel higher (in 2005 dollars) than they would be otherwise. If those increases in crude oil costs were completely passed through to consumers, prices for a gallon of gasoline or diesel could rise by between 16 cents and 33 cents in the United States.

The potential range of effects on oil prices is inferred from the increase in oil consumption through 2010 in the slower- and faster-demand-growth scenarios on the basis of an approximation of the five-year price elasticity of net worldwide supply. That elasticity is an estimate of the percentage change in worldwide oil prices that would be necessary to eliminate a given percentage imbalance in worldwide oil supply and demand over that period. Specifically, it represents the ratio of the percentage net disruption—whether attributable to a change in demand or supply—to the percentage price change. To illustrate those effects, this analysis assumes that the five-year elasticity is 0.2, which means that a 1 percent supply shortfall

Figure 4-3.

Worldwide Spare Capacity for Oil Production, Selected Years from 1990 to 2005

(Millions of barrels a day)



Source: Congressional Budget Office based on data from the Department of Energy, Energy Information Administration, *Short-Term Energy Outlook* (January 2006), Figure 9.

Note: Spare capacity is the difference between production capacity and average annual crude oil production, as reported for members of the Organization of Petroleum Exporting Countries, including Iraq.

would require a 5 percent price increase response to restore balance in the market.[4]

To apply the net supply elasticity to the estimation of price change requires having an estimate of the base price (from which the change takes place) and the percentage change in consumption. In this case, the base price is the 2005 price of crude oil, and the percentage change in consumption is the growth in Chinese demand (from the slower- and faster-demand-growth scenarios) divided by worldwide oil consumption in 2005. On the basis of partial data for the year, worldwide oil consumption in 2005 was about 83 million barrels a day and the average worldwide oil price in 2005 (measured as the spot price for West Texas Intermediate crude oil, as traded on the New York Mercantile Exchange) was about $57 a barrel. With a projected five-year increase in Chinese demand of 2 million barrels a day (in the scenario of slower demand growth), the oil price change necessary to keep the market in balance would be nearly $7 a barrel (or about 16 cents a gallon). With an increase in Chinese demand of 4 million barrels a day (in the scenario of faster demand growth), the oil price increase would be about $14 a barrel (or about 33 cents a gallon).

The price effects from the two scenarios do not encompass the full range of possible outcomes. For example, the International Energy Agency projects that the increase in oil consumption in China by 2010 could be as low as 1.5 million barrels a day (see Table 3-2 on page 19), which would result in smaller price increases than what are shown here. Or, with a return to the demand increases recorded in 2003 and 2004, growth in oil consumption could be above the level in the faster-demand-growth case, which would result in larger price increases.

And in both scenarios, because of the current tight situation in worldwide oil markets, it is hard to know what level of price response would be necessary to keep the world oil market in balance. In particular, there is a new uncertainty underlying future oil supplies, as OPEC shows the first indications of having difficulty keeping pace with worldwide demand. In early 2005, Goldman Sachs suggests that oil prices could spike as high as $105 a barrel in 2007, and IMF described an alternative scenario

wherein oil prices could reach $80 a barrel in 2006.[5] If the worldwide oil supply remained relatively unresponsive to price changes, both the low- and high-end price impacts presented in this analysis could be greater than they would be otherwise. However, some analysts still hold with the view that worldwide supplies remain adequate and that oil prices will fall in the next few years, back below $35 a barrel. That view of falling prices in the face of rising demand suggests an expectation that a strong supply response to prices above $35 should be under way, in which case the price impact of higher demand for oil in China could be smaller than the estimates presented here.

To further underscore the uncertainty about future supplies, with crude oil prices remaining above the $60 a barrel level (for West Texas Intermediate) in early 2006 and no immediate downturn in sight, some forecasters have begun to rethink that downward trajectory. For example, in its July 2005 *International Energy Outlook*, the Energy Information Administration had forecast that worldwide oil prices would reach only about $32.50 a barrel by 2010 (in 2005 dollars). But in January 2006, EIA released a revised outlook that has oil prices falling to only about $45 a barrel by 2010 (in 2005 dollars).[6]

The Impact of Increasing Demand for Light Products on the Costs of Refining Petroleum

In addition to the cost of crude oil, the cost to refine petroleum is the other component of U.S. motor fuel prices that is likely to be affected by developments in China's petroleum markets. As discussed here, the cost to refine petroleum is the average cost of converting crude oil into finished products and distributing those products to wholesale markets. Changes in those costs worldwide are in part a consequence of China's growing total demand for petroleum because within that total demand, the demand for motor fuels (diesel and gasoline) and other light, costly-to-refine products is growing even faster. Yet those demand pressures would probably have only a small impact on costs of refining as long as China's efforts to keep pace with its changing demand did not introduce significant distortions into the worldwide market for refined products.[7] In the absence of such distortions, the impact on costs for gasoline and diesel in the United States would be nearly three cents a gallon in the slower-demand-growth scenario and about five cents a gallon in the faster-demand-growth case (both in 2005 dollars).

A general rule of thumb for gauging how changes in the cost to refine oil relate to the changing product mix can be inferred from the historical relationship between gross refinery margins and light product yields, controlling for other important factors affecting costs (such as inventory change, which affects distribution costs, and environmental requirements) and profitability (such as capacity utilization and interest rates). To illustrate the relationship between costs of refining oil and product yields, the only

4. Both the Energy Information Administration and the International Monetary Fund assume the one-year elasticity of net oil supply to be 0.1. (Mathematically, the net supply elasticity reflects the sum of the absolute values of the demand and the supply elasticities.) See Department of Energy, Energy Information Administration, "Rules-of-Thumb for Oil Supply Disruptions" (September 2, 2004), available at www.eia.doe.gov/emeu/security/rule.html; and International Monetary Fund, *World Economic Outlook* (April 2005), Table 4.7. That figure would be low for an analysis of five-year effects, since the response of petroleum production and consumption to changes in price generally increases over time as oil businesses have more time to find additional oil and consumers have more opportunities to make investments to save energy or switch to other forms of energy. From the models of the Energy Information Administration, the 10-year response of total oil demand to oil prices is about 0.2 (absolute value). With that demand reduction likely to be followed by a very small supply response, the five-year elasticity for net supply would normally be something more than 0.2. Given current market conditions, however, with members of the Organization of Petroleum Exporting Countries generally unable to rapidly increase production, it is likely that the market's response to any given shortfall will have less additional supply to draw on than in past years. For those reasons, 0.2 is taken here to be representative of the likely five-year impact.

5. The investor report by the Goldman Sachs Group is not publicly available; a summary appears in Peter A. McKay, "Goldman Analysts Deliver Oil Shock," *Wall Street Journal*, April 1, 2005, p. C4. A scenario that has oil prices spiking to $80 a barrel is assessed in International Monetary Fund, *World Economic Outlook*, Figure 4.6.

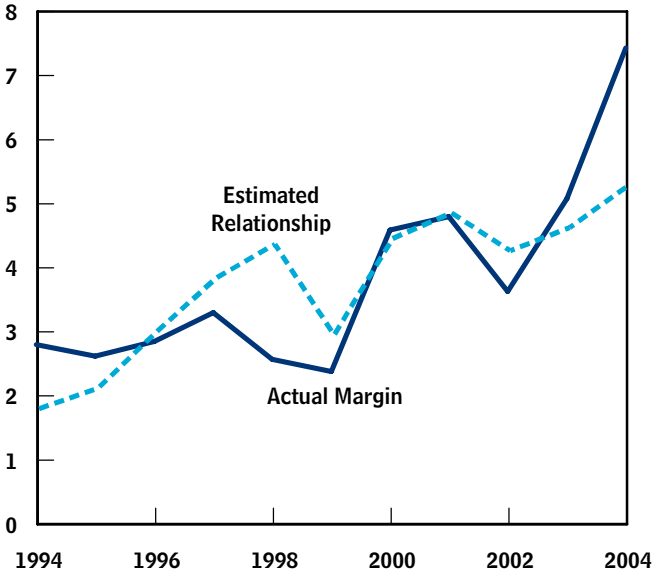
6. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006 (Early Release)*, January 2006. Forecasts are inflated to 2005 dollars using the implicit GDP price deflator.

7. Distortions could be introduced in several ways—for example, if China opted for a policy of pursuing self-sufficiency in its capacity to refine crude oil or, at the opposite extreme, opted to rely completely on increased imports of products from refineries elsewhere. (The cost increases resulting from such distortions of free trade are not evaluated in this analysis.)

Figure 4-4.

Actual Gross Refinery Margins and Margins Estimated from the Relationship Between Light Product Yields and Inventory Change, 1994 to 2004

(2005 dollars a barrel)



Source: Congressional Budget Office based on price data from the Department of Energy, Energy Information Administration, *Petroleum Navigator,* available at http://tonto.eia.doe.gov/dnav/pet/pet_sum_top.asp.

Note: The gross refinery margin represents a "3-2-1 crack spread," under the assumption that a refinery can process three barrels of crude oil into two barrels of gasoline and one barrel of middle distillates.

controlling factor considered here is the change in refined product inventories (see Figure 4-4). (The logic is that when storage tanks are filling rapidly, the costs of delivering finished products will be higher than they otherwise will be; and when tanks are being drained, the delivery costs will be lower. Those cost changes are assumed to be passed through to prices.) The statistical relationship between margins, yields, and stock changes suggests that an overall increase in the yield of motor fuels of 1 percentage point (with no further change in stock additions) will be associated with an increase in average refining costs of $1.33 a barrel (or just over three cents a gallon), in 2005 dollars.

That rule of thumb reflects a number of simplifying assumptions.[8] Its calculation of gross refinery margins (a weighted average of gasoline and diesel prices minus crude oil costs) omits other costs of refinery operations that may have been changing over the past decade. For example, some of the new costs for complying with environmental regulations are not included. Despite that limitation, research indicates that changes in the gross and net margins are closely related.[9] Also, the data on annual stock changes omit information on inventories in China and other developing countries. Those inventory data are generally not available, and it is not known how their omission affects the results. In general, a preferable way to model the determinants of refiners' costs—which is beyond the scope of this paper—would consider the increases in average costs of refining for the different basic configurations of refineries, from simple hydroskimmers to complex coking facilities (see Box 4-1 on page 30). Those increasingly complex configurations add equipment to recover hydrogen, remove sulfur, and extract and recombine hydrocarbons to alter the mix of finished petroleum products.

Both of CBO's scenarios of future growth assume that most of the increase in Chinese petroleum demand through 2010 will be for light products. Adding the respective increases in light product demand—about 2 million barrels a day in the slower-growth scenario (4.5 percent a year) and 4 million barrels a day in the faster-growth scenario (7.5 percent a year)—to the level of worldwide oil consumption in 2004 and recalculating the worldwide yield of light products indicates how Chinese demand may affect those yields and, hence, costs of refining. In the slower-growth scenario, the worldwide yield of

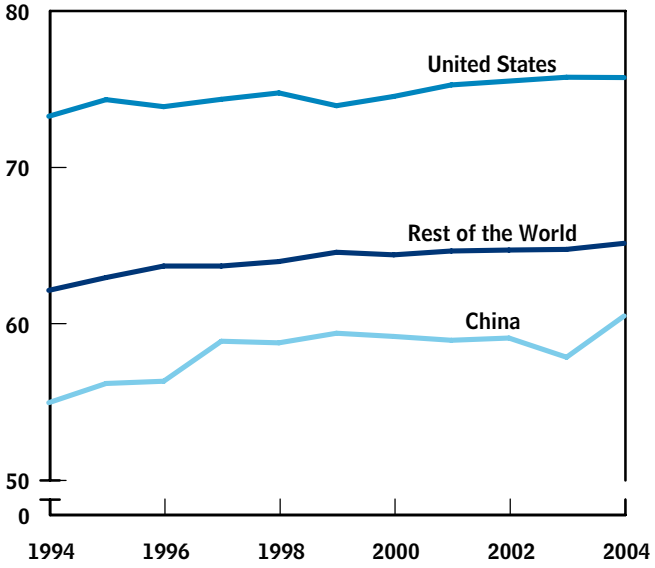
8. In particular, those relatively small impacts assume that worldwide efforts to accommodate the changing demand mix reflect optimal levels of new investment around the world and trade in crude oil and finished products. That is, the world's petroleum refiners (including refiners in China) would be free to respond to the growing and changing demand for petroleum products in China, so that the changes in refining capacity worldwide, combined with new patterns of trade, would help to supply finished products everywhere at the lowest cost. On that basis, the change in the average global refinery yields that was necessary to meet the new Chinese demand for light products would be most relevant for understanding the resulting change in refining costs in the United States.

9. For example, see Department of Energy, Energy Information Administration, *Performance Profiles of Major Energy Producers 2003* (March 2005), Figure 47.

Figure 4-5.

Share of Total Petroleum Demand Met by Light Products, 1994 to 2004

(Percent)



Source: Congressional Budget Office based on data from British Petroleum, *Statistical Review of World Energy* (June 2005).

Note: Light products are gasoline and middle distillates (including diesel and jet fuel).

light products from crude oil in 2010 would increase from 67.5 percent to 68.3 percent, adding about $1 a barrel (or nearly three cents a gallon), in 2005 dollars, to the cost of supplying gasoline and diesel in the United States and other countries.[10] In the faster-growth scenario, the worldwide yield in 2010 would increase from 67.5 percent to 69.1 percent, adding just over $2 a barrel (or about five cents a gallon), in 2005 dollars.

Evidence of changing refinery yields in China is consistent with demand changes there. China's increased production of light products in the past two years stands out compared with the increases for those products in the United States and the rest of the world (see Figure 4-5). But the recent sharp increase in product demand appears to have surprised Chinese refiners as much as it did energy analysts elsewhere. China's oil industry has responded to that high demand growth by accelerating construction of new refineries (with government assistance in the form of expedited siting and construction permits). Refinery investment took an especially large jump from January 2005 to January 2006 (see Figure 4-1 on page 28). Nine projects currently in progress or awaiting government approval would add about 2 million barrels a day of new distillation capacity before 2010 (see Table A-10).[11] If all of those projects are completed as planned, China's total capacity will be about 8 million barrels a day at that time—a level that would be insufficient to meet all the expected increase in oil use in CBO's faster-growth scenario. If China is expecting faster demand growth, consistent with the government's 10-year plan, it is unclear whether the current level of refinery investment reflects a strategy to rely increasingly on imported oil in the future or just a lag in making investments in refinery capacity sufficient to keep pace with demand. In March 2006, the government announced planning goals for refinery capacity in 2010 that would boost that capacity by more than 30 percent above current levels.[12]

Other Influences on Costs to Refine Oil

The impact of increasing light product yields on costs of refining is more complicated than the simple relationship estimated in this paper. Some of the influences that may affect that relationship are transitory, successively pushing costs up and then back down, and others are more sustained in nature.

An example of the type of event that can alter costs temporarily by raising demand or restricting refinery activity is the damage from Hurricanes Katrina and Rita in 2005. That damage significantly disrupted the supply of refined petroleum products in the United States, causing the

10. To illustrate, the calculation is 68.3 percent minus 67.5 percent (or 0.8 percent) times $1.33 a barrel, which equals $1.06 a barrel. With 42 gallons in a barrel, the impact of that slower-growth scenario is equivalent to about 2.5 cents a gallon.

11. Those projects are reviewed in Kang Wu and Fereidun Fesharaki, "As Oil Demand Surges, China Adds and Expands Refineries," *Oil & Gas Journal* (July 25, 2005), pp. 20-24; and Department of Energy, Energy Information Administration, "China," EIA Country Analysis Briefs (updated in August 2005), available at www.eia.doe.gov/emeu/cabs/china.html.

12. *China Daily*, "China To Boost Oil Refinery Capacity," March 17, 2006, available at www.chinadaily.com.cn/english/doc/2006-03/17/content_544001.htm.

margins of refiners in the Gulf Coast to more than quadruple from August to September.[13]

Among the factors that could influence worldwide costs of refining or refinery margins over a long period are changes in the volume of sales, which directly affect the profitability of supplying motor fuels and influence how much of any increase in costs of refining can be reflected in refinery margins and passed through to retail consumers.

Other important factors that could add to costs and would need to be addressed in order to best establish the relationship between refinery yields and margins include:

- The changing quality of available crude oils,
- The increasing costs of complying with environmental rules,
- The increasing use of nonoil inputs (such as ethanol) to produce motor fuels, and
- The growing difficulty of siting new refineries (potentially a concern in China as well as in the United States).

For one additional factor—changes in the relative demand for gasoline and diesel fuel within the total mix of light products—the direction of impact on the costs of refining is less clear. Most of the growth in total petroleum sales worldwide and in sales of light products has been for diesel fuel. In the United States, diesel consumption tends to grow with increases in long-haul trucking and, hence, with overall economic output (which means at a faster pace), whereas gasoline consumption tends to grow with increases in population (which means at a slower pace).[14] Those different causes probably exist in China, too, where the rate of growth in the use of diesel fuel is higher than that for gasoline. In China, truck traffic is growing with the economy, as is the number of small rural vehicles (already in the millions). Outside the transportation sector, growth in the demand for diesel for distributed electricity generation (by individual businesses and for buildings) has been high, too.

It is not clear what the higher growth in the demand for diesel (relative to that for gasoline) may mean for costs of refining. In general, increased yields of gasoline are more costly to obtain than high yields of middle distillates (diesel fuel and heating oil). But in the past few years, wholesale prices for diesel have been approaching and, on occasion, exceeding the prices for gasoline. That may be a short-term phenomenon that will pass with some redesign of refineries. But with an increasing imbalance projected in the light product mix over the next five years, the rise in the cost of diesel relative to that of gasoline could persist.

Implications for Policies Affecting Investment in U.S. Refineries

China's demand for petroleum in general—and for light products in particular—may add to cost pressures on U.S. refiners and could affect future refinery investment and operations. Even before the latest growth in Chinese demand, some analysts were claiming that refineries in the United States faced a number of policy-related constraints on their ability to meet growing demand at home and to comply with new environmental laws affecting product quality and plant emissions.[15] In 2005, the hurricane damage to refineries along the U.S. Gulf Coast and the resulting large increase in refinery margins added to concerns about the adequacy of capacity. Those concerns have been accompanied by calls for specific policy changes to remove such constraints or to otherwise support increased investment in refineries.

Changes in Chinese demand could put pressure on U.S. refiners in two ways. If China consumed an increased share of the light, sweet (or low-sulfur) crude oils to feed its demand for diesel, gasoline, and petrochemicals, then U.S. refiners would have to invest more than they otherwise would in the increased processing of heavy, sour oils. Alternatively, if China decided to rely increasingly on imports of refined petroleum products, that could put increased pressure on U.S. refiners to divert products from domestic markets to export markets—if not directly to

13. Current information on refinery margins in major refining centers is available in International Energy Agency, *Oil Market Report*, October 11, 2005.

14. For a recent analysis discussing the link between freight traffic and economic growth, see Congressional Budget Office, *Freight Rail Transportation: Long-Term Issues* (January 2006).

15. For example, see National Petroleum Council, *Observations on Petroleum Product Supply, A Supplement to the NPC Reports: U.S. Petroleum Product Supply and U.S. Petroleum Refining* (December 2004).

China, then to other countries, who may in turn be the ultimate exporters to China. (Equivalently, U.S. refiners might have to boost output if U.S. importers of refined products saw their foreign sources of gasoline and diesel—mainly in Europe and Latin America—diverted to China.) Aside from additional pecuniary costs for producing clean fuels, the additional refinery activity in the United States also could be related to additional social costs in the form of increased emissions from those plants.

Advocates of a change in policies affecting refineries point to a number of constraints on refiners' ability to process the heavier, more-sour oils and on their ability to expand output and capacity.[16] Those constraints include ones that arise from emissions controls on refineries—a consequence of national clean air laws (establishing ambient air quality standards and limiting plant emissions of sulfurous and nitrous compounds) and restrictions on technologies used at industrial fuel-burning installations (known as New Source Review). Other constraints on refinery operations arise from standards for the motor fuels themselves, including clean air laws that restrict the amount of certain toxic chemicals in gasoline and, more recently, new limits on the sulfur content of gasoline and diesel.

Some analysts also believe that local requirements for permits may be impeding the construction of new refineries. But refiners in the United States have been able to meet growing demand for motor fuels by expanding the downstream capacity at existing refinery complexes.[17]

How much longer that type of expansion can continue is unclear, however. In the future, some all-new refinery complexes may well become the more economical investment—as may be evidenced by the increases in refinery margins that probably will follow the growing worldwide demand for oil products. At that time, local requirements for permits could become restrictive.

The consequences of China's economic growth for the costs to U.S. refiners from complying with existing and new policies affecting their capital spending and operations will depend on changes in the worldwide trade in refined products. Consideration of the full international picture is beyond the scope of this paper, although two basic effects are worth noting. If excess refinery capacity emerged in other countries (whether in countries with low economic growth or in oil-exporting countries that decided to further develop their export capacity), the need for new capacity in the United States would be smaller than what it would be otherwise. Or, if fast-growing countries did not expand their refinery capacity, the call on U.S. refiners to boost their exports would be greater than what it would be otherwise.

That future trade in petroleum products could also have consequences for the types of refinery investment that the United States might want to make. As this paper points out, the mix of products being consumed in Asia is changing, as China and other countries demand more gasoline, diesel, and other light products (especially petrochemical feedstocks). For example, if China did not alter the complexity of its refineries to boost the percentage yield of motor fuels, its efforts to produce additional motor fuels from refineries of a more-standard configuration would yield an excess supply of heavy, residual products. Those heavy products then could be exported to the United States or elsewhere, where significant capacity already exists to process them into more useful products. In that situation, the United States might want even more capabilities to convert those heavy products, although negative environmental consequences could ensue from processing feedstocks that could have an especially high content of sulfur and heavy metals.

16. Ibid.

17. For example, see D.J. Peterson and Sergej Mahnovski, *New Forces at Work in Refining* (Arlington, Va.: RAND Science and Technology, 2003).

APPENDIX

A

Detailed Tables

This appendix presents 10 tables that convey additional background information on the Chinese economy and its energy sector.

Table A-1.

China's Petroleum Balance, Selected Years from 1990 to 2004

	1990	1995	2000	2001	2002	2003	2004
Petroleum Supply (Millions of barrels of crude oil equivalent a day)							
Crude oil production	2.77	3.00	3.26	3.28	3.34	3.39	3.49
Net Imports	-0.47	0.24	1.52	1.41	1.63	2.18	2.99
Crude oil	n.a.	n.a.	1.20	1.05	1.24	1.67	2.34
Refined products	n.a.	n.a.	0.32	0.36	0.39	0.51	0.65
Change in stocks[a]	-0.01	-0.03	-0.25	-0.05	0.02	n.a.	n.a.
Total Supply	2.29	3.21	4.53	4.64	4.99	5.57	6.48
Petroleum Demand (Millions of barrels of crude oil equivalent a day)							
Residential sector	0.06	0.14	0.25	0.26	0.30	n.a.	n.a.
Commercial sector	0.24	0.42	0.57	0.59	0.60	n.a.	n.a.
Industrial sector	1.62	2.07	2.56	2.57	2.83	n.a.	n.a.
Transportation sector[b]	0.34	0.57	1.10	1.14	1.23	n.a.	n.a.
Unaccounted for	0.04	0	0.01	0.01	0.01	n.a.	n.a.
Total Consumption	2.30	3.21	4.49	4.57	4.96	5.33	6.17
Discrepancy[c]	-0.01	0	0.04	0.07	0.03	0.24	0.31

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 7-4, 7-9, 17-8, and 17-9 (for 1990 to 2002); and British Petroleum, *Statistical Review of World Energy* (June 2004) and *Statistical Review of World Energy* (June 2005) for 2003 and 2004.

Notes n.a. = not available.

Source data in metric tons converted using 7.3 barrels a ton. Sectoral data for 2003, available from the International Energy Agency's report on "2003 Energy Balances for China," indicate total supply and consumption of about 5.02 million barrels a day, with transportation activity above 2002 levels, commercial and industrial activity below 2002 levels, and residential activity about the same.

a. Negative amounts indicate additions to stocks.

b. The values for transportation use appear too low, given independent data on the consumption of gasoline, diesel fuel, and jet fuel. Those products also may be counted in the industrial sector because so many vehicles are owned by businesses.

c. Total supply minus total consumption. The high estimates for 2003 and 2004 may reflect the omission of data on additions to stocks in those years.

Table A-2.

China's Consumption of Refined Petroleum Products, 1995 to 2004

(Millions of barrels a day)

	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total
1995	0.904	0.997	0.669	0.819	3.390
1996	0.986	1.080	0.719	0.888	3.672
1997	1.111	1.202	0.750	0.871	3.935
1998	1.098	1.277	0.725	0.946	4.047
1999	1.164	1.455	0.694	1.103	4.416
2000	1.313	1.633	0.725	1.314	4.985
2001	1.252	1.709	0.728	1.342	5.030
2002	1.387	1.786	0.705	1.500	5.379
2003	1.440	1.905	0.791	1.654	5.791
2004	1.686	2.352	0.907	1.739	6.684

Source: Congressional Budget Office based on data from British Petroleum, *Statistical Review of World Energy* (June 2005).

Note: "Gasoline" includes gasoline for aviation and vehicle use as well as light distillates used as feedstocks for petrochemicals (such as naphtha). "Middle distillates" includes kerosene, jet fuel, heating oil, and diesel fuel. "Heavy fuel oil" comprises crude oil consumed as fuel, residual fuel oil for boilers, and bunker fuel for tankers. "Other" includes petrochemicals besides naphtha, liquefied petroleum gases such as propane, lubricating oils, asphalt, and waxes.

Table A-3.

Petroleum Consumption by Major Sectors of the Chinese Economy, Selected Years from 1990 to 2002

(10,000 metric tons)

Sector	1990	1995	2000	2001	2002
Residential	285	682	1,256	1,295	1,478
Commercial[a]	1,192	2,124	2,855	2,960	2,992
Wholesale and retail trade	78	334	545	567	593
Heating	356	400	427	439	421
Other service industries	758	1,390	1,883	1,954	1,979
Industrial[b]	8,111	10,372	12,783	12,854	14,125
Agriculture	1,034	1,203	1,497	1,568	1,674
Construction	327	243	344	372	410
Final consumption in manufacturing and mining	5,180	7,096	9,016	9,060	9,855
Intermediate consumption (Energy conversion)					
Petroleum refinery losses	296	420	722	617	892
Electric power and steam production	1,234	1,359	1,178	1,214	1,276
Gas production	40	52	26	23	19
Transportation	1,683	2,864	5,509	5,693	6,157
Unaccounted for use[c]	215	23	36	37	28
Total Petroleum Consumption	11,486	16,065	22,439	22,838	24,780

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 7-4 and 7-9.

Note: Data on sectoral activity are reported here in units of 10,000 metric tons per year to remain consistent with the presentation of Chinese government publications and avoid the confusion of the multiple conversion factors that would be necessary for reporting in barrels, the commonly used unit in U.S. publications.

a. "Commercial" includes consumption categorized in the *China Statistical Yearbook* as that for "wholesale and retail trade," "heating" (assumed to reflect the production of steam and hot water for buildings), and sectors categorized as "others" (assumed to reflect consumption by service industries, such as those for finance, real estate, information, and so on).

b. "Industrial" includes consumption categorized in the *China Statistical Yearbook* as that for "farming, etc.," "construction," "final industry" (assumed to be utilities' consumption for supplying electricity, steam, and gas in manufacturing and mining), and petroleum refinery losses. If utilities' "gas production" represents natural gas distribution, that consumption should be categorized in the transportation sector instead (for consistency with its treatment in the U.S. national income and product accounts).

c. This is a balancing item, calculated to represent the difference between total petroleum consumption and the sum of consumption in the various sectors.

Table A-4.

China's Consumption of Crude Oil and Selected Petroleum Products, by Industry, 2002

(10,000 metric tons)

Industry	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil
Agriculture	0	203	1	1,495	0
Farming, forestry, animal husbandry, fishery, and water conservation	0	188	1	1,484	0
Logging and transport of wood and bamboo	0	15	0	11	0
Utilities	69	192	61	349	902
Electric power, steam, and hot water	69	24	1	251	883
Natural gas	0	1	0	11	19
Tap water	0	2	0	2	0
Other resident services[a]	0	164	61	84	0
Construction	4	122	0	252	19
Mining and Quarrying	3,379	89	8	307	197
Coal mining and dressing	1	30	6	55	
Petroleum and natural gas extraction	3,378	39	0	187	196
Ferrous metals mining and dressing	0	6	0	16	
Nonferrous metals mining and dressing	0	5	1	14	0
Nonmetal minerals mining and dressing	0	9	0	34	1
Other minerals mining and dressing	0	0	0	1	0
Manufacturing	18,909	500	79	1,150	1,851
Nondurable goods					
Food processing	0	31	0	33	8
Food production	0	13	0	20	9
Beverage production	1	8	0	12	8
Tobacco processing	0	31	0	5	1
Textile industry	0	35	4	44	65
Garments and other fiber products	0	8	1	15	15
Leather, furs, down, and related products	0	5	0	14	3
Timber processing, bamboo, cane, palm fiber, and straw products	0	3	0	6	3
Papermaking and paper products	1	16	3	30	22
Printing and record medium reproduction	0	7	6	8	2
Cultural, educational, and sports articles	0	3	1	16	1
Petroleum processing and coking	16,318	16	17	77	480
Raw chemical materials and chemical products	1,877	55	10	125	370
Medical and pharmaceutical products	0	11	0	7	5
Chemical fiber	646	4	0	11	88
Rubber products	0	8	0	7	12
Plastic products	1	12	0	41	9

Continued

Table A-4.
Continued

Industry	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil
Durable goods					
Furniture manufacturing	0	4	0	3	1
Nonmetal mineral products	50	56	2	302	339
Smelting and pressing of ferrous metals	13	31	6	81	263
Smelting and pressing of nonferrous metals	0	11	1	43	69
Metal products	0	20	2	44	13
Ordinary machinery	0	22	4	32	8
Equipment for special purposes	0	27	1	11	10
Transportation equipment	0	20	7	42	12
Electric equipment and machinery	1	18	0	27	12
Electronic and telecommunications equipment	0	10	0	61	15
Instruments, meters, and cultural and office machinery	0	3	0	11	0
Other manufacturing industry	0	13	11	24	7
Wholesale Trade, Retail Trade, and Catering Services	0	224	13	281	12
Transportation, Storage, and Post and Telecommunications Services	178	1,503	617	2,965	872
Other Services[b]	1	916	140	870	19
All Industries	22,541	3,750	919	7,668	3,874

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Table 7-9. Data categories have been reordered to parallel the presentation of U.S. industry accounts by the Department of Commerce, Bureau of Economic Analysis, in its *Survey of Current Business* and other publications.

Note: According to the *China Statistical Yearbook,* these data measure the consumption of petroleum by "material production sectors, non material production sectors, and households in the country." Industry-level data are not available for the consumption of other petroleum products (such as jet fuel and petrochemical feedstocks) and coking products (such as benzene), so they are not shown here. However, the total volume of those other products is included in the total consumption for all energy, as presented in Table 7-9 of the *Yearbook*. Data on sectoral activity are reported here in units of 10,000 metric tons per year to remain consistent with Chinese government publications and avoid the confusion of the multiple conversion factors that would be necessary for reporting in barrels, the commonly used unit in U.S. publications.

a. "Other resident services" is equivalent to the data category "residential consumption" in the *China Statistical Yearbook*, originally reported as a separate activity and not with utilities.

b. Although not defined in the data, this category presumably includes consumption by industries in finance, real estate, and other services.

Table A-5.

Income and Employment in China, Selected Years from 1990 to 2003

	1990	1995	2000	2001	2002	2003	Annual Growth, 1990-2003 (Percent)
Average Disposable Income (Nominal yuans)							
Urban households	1,510.2	4,283.0	6,280.0	6,859.6	7,702.8	8,472.2	13.3
Rural households	686.3	1,577.7	2,253.4	2,366.4	2,475.6	2,622.2	10.3
Number of Employed People (Millions)							
Urban areas	170.4	190.4	231.5	239.4	247.8	256.4	3.1
Rural areas	477.1	490.2	489.3	490.8	489.6	487.9	0.2

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 5-4 and 10-2.

Note: Income data for urban households are reported as per capita annual disposable income; for rural households, as per capita annual net income.

Table A-6.

China's Population, Indicators of Potential Drivers, and Actual Drivers, Selected Years from 1990 to 2003

	1990	1995	2000	2001	2002	2003
Total Population (Millions)	1,143.33	1,211.21	1,267.43	1,276.27	1,284.53	1,292.27
Percentage of total living in cities	26.4	29.0	36.2	37.7	39.1	40.5
Percentage of total ages 15 to 64	66.7	n.a.	70.2	n.a.	n.a.	71.3
Motor Vehicle Drivers (Millions)	16.36	35.02	76.56	84.55	93.62	106.11
Automobile drivers (Millions)	7.91	16.73	37.47	44.63	48.27	53.68

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 4-1 (population), 4-4, 4-6, and 16-28 (drivers).

Note: n.a. = not available.

Table A-7.

China's Stock of Motor Vehicles, by Type, Ownership, and Sales, Selected Years from 1990 to 2003

(Millions of units)

	1990	1995	2000	2001	2002	2003
Motor Vehicle Stock (End of year)[a]						
Civil vehicles (Registered for highway use)	5.51	10.40	16.09	18.02	20.53	23.83
Passenger vehicles	1.62	4.18	8.54	9.94	12.02	14.79
Trucks	3.68	5.85	7.16	7.65	8.12	8.54
Other civil vehicles[b]	0.21	0.37	0.39	0.43	0.39	0.51
Other motor vehicles (Including motorcycles and off-highway vehicles)	n.a.	n.a.	41.68	47.24	61.74	71.09
Ownership[a]						
Transport vehicles (Fleet vehicles)[c]						
Passenger vehicles	n.a.	n.a.	2.17	2.55	2.90	3.52
Trucks	n.a.	n.a.	4.86	5.09	5.37	5.72
Privately owned vehicles						
Passenger vehicles	0.24	1.14	3.65	4.70	6.24	8.46
Trucks	0.57	1.32	2.59	2.99	3.41	3.67
New Vehicle Sales						
Passenger vehicles	n.a.	n.a.	n.a.	n.a.	2.29	3.16
Trucks[d]	n.a.	n.a.	n.a.	n.a.	1.08	1.18
Motorcycles[e]	n.a.	n.a.	n.a.	12.44	13.00	13.25

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 16-2 (for "other motor vehicles"), 16-28, and 16-30; and information from reports in *China Daily* ("Honda Motorcycle Sales to Grow by 34%," December 27, 2004) and Jialing, Inc. ("China Rolls Out Motorcycles," from AJOT, April 14, 2003, available at www.jialing.co.za/news%202.htm).

Note: n.a. = not available.

a. The total number of civil vehicles does not equal the total number of vehicles by ownership because of differences in definition.

b. "Other civil vehicles" are referred to in the data as "special vehicles," but it is unclear what type of vehicles they are. The numbers are estimated for 1990 to 2001 as the difference between "total" civil vehicles and the sum of "passenger vehicles" and "trucks" in Table 16-28 of the *China Statistical Yearbook*.

c. "Transport vehicles" are vehicles owned by governments, state-owned businesses, and large private businesses. The numbers before 1999, which only indicate the relatively few vehicles owned by the Department of Highway Transportation, are omitted.

d. Estimated as the difference between "total" new registration of civil vehicles and new registration of "passenger vehicles" in Table 16-30 of the *China Statistical Yearbook*.

e. Estimated from data for 2002 and reported rates of growth in that year and in 2003.

Table A-8.

China's Stock of Motor and Agricultural Vehicles, by Type and Size, Selected Years from 1990 to 2003

(Millions of units)

	1990	1995	2000	2001	2002	2003
Motor Vehicle Stock (End of year)						
Civil vehicles (Registered for highway use)	5.51	10.40	16.09	18.02	20.53	23.83
Passenger vehicles						
Large (Including buses)	n.a.	n.a.	n.a.	n.a.	0.75	0.76
Medium and small	n.a.	n.a.	n.a.	n.a	8.95	11.33
Mini	n.a.	n.a.	n.a.	n.a.	2.32	2.70
Total Passenger Vehicles	1.62	4.18	8.54	9.94	12.02	14.79
Trucks						
Heavy	n.a.	n.a.	n.a.	n.a.	1.48	1.37
Middle and light	n.a.	n.a.	n.a.	n.a.	5.79	6.35
Mini	n.a.	n.a.	n.a.	n.a.	0.85	0.82
Total Trucks	3.68	5.85	7.16	7.65	8.12	8.54
Other civil vehicles[a]	0.21	0.37	0.39	0.43	0.39	0.51
Agricultural tractors						
Large and medium	0.81	0.67	0.97	0.83	0.91	0.98
Mini	6.98	8.65	12.64	13.05	13.39	13.78
Total Tractors	7.79	9.32	13.61	13.88	14.30	14.76
Diesel engines on farms	4.11	4.91	6.88	7.29	7.51	7.50
"Tire" tractors	4.63	5.92	8.21	8.26	n.a.	n.a.
Other motor vehicles (Including motorcycles and small rural vehicles)	n.a.	n.a.	41.68	47.24	61.74	71.09

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 13-7 (for "agricultural tractors"), 16-2, 16-28, and 16-30.

a. "Other civil vehicles" are referred to in the data as "special vehicles," but it is unclear what type of vehicles they are. The numbers are estimated for 1990 to 2001 as the difference between "total" civil vehicles and the sum of "passenger vehicles" and "trucks" in Table 16-28 of the *China Statistical Yearbook*.

Table A-9.

China's Highway Infrastructure, Selected Years from 1990 to 2003

(Thousands of miles)

	1990	1995	2000	2001	2002	2003
Length of Transport Routes						
All highways and expressways	639	719	872	1,055	1,097	1,125
Expressways only	0	1	10	12	16	18
First-class highways only	n.a.	n.a.	n.a.	n.a.	n.a.	19
All highways and expressways in coastal provinces and cities	n.a.	n.a.	n.a.	n.a.	n.a.	311
Expressways in coastal provinces and cities	n.a.	n.a.	n.a.	n.a.	n.a.	9
First-class highways in coastal provinces and cities	n.a.	n.a.	n.a.	n.a.	n.a.	13

Source: Congressional Budget Office based on data from the National Bureau of Statistics of China, *China Statistical Yearbook 2004* (Beijing: China Statistics Press, September 22, 2004), Tables 16-3 and 16-4.

Notes: n.a. = not available.

Data for highway and expressway miles in coastal provinces and cities include, from south to north, Guangdong, Fujian, Zhejiang, Shanghai, Jiangsu, Shandong, Beijing, Tianjin, Hebei, and Liaoning.

Table A-10.

Major Ongoing Refinery Projects in China, 2005

Chinese Business	Foreign Partner	Location (City, Province)	Added Capacity (Thousands of barrels a day)	Projected Completion Date
Sinopec	ExxonMobil, Saudi Aramco	Quanzhou, Fujian	80 to 240	Early 2008
CNPC (PetroChina)	n.a.	Dalian	250 to 400	Early 2006
Sinopec		Yangpu, Hainan	160	2006-2007
Sinopec	Saudi Aramco (pending)	Qingdao, Shandong	200	2008-2009
CNOOC	Shell (pending)	Huizhou, Guangdong	240	2008
CNPC (PetroChina)	n.a.	Dushanzi, Xinjiang	100	2009
Sinopec		Dagang, Tianjin	250	Waiting for government approval
CNPC (PetroChina)	n.a.	Dagang, Tianjin	200	Waiting for government approval
Sinopec	n.a.	Beihai, Guangxi	160	Waiting for government approval

Source: Congressional Budget Office based on information from Kang Wu and Fereidun Fesharaki, "As Oil Demand Surges, China Adds and Expands Refineries," *Oil & Gas Journal* (July 25, 2005), pp. 20-24; and Department of Energy, Energy Information Administration, "China," EIA Country Analysis Briefs, available at www.eia.doe.gov/emeu/cabs/china.html.

Note: CNPC = China National Petroleum Corporation; CNOOC = China National Offshore Oil Corporation; n.a. = not applicable.