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"Projections of Chinese Energy Demands in 2020"

by

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Projections of Chinese Energy Demands in 2020

by

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Abstract

As current trends of Chinese economic growth and motorization continue, its demand for higher efficiency fuels (oil, gas, and electric power) will increase. This, coupled with China's limited domestic production, can translate into a massive demand for energy imports. To predict China's energy demand into 2020, an econometric model of the Chinese energy economy is constructed based on its energy balance. This paper suggests that China's increase demand for energy imports will be most sensitive to increases in motorization rather than economic growth. It can be partially offset by increasing domestic energy production or energy efficiency.

JEL Classifications: Q3, Q4, F1, F2, F4, L9, N7, O53, P28

Key Words: China; Energy; Energy Demand; Petroleum and Coal; World Energy Markets; Motorization; Energy Efficiency.

Projections of Chinese Energy Demands in 2020

Introduction

Until a few years ago, the spectacular growth of the Chinese economy has had only modest impact on the world energy economy. But in the recent past, Chinese imports of petroleum have begun to play a perceptible role in world markets. Rapidly growing demand for petroleum in China accounts for an important part of the demand pressures that have raised petroleum prices to record levels. Experts fear that, given China's limited supply potentials from domestic sources, continued rapid economic growth in China will translate into a massive need to expand imports of oil, coal, and gas. Indeed, recent efforts by Chinese authorities to arrange for oil supplies from Venezuela and natural gas from Central Asia and the Indian Ocean suggest that Chinese planners are themselves worried about future energy supplies. (Zweig and Ijanhai, 2005, and Kenny, 2004)

From the perspective of energy economics, the growing consumption of energy in China poses an academic puzzle as well as a practical challenge. Aggregate Chinese energy demand has increased at an average annual rate of 2.3 percent from 1980 to 2002 and showed almost no increase from 1996 to 2000. With GDP growth in the 7 to 11 percent range, one might anticipate that Chinese energy demand would rise more rapidly than it has. It is probable that growing needs for motor fuel will increase China's energy needs more rapidly in the future than in the past.

This paper is concerned with the past and future situation of China in the world energy economy. The purpose of this paper is to look closely at the structure and growth of Chinese energy demand. We develop an econometric/energy balance model of China and we use this system to project future energy use and import requirements.

After a brief introduction, in Part I we analyze Chinese energy statistics. We note that Chinese economic expansion in the past two decades has entailed lower growth of requirements for energy than might have been anticipated. Part II outlines an approach to projection based on the energy balance and econometric linkages to other parts of the economy. In Part III, we examine future prospects under alternative assumptions with regard to Chinese economic growth. Finally, Part IV is devoted to evaluation and conclusions.

The Chinese Energy Economy

China's rapid economic growth has been accompanied by drastic changes in the country's energy economy.

China is a country in "energy transition"[1]. The ongoing changes have various dimensions:

- from a user of low efficiency solid fuels to higher efficiency gaseous and liquid fuel and electric power,
- from a predominantly agricultural economy to increasing urbanization and industrialization,
- from heavy industry to lighter and, increasingly, high technology industry,
- from a country with low motorization to rapid growth of the motor vehicle population,

- from a country that was largely energy self-sufficient to a significant petroleum importer.

Energy consumption in China has shown growth, except during 1995-2002, but, given the rapid growth of GDP, energy consumption growth has been surprisingly modest, averaging 3 percent per year. (Table 1 and Figure 1 and 2) The aggregate energy demand elasticity with respect to GDP was 0.34 until 1996 and averaged only 0.26 over the entire 1980-2002 period.[2] This contrasts sharply with the typical expectation that the energy elasticity in developing countries exceeds unity, in other words, energy consumption rises proportionately more rapidly than GDP. (Zilberfarb and Adams, 1981) This can be explained by changes in the composition of production and the energy intensity of production ((Medlock and Soligo, 1999, Brookes, 1971) and by substitution between fuels, (Adams and Miovic, 1968).

In the 1996-2002 years, the computed energy elasticity is only 0.04 and the relationship between growth of GDP and energy consumption is not statistically significant. As we shall see, China represents a special case, reflecting the initial heavy use of coal and waste materials. Unless one discounts China's rapid GDP growth, a low aggregate elasticity must reflect sharp gains in the efficiency of energy use. In view of the pattern of the energy elasticity of China, reflecting the transitional nature of the Chinese energy economy, it is not useful to rely on an aggregate elasticity to forecast Chinese energy use. A more detailed analysis (of) fuel by fuel is required.

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[1] For a summary discussion see EIA (2005)

[2] The discrepancy between Chinese growth and energy consumption has caused a number of scholars to raise questions about Chinese national accounts statistics, (Adams and Chen, 1996, Rawski, 2001). In this connection one of the authors can report an illuminating episode. In the early 1990s, presenting a lecture to students in Tianjin, Adams mentioned the elasticity linking demand for energy and GDP. A hand quickly shot up. The student explained that, "Of course, the energy elasticity in China is 0.5, just like in the United States!"

Moreover, it is not helpful to use data on fuel prices as an input into a forecast study. Market signals appear to have had little effect on Chinese energy use and related investment (Austin, 2005). Chinese energy prices are administered and, though there have been some efforts at deregulation, so far they do not reflect underlying market scarcities. In any case, appropriate domestic price data series are not available and would be difficult to project.

Table 1 here

Figure 1 here

Figure 2 here

The composition of Chinese energy use (Table 2 and Figure 3) is remarkable. In 1980, final energy consumption was dominated by coal and combustible wastes (over 80 percent). Combustible waste materials that go entirely into the residential sector declined steadily as a share of total consumption until the mid 1990s and have remained fairly steady since then. [3] Coal, on the other hand, showed some increase until the mid 1990s but has declined sharply since then. These fuels, which represent the "old" Chinese economy, today still account for approximately 56 percent of total final energy use. The decline in the use of these fuels has been offset by a rapid increase in the use of electricity and petroleum products, which accounted for 13 and 24 percent, respectively, of total consumption in 2002.

Table 2 here

Figure 3 here

On a per capita basis, energy consumption in China remains modest in comparison to other East Asian developing countries and/or in comparison with the advanced countries. (Table 3, Figure 4). On the other hand, energy inputs per unit of GDP (PPP basis) are close to the world average and even a little higher than in the advanced countries. This is consistent with the fact that energy use, particularly of coal, is not efficient by advanced country standards. (Sinton et al, 1998) Given China's large size, energy consumption in China represents a significant (12 percent) and rapidly increasing fraction of the world total.

Table 3 here

Figure 4 here

The import requirements of the Chinese economy are of particular importance from a world perspective. Since the mid 1990s, China has changed from a moderate net exporter of coal to significant reliance on imported crude oil and petroleum products. (Table 4, Figure 5) Recently net imports of crude oil have accounted for 28 percent of total Chinese crude petroleum use and imports of petroleum products represent an additional 8 percent of petroleum products consumption. Perhaps more important is the rapid increase of Chinese petroleum imports at 15 to 20 percent annually. While Chinese

[3] Many projections of Chinese energy consumption understate use by ignoring the consumption of combustible waste.

imports of crude oil only accounted for 3.5 percent of total world crude oil trade, their growth represents a much larger fraction of the expansion of total world supply.

Table 4 here

Figure 5 here

Energy Modeling and the Energy Balance

In recent years, as concerns regarding China's energy use and its environmental impact have become more immediate, there have been numerous efforts to make long term projections of China's energy system. (Loose and McCreary, 1996: Li, Shatung, 2000; Lamont et al, 2000; Kato, 2003: IEA, 2006a and b, Schcattenholzer, 2004) Most of these studies point in the same general direction: China's needs for energy are rising rapidly and that China's imports of oil, coal, and natural gas will increase rapidly in absolute terms as well as a fraction of world supply. Much of this work is extremely detailed and based heavily on engineering information. Some of these studies use cost minimization algorithms: the EIA's Sage (IEA, 2006b) applies cost minimization to 42 energy consumption categories, for example. Others are computable general equilibrium systems. They are conceptually difficult and burdensome to use unless the forecaster has direct access to the appropriate software system like LEAP (Stockholm, 1997). Some are scenario studies such as the ERI study (ERI, 2003), for example. The outcomes of these predictions are, of course, entirely dependent on the methodologies and underlying assumptions

Our objective was to build an econometric model system based on the energy balance framework.[4] The energy balance approach is traditionally used as an accounting system for analyzing a country's energy supply and utilization. The energy balance (Table 5) reconciles the flow of energy supply, transformation, and final demand, by sector and by source of energy. It shows, for example, that final consumption of petroleum products translates into requirements for refining output and in turn influences refinery input of crude oil. In turn, given crude oil production and exports, and demand for crude oil, imports should be the balancing item, except for statistical discrepancies. Other secondary energy consumption can similarly be traced to its origins in supplies of primary energy.

Table 5 here

To transform the energy balance accounting statement into a "model", it is necessary to introduce behavioral linkages from the energy using sectors and from secondary energy to primary energy sources and to hypothesize the balancing identities. Econometric estimation of the linkage parameters between energy use and the economy has the advantage that fuel use is clearly linked to recent empirical realities, a condition that is not always met by cost minimization routines. Parameters have been estimated econometrically by principal sector and fuel. The balancing assumption is that requirements exceeding domestic production are satisfied by imports of crude oil, gas, and coal.

The structure of the model system is described in Figure 6 which shows the energy balance framework and imposes lines with arrows to indicate the direction of

[4] For an earlier version of our approach see Adams and Prazmowski, 2000.

causation. We begin with final demand requirements for secondary or directly utilized primary fuels. The demand categories are broad—industry, transportation, residential, and other--reflecting the availability of the national accounts and motor vehicle information used to establish linkages between the energy sector and the economy. Demands for secondary fuels are then allocated to the transformation sector to generate primary fuel requirements. The requirements for fuels are then confronted with estimates of available supplies from the domestic economy. Hydro electricity, nuclear electricity, and natural gas are determined from the supply side. Demand for coal and combustible materials are based on recent trends. Petroleum and coal imports are computed to meet the difference between demand and domestic production. Important links to the real economy are:

- The relationship between industrial growth and GDP and oil and electric power consumption in industry, residential use, other non residential uses. The coefficients suggest that the elasticities of fuel consumption with respect to industrial output as well as GDP are in the range of 0.5-0.6, indicating that there must be substantial ongoing improvements in the efficiency of energy use or shifts toward products that are less energy intensive.
- The relationship between petroleum products consumption and the growth of the automobile population: The functions recognize the fact that consumption per vehicle declines systematically as the automobile per capita increases (Figure 7) reflecting the increased share of privately owned pleasure vehicles as compared to autos used more intensively for business purposes.

- The relationship between consumption of coal and the generation of electric power. The estimated equation shows requirements for coal consumption inputs with respect to electrical power production with a coefficient of 3.22. Coal and electrical power are measured on a calorific equivalent basis in KTOE. In other words, it takes 3.2 calories of coal to produce one calorie equivalent of electrical power. The efficiency of electric power generation from coal is very low.

Figure 6 here

Figure 7 here

The detailed linkage equations are available from the authors on request.

Base Projection

Forecast and simulation exercise depend on the assumptions about the exogenous variables of the system. Following Wilson and Prushothaman (2003), we have assumed growth of GDP ranging from 9% at the beginning of the forecast 2002 period (2002-2005) to 5.6 percent at the end (2015-2020) Industrial production is assumed to grow 20 percent more rapidly. The motor vehicle population is assumed to grow at a compound growth rate of 10% annually, a little more slowly than recent growth from 16 million cars in 2002 to 158 million in 2020 (still less than one car for every 10 people).

The projected energy balance for 2020 is shown in Table 6.

Table 6 here

Final Demand

Final demand prospects for 2010 and 2020 are summarized in Table 7. Total final energy consumption (TFC) increases in the base solution at annual rates of 2.6 percent and 4.8 percent in the 2002-2010 and 2010 to 2020 periods, respectively. This remains substantially lower than the growth of GDP, indicating aggregate energy elasticities of 0.29 and 0.74 for the two periods, respectively. The continued low elasticities for the aggregate economy occur despite the fact that motorization sharply increases consumption of petroleum products.

Table 7 here

Looking at the detail, we find that this is in part the result of substitution of more efficient fuels for coal and in part a compositional impact. Consumption of coal declines at approximately 6 percent per year, while consumption of petroleum products, gas, and electricity are increasing. Considering consumption from a sectoral perspective, consumption is increasing mort rapidly in the transportation sector, with double digit increases in the consumption of petroleum products, and very little increase in industry. Note, moreover, that in the industrial sector, the elasticity is extremely low, reflecting the fact that most growth has been in lighter or high tech industry and there has been much substitution out of coal. Even for electricity, the estimated elasticity with respect to industrial production is only 0.62.

Transformation

The implications of these demand trends on transformation are summarized in Tables 8 and 9. Coal inputs into electricity and heat plants and inputs of crude oil into refineries continue to grow rapidly (6%-8% per year) Note that the growing consumption of coal in electric and heat plants contrasts sharply with its reduced use in final consumption. Outputs of secondary fuel products, i.e. petroleum products etc., (shown in bold print in Table 8) all show rapid growth.

Table 8 here

Table 9 here

Energy Requirements and Imports

The implications for energy requirements and imports, given projections of domestic primary energy production are shown on Tables 10 and 11. It is important to view supplies and imports from a quantitative as well as from a growth rate dimension. Domestic production of energy is rising at slow rates relative to consumption. As a result, imports of coal and crude oil will grow sharply over the period to 2020. Crude oil imports increase roughly 3 times from 2002 to 2010 and again from 2010 to 2020. In terms of millions of barrels per day, these import quantities amount to approximately 3.8 million b/d in 2010 and 10 million b/d in 2020 (compared to 1.3 million b/d in 2002). Similar results are apparent for imports of coal. Gas imports (presumably in part in the form of LNG) also show substantial increases in the 2010-2020 period. These estimates, of course, depend greatly on our assumptions for domestic production as well as consumption, so that presently unforeseen increases in domestic supplies could reduce imports, ton per ton.

Table 10 here

Table 11 here

Sensitivity analysis

A sensitivity analysis to 2020 was carried out to establish how the results would be affected by changes in the underlying assumptions (Table 12). The following cases were considered:

- Increase of 10,000 KTOE in nuclear or hydro electricity translates into a 32,207 TKOE reduction in coal inputs into electricity production. There is an equal reduction in imports of coal: 7.3% of the base estimate of coal imports in 2020. The explanation lies in the inefficient use of coal in electric power plants— we have noted, above, the high coefficient for coal inputs into electrical power output. In comparison, the energy balance assumes equivalence in calorific terms of nuclear electrical power with other electrical power.
- Increase of 10,000 KTOE in coal or oil production or reduction of exports results in equivalent decrease in imports. This results from the fact that coal imports balance domestic requirements and supplies.
- Increase in GDP and industrial growth at an annual rate of 1% above that of the base projections There is little impact on direct final consumption of coal, but import requirements for coal increase by 166,724 KTOE in 2020, an increase of 38 percent over the base projection estimate, due to increased demand for electricity. Petroleum products, gas, and electricity consumption are higher by 28,145 KTOE, 26,323 KTOE, and 58,796 KTOE in 2020, 3.8 percent, 26.9 percent, and 17.7 percent, respectively, above base solution values. Imports of

crude oil are 32,455 KTOE (approximately 625 thousand b/d) or 5.2% above the base forecast.

- Increase in rate of motorization—assuming a 1% additional annual rate of increase of the auto population, from 10% to 11%, increases consumption of petroleum products by 8,976 KTOE in 2010 and by 53,001 KTOE in 2020, approximately 5% and 10% of base petroleum products consumption estimates. This represents approximately 170 thousand b/d in 2010 and 1 million b/d, in 2020. Refinery inputs and imports of crude oil increase by 10,351 KTOE in 2010 and by 61,118 KTOE in 2020. Improvements in automotive efficiency at the rate of 1% per year would have similar impact in the opposite direction.

Table 12 here

Evaluation

Estimates of Chinese energy futures range widely, depending on the methodology and the underlying assumptions. Evaluation is difficult because of the complexity and detail of the underlying systems. For this reason, it is useful to project with a relatively simple system based on econometric relationships and structured on the energy balance. On the other hand, one must be mindful of the fact that econometrically estimated parameters quantify relationships that prevailed over the sample period. Anticipated changes in the production process or in the behavior of energy consumers apart from those embodied in the historical data must be introduced explicitly in the model system. Policy measures, such as energy taxes, investments in improved energy efficiency, or changes in output composition, other than those observed historically, must be considered explicitly.

The dis-aggregation of the relationship between final energy consumption and sector growth by energy source does not eliminate the relatively low energy elasticity observed in China. It appears to be the result of shifts in the composition of industrial output toward less energy-intensive products and/or of gains in energy efficiency. Shifts between different types of energy have been allowed for in the model.[5]

As a result of the low Chinese energy elasticities, energy demand is not very sensitive to the underlying assumptions about economic growth. On the other hand, given the limitations of domestic energy production, even relatively small changes in assumptions have substantial impact on import requirements for coal and oil. Import requirement estimates are also sensitive to projections of domestic production of primary energy, particularly alternative sources of electricity that can displace inefficient production of electrical power from coal. Not surprisingly, alternative assumptions about motorization and/or improvements in automotive efficiency sharply influence import needs for petroleum.

Conclusions

This paper has used an energy balance framework to project future energy requirements and import needs of China in 2010 and 2020. Rapid economic growth in China has had less impact on energy consumption than might have been expected. However, looking forward to 2020, continued rapid growth of industrial output and GDP and the prospect of continued rapid motorization suggest that China will import

[5] Renewed growth in China of energy intensive industries like steel and aluminum, which some observers anticipate, could increase the future energy elasticity.

increasing quantities of coal, oil, and, eventually, natural gas from world markets. Chinese petroleum imports in 2020 are likely to amount to almost 12 million b/d, almost 20 percent of world imports at that time. Imports of coal in 2002 may amount to more than 50% of world trade in coal.

These estimates suggest that Chinese fuel requirements may loom very largely in the world energy economy if present trends continue. However, our sensitivity analysis suggests that there is potential for change through additional production of nuclear energy, hydro power, and alternate energy sources in China and/or through policies to improve energy efficiency in the Chinese economy.

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Tables

Table 1: Growth of Energy Consumption (% change per year)

	Coal	Natural gas	Crude, NGL	Electricity	Petroleum .Products	Heat	Wastes if you are a culture	Total less Waste	Total
1980-1985	4.8%	6.1%	-28.4%	4.4%	2.7%	4.2%	0.9%	4.1%	3.0%
1985-1990	3.6%	5.0%	15.3%	8.9%	5.2%	7.4%	1.2%	4.5%	3.5%
1990-1995	2.0%	2.0%	-13.4%	9.3%	8.3%	7.8%	0.4%	4.0%	3.0%
1995-2000	-7.9%	6.0%	10.3%	6.2%	7.3%	5.4%	0.8%	-1.0%	-0.6%
2000-2002	-1.4%	9.9%	2.0%	9.5%	4.6%	8.0%	0.7%	3.2%	2.6%

Table 2

Energy Source as Share of Total Final Energy Consumption)

	Coal	Natural Gas	Crude, NGL	Electricity	Petroleum Products	Heat	Wastes
1980	44.2%	1.4%	1.0%	4.3%	11.0%	1.5%	36.5%
1985	48.2%	1.6%	0.2%	4.6%	10.9%	1.6%	32.9%
1990	48.7%	1.7%	0.4%	6.1%	11.8%	1.9%	29.4%
1995	46.2%	1.7%	0.2%	8.3%	15.4%	2.5%	25.8%
2000	32.0%	2.3%	0.3%	11.6%	22.8%	3.3%	27.6%
2005 est	27.0%	3.0%	0.4%	15.0%	25.0%	3.8%	25.8%

Table 3: Chinese Energy Consumption in a World Perspective 2002

	EC per capita (KTOE per million)	EC per unit of GDP (KTOE per million ppp $)	Total Energy Consumption (in KTOE)	Share of World (%)
China	635	156.37	812743	11.5%
Indonesia	539	193.25	114171	1.6%
Korea	2899	192.16	137974	1.9%
Malaysia	1408	178.95	34215	0.5%
Philippines	325	84.98	25944	0.4%
Singapore	3298	163.16	13852	0.2%
Taiwan	2620	143.62	58685	0.8%
Thailand	916	148.03	56400	0.8%
Vietnam	471	204.21	37861	0.5%
US	5417	139.65	1557391	22.0%
Japan	2815	117.89	358666	5.1%
EU	2772	120.75	1056833	14.9%
India	366	154.60	383264	5.4%
World	1145	163.43	7094972	100.0%

Source: World Bank

Table 4 Chinese Trade in Crude Oil and Petroleum Products

	Crude (as % of crude inputs)			Products (as % of product use)		
	Imports	Exports	Net Imports	Imports	Exports	Net Imports
1980	0.4%	15.9%	-15.5%	0.9%	8.7%	-7.8%
1985	0.3%	34.5%	-34.2%	1.4%	11.0%	-9.6%
1990	2.6%	21.4%	-18.8%	4.4%	8.2%	-3.8%
1995	11.8%	12.6%	-0.8%	14.2%	4.2%	10.0%
2000	34.2%	5.0%	29.2%	14.1%	5.8%	8.3%
2002	31.8%	3.5%	28.3%	14.8%	6.7%	8.1%

Table 5: Energy Balance---China 2002

(in thousands of tons oil equivalent, KTOE)

	Coal	Crude Oil	Petroleum Products	Gas	Nuclear	Hydro	Combust. Wastes	Electric.	Heat	Total
Production	771057	167223	0	33776	6548	24766	217441	0	0	1220811
Imports	5665	69406	28659	0	0	0	0	198	0	103928
Exports	-63066	-7665	-16984	-1923	0	0	0	-835	0	-90473
Stock change	-6472	-1052	1831	0	0	0	0	0	0	-5693
TPES	707184	227912	13506	31853	6548	24766	217441	-637	0	1228573
Electricity Plants	-330734	-783	-11673	-1143	-6548	-24766	-844	141081	0	-235410
Heat plants	-38302	-128	-3912	-1760	0	0	-493	0	39209	-5386
Gas works	-5179	0	-189	3754	0	0	0	0	0	-1614
Petro. refineries	0	-215802	210773	0	0	0	0	0	0	-5029
Coal transf.	-48136	0	0	0	0	0	0	0	0	-48136
Own use	-28926	-4632	-15083	-7966	0	0	0	-21708	-8837	-87152
Distrib. losses	0	0	-22	-643	0	0	0	-10044	-480	-11189
Stat. Disc.	-15448	-4214	227	-2478	0	0	0	0	-1	-21914
TFC	240459	2353	193627	21617	0	0	216104	108692	29891	812743
Industry	163673	2162	55344	13437	0	0	0	69777	22277	326670
Transportation	5369	0	73621	258	0	0	0	1428	0	80676
Other non resid	19508	191	33978	628	0	0	0	20285	1260	75850
Residential	42741	0	15510	7294	0	0	216194	17212	6355	305306
Non-energy use	9169	0	153740	0	0	0	0	0	0	162909

(Source: IEA)

Table 6: Forecast Energy Balance---China 2020

	Coal	Crude Oil	Petro Products	Gas	Nuclear	Hydro	Combus. Wastes	Electri,ty	Heat	Total
Production	1213383	223840	0	73766	36406	75999	251595	0	0	1874989
Imports	438492	625136	20270	24181	0	0	0	0	0	1108079
Exports	-220206	-7500	-24508	0	0	0	0	0	0	-252214
stock change	0	0	0	0	0	0	0	0	0	0
TPES	1431669	841477	-4238	97947	36406	75999	251595	0	0	2730854
Elec. Plants	-1072375	0	-3827	-1500	-36406	-75999	0	430650	0	-759457
Heat plants	-126064	0	-4000	-2000	0	0	0	0	121248	-10816
Gas works	-4500	0	0	3500	0	0	0	0	0	-1000
Petro. Refineries	0	-841477	827420	0	0	0	0	0	0	-14057
Coal transf.	-77276	0	0	0	0	0	0	0	0	-77276
Own use	-75263	0	-73627	0	0	0	0	-70748	-27099	-246737
Distrib. losses	0	0	0	0	0	0	0	-27641	-1472	-29112
Statis. discrep.	0	0	0	0	0	0	0	0	0	0
TFC	76191	0	741728	97947	0	0	251595	332262	92677	1592399
Industry	52427	0	114930	18038	0	0	0	141457	73496	400348
Transportation	2036	0	503193	0	0	0	0	6608	0	511837
Other non residential	8751	0	66672	500	0	0	0	51668	2150	129741
Residential	12976	0	56932	79410	0	0	251595	132529	17031	550473

Table 7: Projected Final Energy Consumption

(% change per year)

	Coal	P.Products	Gas	Comb Waste	Electricity	Heat	Total
			2002-2010				
TFC	-6.9%	7.2%	8.9%	0.9%	6.9 %	6.6%	2.6%
Industry	-6.5%	5.3 %	1.1%		4.3%	6.9%	0.3%
Transportation	-5.7%	11.3%			8.6%		10.5%
Other non residential	-4.8%	4.4%	-2.8%		6.1%	3.4%	3.0%
Residential	-6.7%	8.1%	17.2%	0.9%	14.3%	5.2%	2.7%
			2010-2020				
	Coal	**P.Products**	**Gas**	**CombWaste**	**Electricity**	**Heat**	**Total**
TFC	-6.0%	7.7%	8.0%	0.8%	5.7%	6.0%	4.7%
Industry	-6.2%	3.1%	2.0%		3.6%	6.4%	1.8%
Transportation	-5.1%	10.2%			8.5%		10.0%
Other non residential	-4.2%	3.3%	0.0%		4.5%	2.6%	2.9%
Residential	-6.6%	6.5%	10.1%	0.8%	9.0%	4.9%	3.7%

Table 8 Transformation Inputs and Outputs (% per year)

	Coal	Crude	PetroProd	Gas	Nuclear	Hydro	Electricity	Heat	Total
					2002-2010				
Electricity Plants	6.0%		--6.1%	3.4%	**9.5%**	**5.9%**	**6.9%**		5.0%
Heat plants	7.1%		0.3%	1.6%				**6.6%**	3.9%
Gas works	-1.8%			**-0.9%**					-6.0%
Petro. Refineries		7.2%	**7.2%**						2.4%
					2010-2020				
Electricity Plants	7.0%		-6.3%	0.0%	**9.5%**	**6.5%**	**5.7 %**		7.7 %
Heat plants	6.2%		0.0%	0.0%				**6.0%**	3.8%
Gas works	0.0%			**0.0%**					0.0%
Petro. Refineries		7.9%	**7.9%**						8.4%

Bold = Output Growth : not Bold = Input Growth

Table 9 Energy Transformation (+ output, - input, in KTOE)

	Coal	Crude Oil	PetroProd.	Gas	Nuclear	Hydro	Waste	Elect.	Heat	Total
					2002					
TPES	707184	227912	13506	31853	6548	24766	217441	-637	0	1228573
Elec. Plants	-330734	-783	-11673	-1143	-6548	-24766	-844	141081	0	-235410
Heat plants	-38302	-128	-3912	-1760	0	0	-493	0	39209	-5386
Gas works	-5179	0	-189	3754	0	0	0	0	0	-1614
Petro. refineries	0	-215802	210773	0	0	0	0	0	0	-5029
					2010					
TPES	853116	382408	10963	44067	14036	39598	232013	0	0	1576203
Elec. Plants	-532407	0	-7185	-1500	-14036	-39598	0	244699	0	-350027
Heat plants	-67729	0	-4000	-2000	0	0	0	0	66350	-7378
Gas works	-4500	0	0	3500	0	0	0	0	0	-1000
Petro.refineries	0	-382408	376316	0	0	0	0	0	0	-6092
					2020					
TPES	1431669	841476	-4238	97947	36406	75999	251594	0	0	2730854
Elec.Plants	-1072375	0	-3827	-1500	-36406	-75999	0	430650	0	-759457
Heat plants	-126064	0	-4000	-2000	0	0	0	0	121248	-10816
Gas works	-4500	0	0	3500	0	0	0	0	0	-1000
Petro. refineries	0	-841476	827420	0	0	0	0	0	0	-14057

Table10 Projected Production and Trade of Energy Products (in ktoe)

	Coal	Crude Oil	Pet. Products	Gas	Nuclear	Hydro	Comb Wastes	Total
			2002					
Production	771057	167223	0	33776	6548	24766	217441	1220811
Imports	5665	69406	28659	0	0	0	0	103928
Exports	-63066	-7665	-16984	-1923	0	0	0	-90473
			2010					
Production	934760	191349	0	44406	14036	39598	232013	1456161
Imports	53545	198559	27727	0	0	0	0	279832
Exports	-135186	-7500	-16764	-338	0	0	0	-159790
			2020					
Production	1213383	223840	0	73765	36406	75999	251595	1874989
Imports	438492	625136	20270	24181	0	0	0	1108079
Exports	-220206	-7500	-24507	0	0	0	0	-252214

Table 11: Projected Production and Trade of Energy Products
(% change per year)

	Coal	Crude Oil	Petro Products	Gas	Nuclear	Hydro	Comb Wastes	Total
				2002-2010				
Production	2.4%	1.7%		3.4%	9.5%	5.9%	0.8%	2.2%
Imports	28.1%	13.1%	-0.4%					12.4%
Exports	9.5%	-0.3%	-0.2%					7.1%
				2020-2020				
Production	2.6%	1.6%		5.1%	9.5%	6.5%	0.8%	2.5%
Imports	21.6%	11.6%	-3.1%	n.a.				13.8%
Exports	4.9%	0.0%	3.8%					4.6%

Table 12: Effects of More Rapid Growth (1% faster) on KTOE

	Coal	Crude Oil	Petro. Prod.	Gas	Electricity	Heat	Total
			2010				
Imports	36171	9221	-535	0	0	0	44857
TFC	167	0	7997	4063	12650	646	25523
Industry	0	0	3587	266	4539	0	8392
Transpor.	0	0	0	0	0	0	0
Other non Res.	0	0	1953	0	1851	0	3804
Residential	167	0	2456	3798	6260	646	13326
			2020				
Imports	166764	32456	-2220	26323	0	0	223322
TFC	86	0	28145	26323	58796	2472	115822
Industry	0	0	10768	856	14906	0	26530
Transport.	0	0	0	0	0	0	0
Other non Rres	0	0	6241	0	6730	0	12971
Residential	86	0	11136	25466	37160	2472	76321

Figures

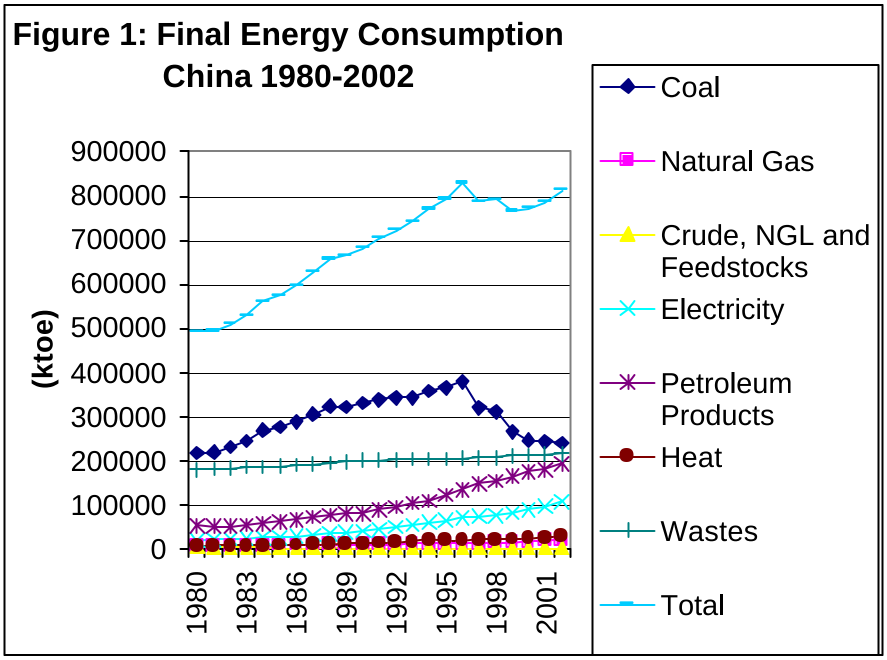


Figure 1: Final Energy Consumption
China 1980-2002
(ktoe)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
1980
1983
1986
1989
1992
1995
1998
2001
Coal
Natural Gas
Crude, NGL and Feedstocks
Electricity
Petroleum Products
Heat
Wastes
Total

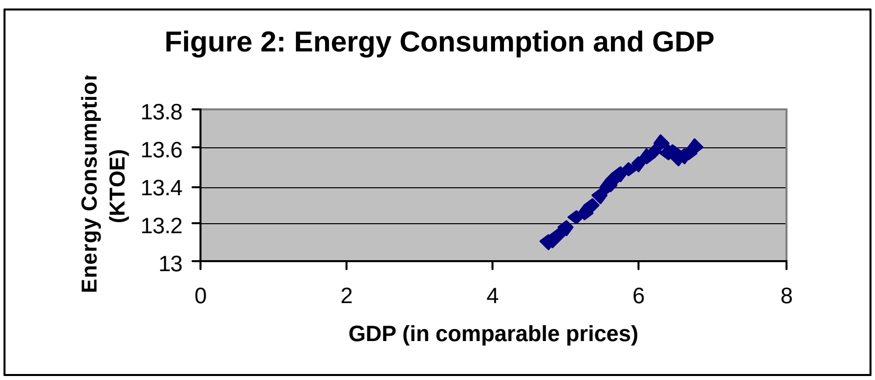


Figure 2: Energy Consumption and GDP
Energy Consumptio
(KTOE)
13.8
13.6
13.4
13.2
13
0
2
4
6
8
GDP (in comparable prices)

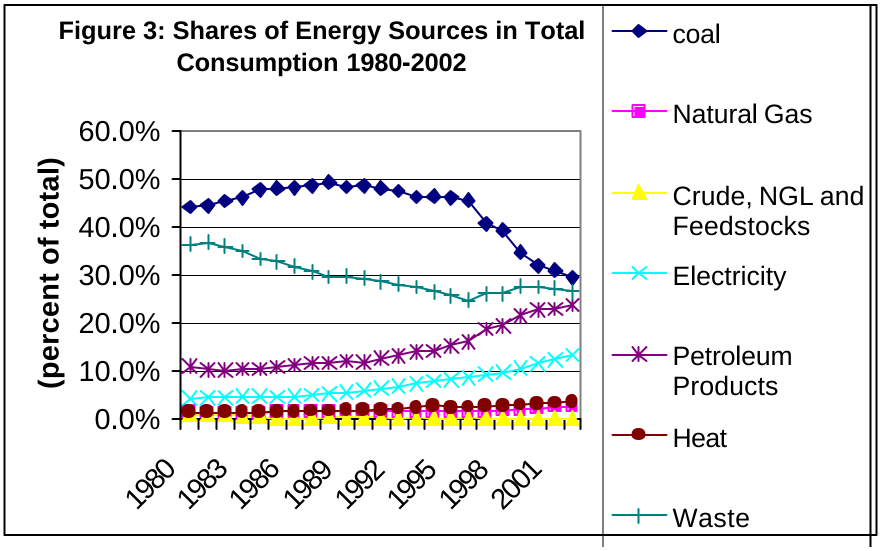


Figure 3: Shares of Energy Sources in Total Consumption 1980-2002
(percent of total)
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1980
1983
1986
1989
1992
1995
1998
2001
coal
Natural Gas
Crude, NGL and Feedstocks
Electricity
Petroleum Products
Heat
Waste

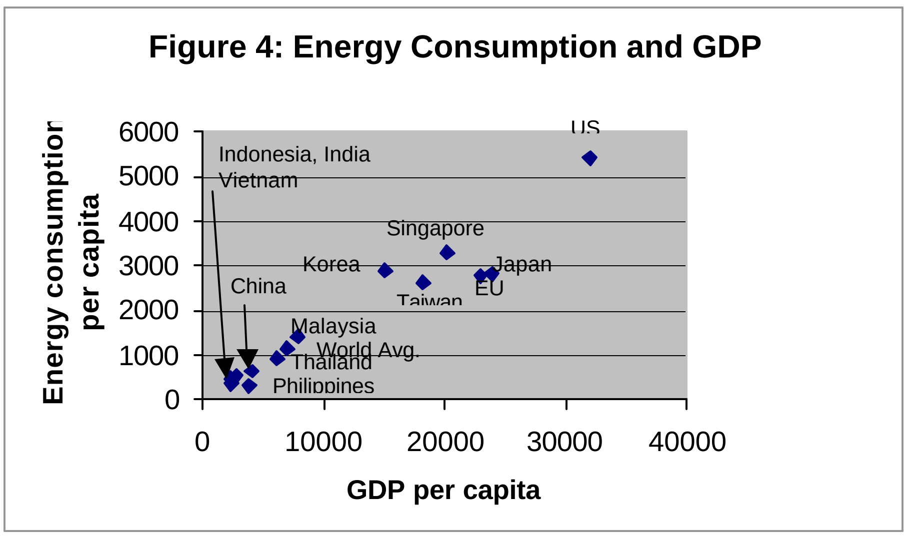


Figure 4: Energy Consumption and GDP
Energy consumption per capita
6000
5000
4000
3000
2000
1000
0
US
Indonesia, India
Vietnam
Singapore
Korea
Japan
EU
China
Malaysia
World Avg.
Thailand
Philippines
0
10000
20000
30000
40000
GDP per capita

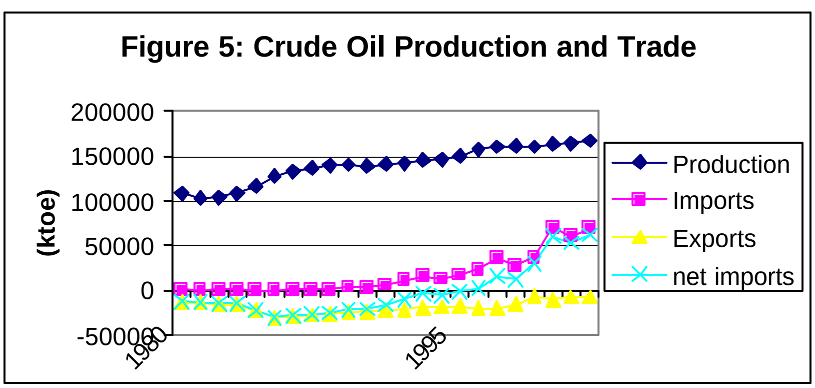
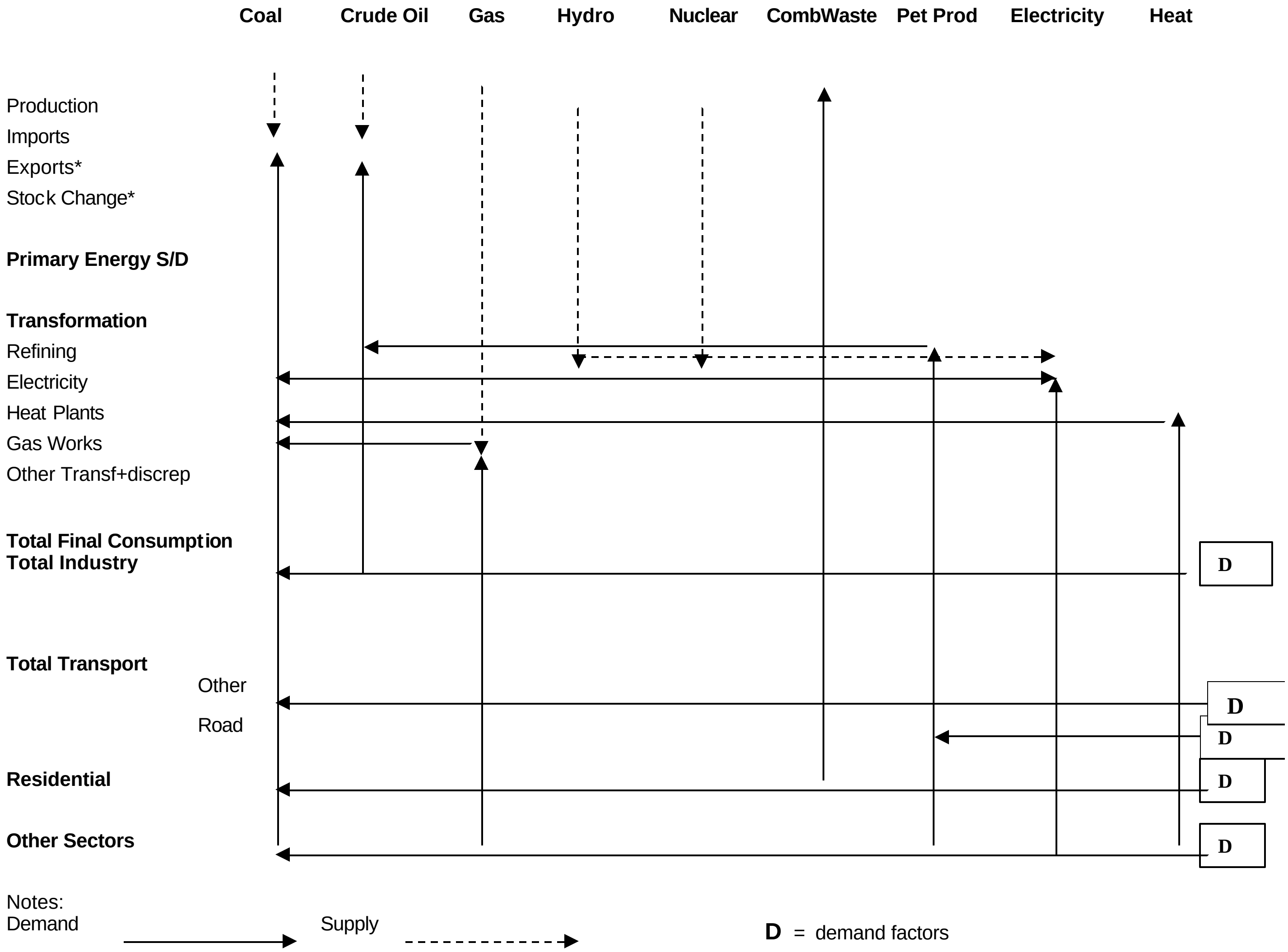


Figure 5: Crude Oil Production and Trade
(ktoe)
200000
150000
100000
50000
0
-50000
1980
1995
Production
Imports
Exports
net imports

Figure 6
Model Structure
Principal Channels of Chinese Energy Model



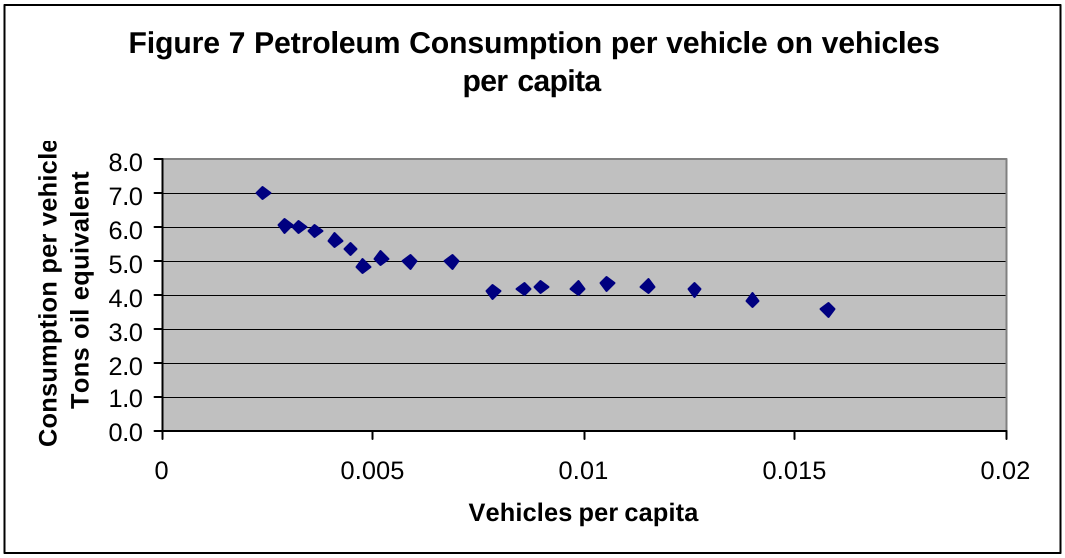


Figure 7 Petroleum Consumption per vehicle on vehicles per capita
Consumption per vehicle
Tons oil equivalent
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
0.005
0.01
0.015
0.02
Vehicles per capita

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