Chapter Six

GDP EFFECTS OF AN ENERGY PRICE SHOCK

This chapter attempts to derive rough estimates of the adverse effects on Chinese GDP growth attendant upon an energy price "shock," defined as a substantial increase in oil prices, with ensuing empirical effects on such oil substitutes as coal and natural gas as outlined below. We begin with the case of a "severe" production cut and price increase and, for sensitivity purposes, also consider proportionately smaller "large" and "moderate" cases as well. As an ancillary effect in the context of China, such increases in the price of oil can be envisioned to produce an additional adverse impact on public health because of a renewed intensive use of "dirty" (high-sulfur) coal for electric power generation, industrial processes, space heating, and other purposes; however, the available literature does not offer a uniform estimate of that effect in terms of mortality and morbidity, in that the effects are difficult to separate from those of dust from construction sites and agricultural areas.[1]

We begin with the presentation of some basic data and projections on the Chinese energy sector, followed by a discussion of the effects of a severe increase in international oil prices. GDP effects are derived, and the three sensitivity cases are discussed.

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[1]See, e.g., World Bank, 2001c, especially pp. 77–98.

SOME BASIC DATA ON THE CHINESE ENERGY SECTOR AND CHINESE GDP

Table 6.1 presents basic data and projections on Chinese primary energy consumption, while Table 6.2 presents analogous data for production.

Table 6.3 presents data and projections on Chinese GDP.

Table 6.4 presents data and projections on primary energy consumption (in Btu) per dollar of GDP for China and for the United States, as a crude measure of the energy intensity pattern of GDP. These data are rough estimates, particularly for the years after 2000, but provide a glimpse at the potential for reduced energy intensity of GDP available to the Chinese economy over time. Under an assumption that U.S. energy use is economically efficient as a first approximation, because it is driven largely (but certainly not wholly) by market forces, the difference between the energy intensities of Chinese and U.S. GDP may provide a very crude estimate of the future behav-

Table 6.1

Primary Energy Consumption in China (quadrillion Btu)

Year	Coal	Natural Gas	Petroleum	Total
1980	12.5	0.6	3.8	17.3
1985	16.9	0.5	4.0	22.2
1990	20.7	0.6	4.9	27.0
1995	27.5	0.7	7.2	35.2
2000	22.7	1.2	9.7	36.7
2005	26.4	2.2	11.2	43.2
2010	33.3	3.4	14.2	55.3
2015	40.1	5.3	17.9	69.1

SOURCE: Energy Information Administration (EIA), *International Energy Database,* Washington, D.C., 2002.

NOTES: Totals may not sum because of other fuels and rounding. Figures for 2005–2015 are EIA projections, reference case.

Table 6.2

Primary Energy Production in China (quadrillion Btu)

Year	Coal	Natural Gas	Petroleum	Total
1980	12.6	0.6	4.5	18.1
1985	17.7	0.5	5.4	24.3
1990	21.9	0.6	6.0	29.4
1995	28.3	0.7	6.4	35.4
2000	18.4e	1.1e	7.0	27.8e
2005	n.a.	n.a.	6.7	n.a.
2010	n.a.	n.a.	6.6	n.a.
2015	n.a.	n.a.	6.5	n.a.

SOURCE: EIA, *International Energy Database,* Washington, D.C., 2002.

NOTES: Totals may not sum because of other fuels and rounding. Petroleum includes crude oil, natural gas liquids, and refinery processing gain. Figures for 2005–2015 are EIA projections, reference case. Total is primary energy only.

e = estimated.

n.a. = not available.

ior of a Chinese economy driven increasingly by market forces and confronted with a large increase in energy prices.[2]

OIL PRICE EFFECTS OF A "SEVERE" OIL SUPPLY DISRUPTION

The most obvious "crisis" scenario in the energy context is a supply disruption in international supplies of crude oil, perhaps attendant upon a war in the Middle East affecting supplies from the Persian

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[2]This is a very rough first approximation, since the economic structures of the Chinese and U.S. economies, enjoying different comparative advantages in the world economy, do and will continue to differ, even apart from differences in resource allocation outcomes yielded by government policies. These sorts of structural variations yield differences in the relative sizes of the industrial, commercial, and residential sectors, and in the specific characteristics of each. Accordingly, there is no efficiency reason for the energy intensities of different economies in the aggregate to converge, but the "starting points" of the Chinese and U.S. economies (say, in 1980) provide strong grounds for the hypothesis that the energy intensity of the former will tend to move toward that of the latter as market forces increasingly drive resource allocation.

Table 6.3

Chinese GDP (billions of 2000 dollars)

Year	IMF	EIA	Wolf et al.
1980	169.8	n.a.	n.a.
1985	282.3	n.a.	n.a.
1990	412.2	448.3	n.a.
1995	726.6	n.a.	943.9
2000	1080.4	1168.2	1250.9
2005	n.a.	1669.4	1589.0
2010	n.a.	2389.6	2009.1
2015	n.a.	3284.2	2601.3

SOURCES: International Monetary Fund (IMF), *International Financial Statistics Yearbook 2001,* Washington, D.C., 2001; EIA, *International Energy Outlook 2001,* Washington, D.C., 2001, Appendix A; Wolf et al., 2000.

NOTES: IMF dollars were converted at the market exchange rate; EIA the reference case, and Wolf et al. the stable growth scenario. We converted to year 2000 dollars from Council of Economic Advisers, *Economic Indicators*, Washington, D.C., February 2002.

n.a. = not available.

Gulf, yielding a large increase in the world market price of oil and oil substitutes. Table 6.5 presents data on world production of petroleum.

There are some reasons to believe that the forecast of an increasing share of Persian Gulf output as a proportion of world output is somewhat unrealistic, although certainly plausible;[3] but since this study examines the effects of adverse circumstances, it is a useful general assumption. Let us adopt a worse-case assumption of an oil supply disruption in 2005, perhaps as a result of a major military

[3]See, e.g., Eliyahu Kanovsky, *The Economy of Saudi Arabia: Troubled Present, Grim Future*, Washington Institute for Near East Policy, Washington, D.C., September 1994.

Table 6.4

Primary Energy Consumption Per Dollar of GDP (in Btus)

Year	China	United States	China/U.S. (Btu ratio)
1980	76549	14945	5.1
1985	61006	12550	4.9
1990	46067	11727	3.9
1995	37292	11257	3.3
2000	26861	9956	2.7
2005	27187	9121	3.0
2010	27525	8415	3.3
2015	26564	7705	3.4

SOURCES: Tables 6.1 and 6.3; 10 percent annual growth rate for 1980 through 1990 applied to Wolf et al., 2000, GDP projections. U.S. energy consumption is from EIA, *International Energy Database,* 2002, and *International Energy Outlook 2001,* 2001, Washington, D.C. U.S. GDP is from Council of Economic Advisers, *Annual Report of the Council of Economic Advisers*, February 2002, and *Economic Indicators*, February 2002, Washington, D.C.; and from Office of Management and Budget, *Budget of the United States Government*, Washington, D.C., fiscal year 2003.

conflict in the Middle East, which removes Persian Gulf oil from the world market for, say, 10 years.[4] Let us assume in addition that the world price elasticity of demand for oil is 0.10 (in absolute value) in the short run, increasing by 0.025 each year for the duration of the disruption.[5] The immediate effect upon the world market price of oil, caused by a supply reduction of 28 percent (ignoring any immediate production response outside the Persian Gulf), would be an in-

[4]This assumed magnitude and duration of the supply disruption are extreme, but they serve to put a useful bound on the analysis of "crisis" effects on the Chinese economy.

[5]This assumption reflects the standard axiom that the elasticities of demand (in absolute value) and supply increase with time, that is, that greater adjustments to a shift in exogenous conditions become economic as more time becomes available to make them.

Table 6.5

World Petroleum Production and Consumption (thousands of barrels per day)

Year	China	United States	Persian Gulf	World	Persian Gulf/ World Ratio	World Consumption
1980	2114	10809	18860	64139	.294	63067
1985	2505	11192	15668	59249	.264	60091
1990	2774	9677	16529	66743	.248	65974
1995	2990	9400	18351	69868	.263	69878
2000	3249	9000	20503	75614	.271	76515
2005	3100	9000	23800	84800	.281	85100
2010	3070	8700	28500	94700	.301	95000
2015	3050	9000	34600	106600	.325	106900

SOURCE: EIA, *International Energy Database,* 2002, and *International Energy Outlook 2001,* 2001, Washington, D.C.

NOTE: Production includes crude oil, natural gas and other liquids, and refining gain.

crease of about 280 percent, or roughly a quadrupling. Let us assume also that producers outside the Persian Gulf increase output in response to the price increase, by, say, 1 million barrels per day per year beginning in the second year (2006); a response is partly caused by the price increase and partly helps to moderate the price increase.[6] Let us assume that half of that total effect moderates prices, so that the true "supply" response is 500,000 barrels per day per year. Table 6.6 summarizes these production and price effects as rough parameters.[7]

EFFECTS ON CHINESE GDP

Oil Market Effects

One rough method for estimating the GDP effects of the simulated pattern of oil price increases is presented in Table 6.7. These estimates use Chinese GDP energy intensity data as shown in Table 6.4,

[6]In other words, part of the response is a movement along the supply curve, and part is a shift of the non–Persian Gulf supply curve resulting from an increase in the expected rate of return resulting from the price increase.

[7]Note that the price of the benchmark crude oil (Arabian light) was $34 per barrel in 1982, which is about $55 per barrel in year 2000 dollars.

Table 6.6

Simulated Petroleum Production and Price Effects

Year	Disruption	Non–Persian Gulf Supply Response	Net Production Cut	Price Increase (percentage)	Price (year 2000 $ per barrel)
	(millions of barrels per day)				
2004	0	0	0	0	25.00
2005	23.8	0	23.8	281	95.25
2006	24.7	0.5	24.2	223	80.75
2007	25.6	1.0	24.6	185	71.25
2008	26.5	1.5	25.0	158	64.50
2009	27.5	2.0	25.5	138	59.50
2010	28.5	2.5	26.0	122	55.50
2011	29.6	3.0	26.6	110	52.50
2012	30.8	3.5	27.3	100	50.00
2013	32.0	4.0	28.0	92	48.00
2014	33.3	4.5	28.8	85	46.25
2015	34.6	5.0	29.6	79	44.75

NOTE: We assume an initial price of $25 per barrel (in year 2000 dollars).

in combination with assumptions about the Chinese demand elasticity for oil, the cross-elasticities of demand among primary fuels, and the evolution of the energy intensity of GDP. Let us assume that the Chinese demand elasticity for petroleum (and for energy generally) is equal to the world demand elasticity noted above.[8] Let us assume further that the energy content of a barrel of oil is 5,879 thousand Btu (EIA, *International Energy Database,* Washington, D.C., 2002). Table 6.7 shows estimates of these effects on Chinese oil consumption.[9]

One very rough method with which to estimate the GDP impact of the increase in oil prices and the attendant reduction in oil con-

[8]This is unlikely to be strictly correct; moreover, across nations the relative demand elasticities among alternative fuels are unlikely to be equal. But this assumption simplifies the analysis greatly, allows us to avoid the need for data that are unavailable in any event, and provides an answer unlikely to vary too greatly from the underlying truth. We also assume that Chinese energy demands do not affect world prices, a premise that is very likely to be correct except in some possible cases of such localized markets as (future) natural gas trade with Russia.

[9]We use the standard simple elasticity definition: percentage change in quantity equals elasticity times percentage change in price. For example, for 2005, 28.1 = 0.1 × 281.

Table 6.7

Chinese Oil Consumption Response to Price Increases

Year	Base Consumption (millions of barrels per day)	Reduced Consumption (millions of barrels per day)	Reduced Consumption (quadrillion Btus per year)
2005	5.2	1.5	3.2
2006	5.5	1.5	3.3
2007	5.7	1.6	3.4
2008	6.0	1.7	3.6
2009	6.3	1.7	3.7
2010	6.6	1.8	3.9
2011	6.9	1.9	4.1
2012	7.3	2.0	4.3
2013	7.6	2.1	4.5
2014	7.8	2.2	4.6
2015	8.4	2.3	5.0

SOURCES: Table 6.1 (with interpolations), Table 6.6, and author computations.

sumption is to apply the estimated reduction in oil consumption (Table 6.7) to total primary energy consumption in China (Table 6.1) and the energy intensity of Chinese GDP (Table 6.4). This is a reasonable approach for purposes of rough estimation, in that the energy-using (or substitute) capital stock is fixed in the short run (by definition), so that lost output occasioned by the increase in the price of oil is driven by the price elasticity of demand for oil and the oil-intensity of GDP. Table 6.8 presents that simulation as an "energy inefficiency" scenario.

Note that the energy intensity of Chinese GDP predicted by the EIA, as shown in Tables 6.4 and 6.8, is roughly constant after 2005; it declines sharply between 1980 and 2000. It is reasonable to assume that a sharp increase in energy prices beginning in 2005 would induce a substitution toward more energy-efficient capital, among other important effects, so that the assumed Btu/GDP ratios in Table 6.8 may be unrealistic in terms of the conceptual experiment under examination here. Accordingly, let us assume that Chinese energy consumption per dollar of GDP declines between 2005 and 2015 at a rate of 1 percent per year, as opposed to the rate of less than about 0.2 percent per year in the inefficiency scenario. With a capital stock improving in terms of reduced energy intensity over the period, each unit of energy consumed would have a higher marginal value at the

Table 6.8

Simple Oil Consumption Effects on Chinese GDP, "Energy Inefficiency" Scenario

Year	Reduced Consumption (quadrillion Btu)	Btu/Dollar of GDP	Implied GDP Reduction (billions of 2000 $)	Base GDP (billions of 2000 $)	% Reduction
2005	3.2	27187	117.7	1589.0	7.4
2006	3.3	27254	117.4	1665.3	7.1
2007	3.4	27322	124.4	1745.2	7.1
2008	3.6	27389	131.4	1829.0	7.2
2009	3.7	27457	131.1	1916.8	6.8
2010	3.9	27525	141.7	2009.1	7.1
2011	4.1	27330	150.0	2115.6	7.1
2012	4.3	27136	158.5	2227.7	7.1
2013	4.5	26944	167.0	2345.8	7.1
2014	4.6	26753	175.7	2470.1	7.1
2015	5.0	26564	184.5	2601.3	7.1

SOURCES: Tables 6.3 and 6.4 (interpolated), Table 6.7, and author computations.

higher prices and improved energy efficiency. So let us assume that the demand elasticity (in absolute value) increases only from 0.1 to 0.2 over the period.[10] Table 6.9 outlines this scenario.

Oil Import Cost. An increase in the amount of real resources that China would have to send (pay) overseas in the face of a rise in international oil prices represents a loss of national wealth relevant to the reduction in GDP under examination here. Table 6.10 presents calculations of the increase in the Chinese oil import cost attendant upon the oil supply disruption hypothesized above. We assume a reduction in oil consumption at the average of those shown in Tables 6.8 and 6.9; and we assume, for "severe-case" analytic purposes, constant Chinese oil output at 3,100 thousand barrels per day, as shown in Table 6.5. This loss of national wealth would be likely to have an additional effect on energy consumption, which must be a normal good in the economic sense,[11] but that effect is ignored here, as is the adverse exchange rate effect of increased spending on imported oil.

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[10]In the former case, the demand elasticity rises from 0.1 in 2005 to 0.35 in 2015.

[11]A normal good is one for which demand rises as income (or wealth) rises.

Table 6.9

Simple Oil Consumption Effects on Chinese GDP, "Energy Efficiency" Scenario

Year	Reduced Consumption (quadrillion Btu)	Btu/Dollar of GDP	Implied GDP Reduction (billions of 2000 $)	Base GDP (billions of 2000 $)	% Reduction
2005	3.2	27187	117.7	1589.0	7.4
2006	2.9	26915	107.7	1665.3	6.5
2007	2.7	26646	101.3	1745.2	5.8
2008	2.7	26380	102.4	1829.0	5.6
2009	2.6	26116	99.6	1916.8	5.2
2010	2.6	25855	100.6	2009.1	5.0
2011	2.6	25596	101.6	2115.6	4.8
2012	2.7	25340	106.6	2227.7	4.8
2013	2.7	25087	107.6	2345.8	4.6
2014	2.7	24836	108.7	2470.1	4.4
2015	2.8	24587	113.9	2601.3	4.4

SOURCES: Tables 6.3 and 6.4 (interpolated), Table 6.7, and author computations.

Table 6.10

Increase in Chinese Oil Import Cost

Year	Base Imports	Disruption Imports	Base Import Cost	Disruption Cost	Difference	% of Base GDP
2005	2.1	0.6	19.2	20.9	1.7	0.1
2006	2.4	1.0	21.9	29.5	7.6	0.5
2007	2.6	1.1	23.7	28.6	4.9	0.3
2008	2.9	1.4	26.5	33.0	6.5	0.4
2009	3.2	1.8	29.2	39.1	9.9	0.5
2010	3.5	2.0	31.9	40.5	8.6	0.4
2011	3.8	2.3	34.7	44.1	9.4	0.4
2012	4.2	2.6	38.3	47.5	9.2	0.4
2013	4.5	2.8	41.1	49.1	8.0	0.3
2014	4.7	3.0	42.9	50.6	7.7	0.3
2015	5.3	3.5	48.4	57.2	8.8	0.3

SOURCES: Tables 6.1, 6.2, 6.7, 6.8, 6.9; author computations.

NOTES: We assume $25 per barrel price in absence of supply disruption. Imports are in millions of barrels per day. Costs are in billions of year 2000 dollars.

Fuel Substitution Effects. The adverse GDP effects summarized in Tables 6.8 and 6.9 are driven by the effect of a reduction in the consumption of oil in terms of the energy intensity of GDP. Some of that adverse effect would be offset by substitution of other primary fuels—coal and gas—for oil. Rothman et al.[12] estimate a cross-elasticity of demand among fuels of 0.33 for 53 nations, an estimate very likely to represent a long-run estimated parameter; for China under the conditions postulated here, a much smaller short-run cross-elasticity of demand is reasonable. Bjoner and Jensen have estimated more recently for Danish industry a cross-elasticity of demand range of 0.05–0.57.[13] For China, we assume heavy constraints on increased coal use due to environmental/health concerns, and on increased gas use because of importation costs and constraints. Accordingly, we assume a cross-elasticity of fuels demand of 0.02 for China. Table 6.11 summarizes the fuel substitution effect for Chinese GDP; we ignore price effects for coal and natural gas, and we assume the average energy intensity of GDP from Tables 6.8 and 6.9.

Table 6.11

Fuel Substitution Toward Coal and Gas

	Base Consumption		Disruption Consumption					
Year	Coal	Gas	Coal	Gas	Total Btu Increase	Btu/GDP (ratio)	Increased GDP	% Increase
2005	26.4	2.2	27.9	2.3	1.6	27187	58.9	3.7
2006	27.7	2.4	28.9	2.5	1.3	27085	48.0	2.9
2007	29.0	2.6	30.1	2.7	1.2	26984	44.5	2.6
2008	30.3	2.9	31.3	3.0	1.1	26885	40.9	2.2
2009	31.8	3.1	32.7	3.2	1.0	26787	37.3	1.9
2010	33.3	3.4	34.1	3.5	0.9	26690	33.7	1.7
2011	34.6	3.7	35.4	3.8	0.9	26463	34.0	1.6
2012	35.9	4.1	36.6	4.2	0.8	26238	30.5	1.4
2013	37.2	4.4	37.9	4.5	0.8	26016	30.8	1.3
2014	38.6	4.8	39.3	4.9	0.8	25810	31.0	1.3
2015	40.1	5.3	40.7	5.4	0.7	25576	27.4	1.1

NOTE: Consumption is in quadrillion Btu. GDP is in billions of year 2000 dollars.

[12]Dale Rothman, J. Hong, and T. Mount, "Estimating Consumer Energy Demand Using International Data: Theoretical and Policy Implications," *Energy Journal*, Vol. 15, No. 2, 1994, pp. 67–88.

[13]Thomas Bue Bjoner and Henrik Holm Jensen, "Interfuel Substitution Within Industrial Companies—An Analysis Based on Panel Data at Company Level," *Energy Journal*, Vol. 23, No. 2, 2002, pp. 27–50.

Table 6.12 aggregates the separate effects on Chinese GDP for the "severe" disruption case assuming the "energy efficiency" scenario from Table 6.9, in percentage change from the baseline in Table 6.3. As a crude summary, an increase in the price of oil following a "severe" cutoff of Persian Gulf exports would reduce annual Chinese GDP by about 3.5–4.0 percent over the period 2005–2015.

Effects of Smaller Disruptions. For purposes of sensitivity analysis, we consider significant but smaller disruptions in the supply of oil: A "large" disruption might be defined as two-thirds of the "severe" case, while a "moderate" disruption might be defined as one-third of the "severe" case. If we maintain our elasticity assumptions as outlined above,[14] the price, consumption, import, and fuel substitution effects remain proportional. Accordingly, a "large" disruption engendering effects at two-thirds of the "severe" case would reduce annual Chinese GDP by about 2.3–2.7 percent. A "moderate" disruption, one-third of the "severe" case, would reduce annual GDP by about 1.2–1.4 percent.

Table 6.12

Summary of GDP Effects, "Severe" Disruption (percentage)

Year	Oil Consumption	Import Cost	Fuel Substitution	Total
2005	(7.4)	(0.1)	3.7	(3.8)
2006	(6.5)	(0.5)	2.9	(4.1)
2007	(5.8)	(0.3)	2.6	(3.5)
2008	(5.6)	(0.4)	2.2	(3.8)
2009	(5.2)	(0.5)	1.9	(3.8)
2010	(5.0)	(0.4)	1.7	(3.7)
2011	(4.8)	(0.4)	1.6	(3.6)
2012	(4.8)	(0.4)	1.4	(3.8)
2013	(4.6)	(0.3)	1.3	(3.6)
2014	(4.4)	(0.3)	1.3	(3.4)
2015	(4.4)	(0.3)	1.1	(3.6)

SOURCE: Tables 6.8–6.11.

NOTES: Oil consumption effect is the average of Tables 6.8 and 6.9. Numbers in parentheses are negative.

[14] This is reasonable, in that the assumed elasticities at any given price are more likely to hold for smaller price changes than for larger ones.