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CHINA AND LONG-RANGE ASIA ENERGY SECURITY: AN ANALYSIS OF
THE POLITICAL, ECONOMIC AND TECHNOLOGICAL FACTORS SHAPING
ASIAN ENERGY MARKETS

THE COMPOSITION AND GROWTH OF ENERGY DEMAND IN CHINA

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I. Energy and Development – An Overview

The economics of energy demand is concerned with the relationship between energy consumption and aggregate economic output. Moreover, it is concerned with how this relationship changes through time, and the extent to which the cost of energy consumption is affected by factors such as environmental degradation, dependence on an exhaustible resource, and technology. Important factors in determining the growth of energy consumption are the structural changes that occur as economic development progresses. Furthermore, the mix of the fuels consumed will be reflective of the costs associated with consumption.

The relationship between economic development and the structure of production is one that is well documented by authors such as Kuznets (1971) and Chenery and Syrquin (1975). Aggregate economic output is the sum of the output contributions of the agricultural, industrial and service sectors of an economy. In the initial stages of economic growth, the share of agriculture in total output falls while the share of industry rises. In the latter stages of development, as domestic demand for financial services, communications, and transportation begins to rise, the share of services begins to increase, and eventually dominate total output.

Evidence of the patterns of the structural change of production that occurs during economic development is given in Table 1. GDP and the structure of production are presented for a few countries that have experienced fairly rapid rates of economic growth in recent years. (The US is included as a point of reference.) There is an obvious trend of declining agricultural share in GDP in every country. Furthermore, the share of industry increases in every country except the US. This is indicative of the accelerated growth of the industrial sector that occurs as economies begin to develop. The trend in the US is indicative of 'post-industrialized' societies in that the growth of services outpaces the growth of industry thereby obtaining an increasing share of total GDP.

Table 1: Structure of Production for Selected Nations					
				Share of GDP	
		GDP/cap	Agriculture	Industry	Services
Country	Year	(1985 int$)	(%)	(%)	(%)
	1965	751	44	22	34
India	1980	837	38	26	36
	1995	1514	29	29	42
	1965	577	38	35	27
China	1980	879	30	49	21
	1995	1863	21	48	31
	1965	1671	28	25	47
Malaysia	1980	2470	22	38	40
	1995	6556	13	43	44
	1965	1058	38	25	37

S. Korea	1980	3321	15	40	45
	1995	8465	7	43	50
	1965	1136	32	23	45
Thailand	1980	2156	23	29	48
	1995	4805	11	40	49
	1965	11649	3	38	59
USA	1980	15637	2	34	64
	1995	19369	2	26	72
Sources:	*World Bank Development Reports, various issues*				
	Penn World Tables 5.6				

How does the shifting composition of production effect energy demand? The relative sizes of the agricultural, industrial, and service sectors will be very important in determining the aggregate energy demand of an economy. The industrialization process is typified by enormous increases in energy consumption due to the fact that industry is more energy intensive than agriculture. Accordingly, the energy intensity of GDP increases (energy intensity is defined as energy input per unit of GDP). As development continues, the production of consumer goods and services begins to dominate total output, and advances in

technology provide increases in fuel efficiency. The combined result is a long run reduction in energy intensity. This point is illustrated in Figure 1. A cross-section of selected nations from differing levels of per capita GDP reveals a trend of declining energy intensities as incomes rise.

Figure 1: Energy Intensity of Selected Nations (1995)
Source: Compiled from the World Bank Development Indicators, 1997
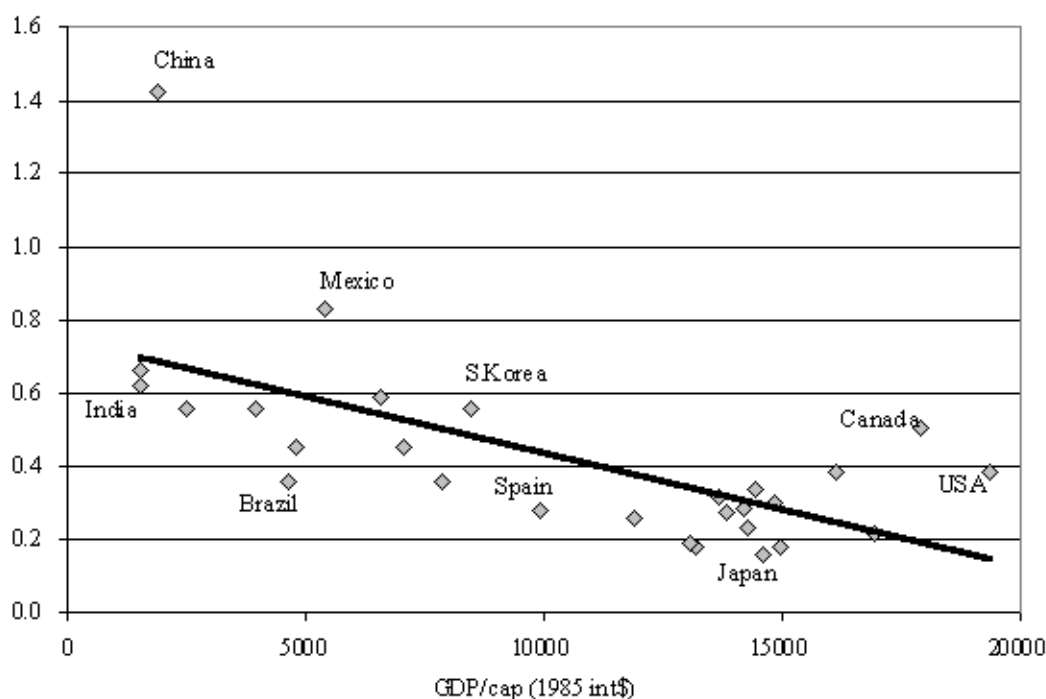
Changes in the structure of production are motivated by shifts in consumer demand. As incomes rise, a decreasing share of the consumer budget is devoted to food, and an increasing share is devoted to manufactured goods. The ensuing growth of industry leads to increases in the demand for intermediate inputs such as energy. In addition, the types of manufactured goods produced will be of considerable importance. For example, the production of cement requires much more energy input than the production of telecommunications equipment. Thus, as consumer demands change with increasing income, the composition of the industrial sector will change to be at least partially reflective of the shifting structure of consumption.

Economic development is also characterized by growth in energy demand for transportation and for residential and commercial uses, both of which are reflective of the changing composition of the consumer bundle. Energy is required for the utilization of durable goods such as household appliances and motor vehicles. As per capita incomes rise consumers are more able to afford particular items such as air-conditioners, furnaces, refrigerators, and automobiles. Furthermore, to the extent that the services such as heating, refrigeration, and personal transport yield increasing utility to the representative consumer, utilization will increase with income thereby further increasing energy demand. Table 2 is illustrative of the manner in which the consumer bundle changes. The share of consumer expenditures devoted to transportation and durable goods approximately doubles at levels of per capita income between 4,000 and 10,000 US$.

Table 2: Structure of Consumption						
			Share of Total Consumer Expenditure			
GDP/cap (PPP $)	Food and Clothing	Rent	Health Care	Education	Transport and Communications	Durables and Other
0-1000	39	23	6	13	5	15
1001-4000	35	18	8	14	6	19
4001-10000	25	23	11	13	6	23
10001-20000	20	16	11	9	11	33
20001-	16	18	14	9	11	31
Source:	World Bank Development Indicators, 1997					

The growth of motor vehicle stocks has recently received a considerable deal of attention in the economic literature (see, for example, Dargay and Gately (1997) or Medlock and Soligo (1999)). Figure 2 illustrates a time-series/cross-section of motor vehicle registrations for 28 countries from different levels of development. Notice the apparent 's-shape'. The lower region of the curve is indicative the existence of a threshold at which consumers begin to attain income levels sufficient for the initial purchase of automobiles. As per capita income increases, the number of consumers at the threshold will initially rise, then fall as an

increasing proportion of consumers achieve incomes above this threshold. Hence, there will be periods of large increases in the aggregate vehicle stock followed by incrementally smaller increases as per capita income rises. As utilization of the vehicle stock begins to increase, so must motor fuel demand.

Figure 2: Vehicle Registrations for Selected Nations (1979-1995)
*Source: 1997 World Motor Vehicle Data Book and Penn World Tables 5.6*
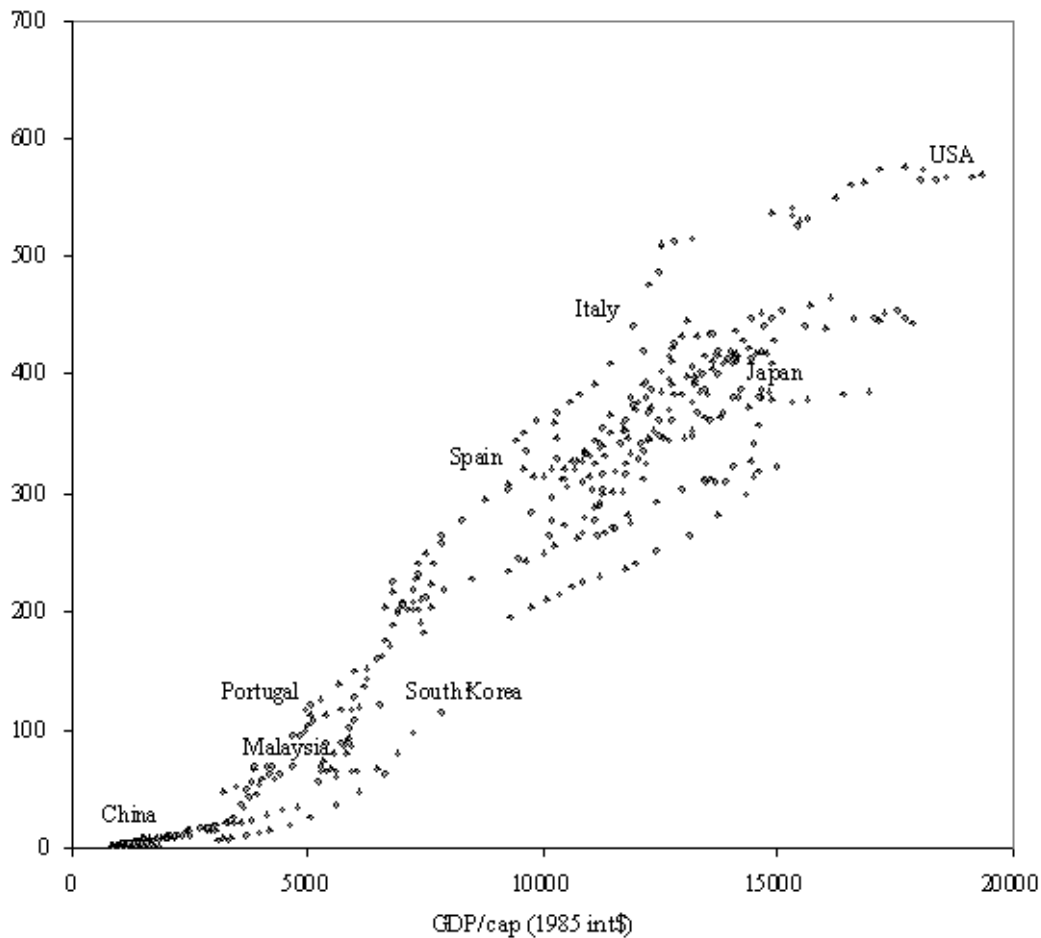
An obvious prerequisite for satisfying the increased demand for transportation services is the development of sufficient transport infrastructure. However, as is evidenced in Figure 3, there is an increasing trend of infrastructure development as per capita GDP increases. Infrastructure investment can be attributed, in part, to manufacturer's demands. Increasing levels of specialization and division of labor of the production process promotes an increase in the growth of demand for commercial transportation, which requires an increase in

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transport infrastructure. Therefore, governments, to the extent that they wish to promote economic development, have incentive to encourage investment in infrastructure development.

Figure 3: Transport Infrastructure for Selected Nations (1995)

*Source: Compiled by authors from the CIA World Factbook, 1997*
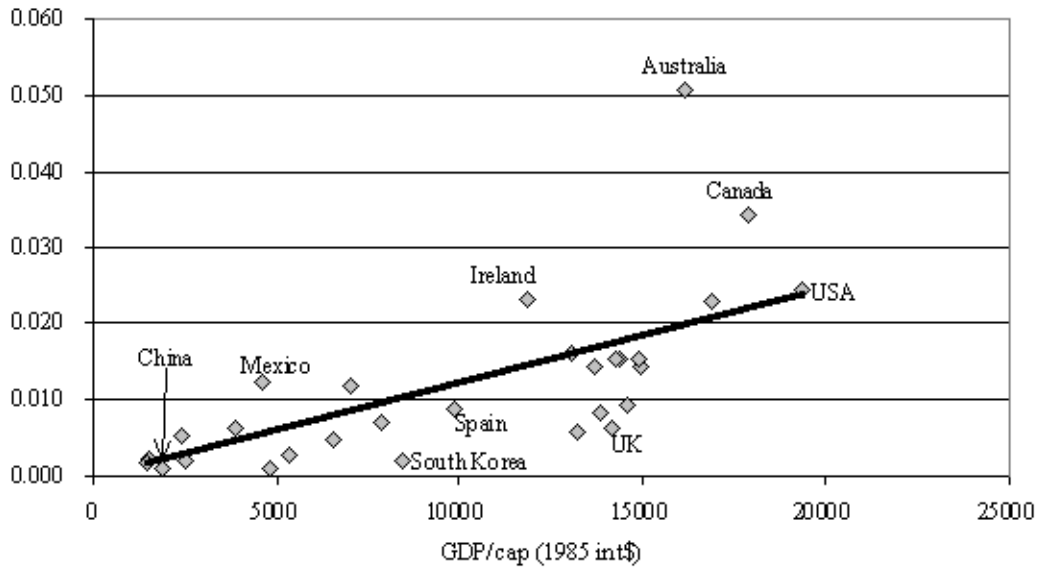
The energy demand of households for non-transport uses (for example, for the utilization of refrigerators, heaters, air-conditioners) also requires the development of infrastructure. Cross-section data in Figure 4 reveals that this infrastructure increases with the level of development.

Figure 4: Electricity Capacity/cap for Selected Nations (1995)
Source: Compiled by authors from the CIA World Factbook, 1997
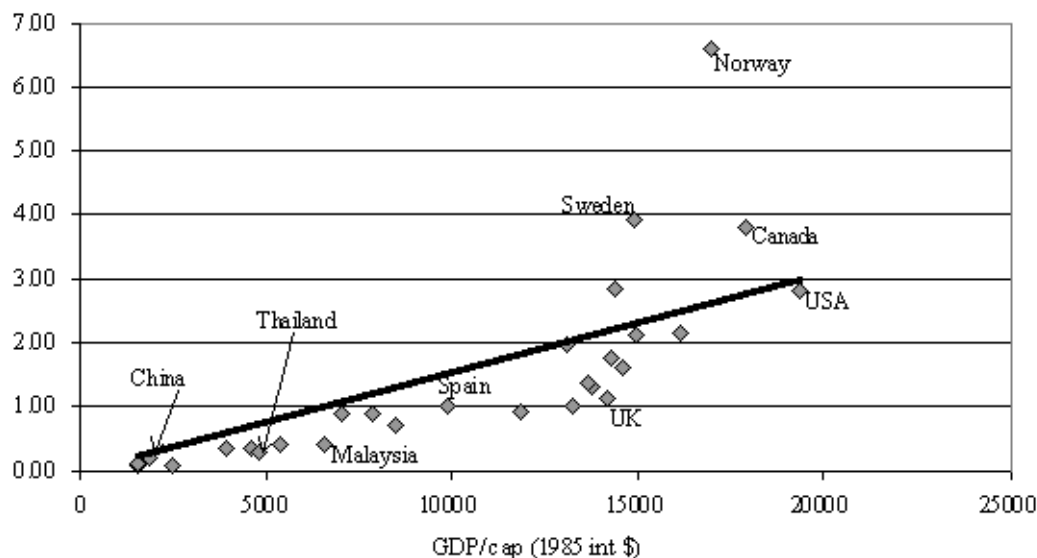
Due to the simultaneity of output growth and energy demand growth, lack of sufficient energy resource inflows will inhibit substantial economic advancement. Growth in transportation demand, as well as the demand for energy consuming durable goods, will only exacerbate the growing need for energy resources. The need to meet these growing demands will place pressures on governments to either develop domestic resource stocks or increase national dependence on international sources.

II. The Chinese Experience

During the period from 1978 to 1995, total final energy demand in China increased by approximately 150%, with most of the increase coming in the industrial and transportation sectors. The growth in the industrial sector was the result of continued reliance on the build-up of heavy industry as a basis for development. The growth in the transportation sector was reflective of the rapid growth, and subsequent utilization, of motor vehicle stocks. (Stocks grew from 0.3 to 3.2 passenger vehicles per thousand people, an increase of almost 1000%.)

Figure 5: Chinese Final Energy Consumption (1978-1995)
Source: Asian Development Bank, Energy Statistics for Developing Member Nations
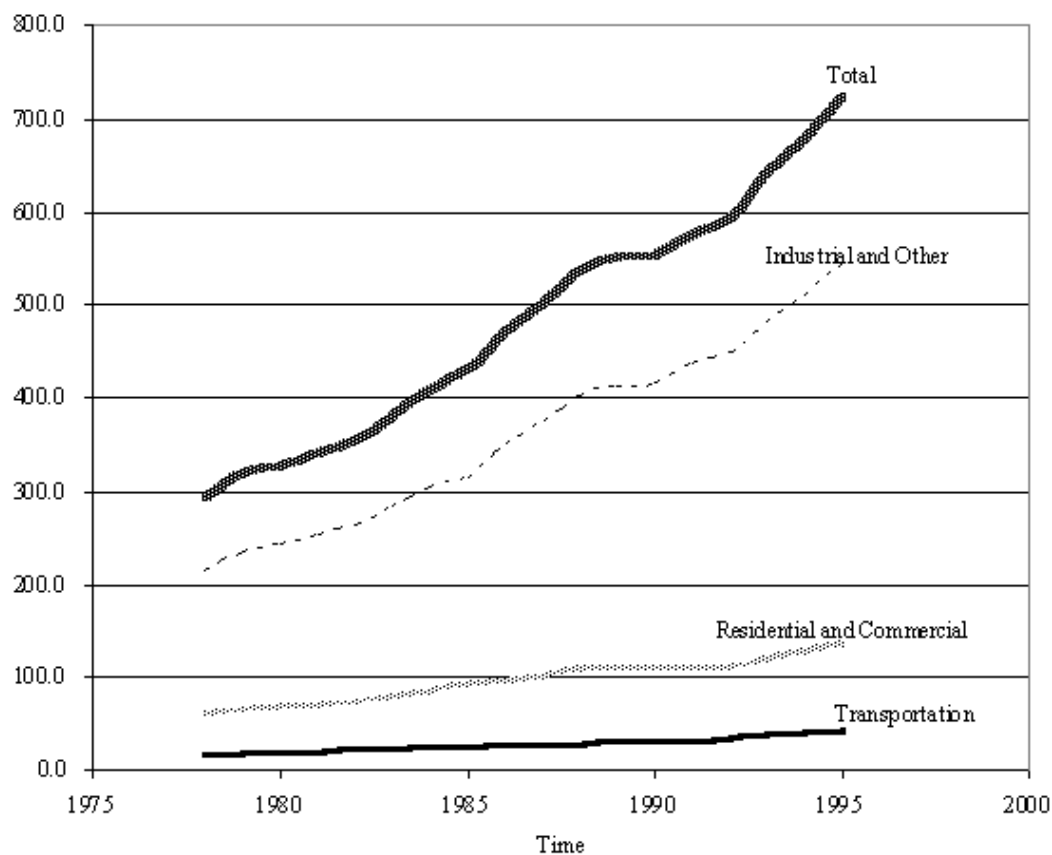
The continued growth of energy demand in China will depend upon the growth of GDP as well as the future changes in the structural characteristics of production and consumption. In particular, as the structure of production becomes more intensely represented by services, the energy intensity of production will decline. As the structure of consumption changes to reflect consumer desires to obtain services such as heating, refrigeration, and personal transport, the energy content of the consumer bundle will increase. Whether or not the energy intensity of GDP increases or decreases in the short run is dependent upon the relative strengths of these two trends.

We can expect the bulk of total energy demand to continue to come from industrial activities for the foreseeable future due to the fact that so much of Chinese GDP originates in the

industrial sector (on the order of 50% in 1995). Further growth in industry will only lead to increases in energy demand, even if industry's share in total output declines. Residential and commercial energy use and transportation energy use will begin to account for an increasing share of total energy consumption as more and more consumers achieve higher levels of income. For example, Medlock and Soligo (1999) predict that motor vehicle stocks in China could grow to 30 vehicles per thousand individuals by 2015 at a per capita GDP growth rate of 5.0% per annum. With a projected population of about 1.4 billion, this amounts to a total stock of automobiles of about 42 million, an increase of about 37.5 million from their 1995 levels. Given the nature of the transportation sector, increased utilization translates into a huge increase in the demand for oil and petroleum products.

To the extent that energy in China is derived from coal, increases in energy demand, especially in the industrial sector, will have considerable ramifications on the environment (coal emits 34% more carbon per BTU than oil and 81% more carbon than natural gas). A mitigating factor is the extent to which alternative resources are substituted for coal. The greater the value placed on environmental quality, the higher the implicit cost of burning dirty fuels. Barring any significant new energy technologies, this can only result in an increase in demand for alternative energy resources (oil and gas, for example). Given the outlook for China's oil and gas production, this will result in an increase in import dependence. However, there is currently inadequate pipeline infrastructure to facilitate any rapid substitution away from coal. Thus, the environmental costs of the future economic growth of China will depend somewhat upon the rate at which pipeline infrastructure is developed so that fuels such as oil and natural gas can be more effectively transported throughout China.

III. Data analysis

Energy demand patterns are analyzed for three different energy consuming sectors of the economy - the residential and commercial sector, the transportation sector, and the industrial and other sector. Growth of energy demand in the residential and commercial sector is the result of increases in electricity and heating fuel consumption. The energy consumed in the transportation sector is primarily for the movement of passengers and freight. Energy growth in the rest of the economy, insomuch as industrial energy demand dominates, will be reflective of the growth of heavy and light industries. As consumer purchases shift toward durable goods and transportation, energy demand in both the residential and commercial sector and the transportation sector will increase fairly rapidly. Furthermore, as the structure of industry changes to reflect consumer desires, the energy intensity of production will fall, resulting in slower energy demand growth in the industrial and other sector. The rates at which these effects offset each other will determine the rate at which overall energy intensity declines.

Using per capita GDP as a benchmark for comparison, China is at the lower end of the development spectrum. Therefore, a difficulty in forecasting Chinese energy demand lies in predicting the development patterns of the individual sectors of the economy. However, there exists a basis upon which to form expectations about these patterns. Using longitudinal data for 29 countries from all levels of development, we construct a 'map' for a general development path. We then use this global development pattern in order to ascertain the expected rates of growth of energy demand in the various sectors of the Chinese economy.

Figure 6 depicts energy demand as a function of real GDP for various countries (only a few of which are labeled) from 1978-1995. There clearly exists a trend of increasing energy use with income. It is precisely this trend, the proposed long run relationship between energy

demand and aggregate output, with which we are concerned. It is the map we will use to forecast the future growth of energy demand in China. There are, however, variations about this trend that must be explicitly taken into account.

Figure 6: Final Energy Demand for Selected Nations (1978-1995)

Source: Compiled by authors
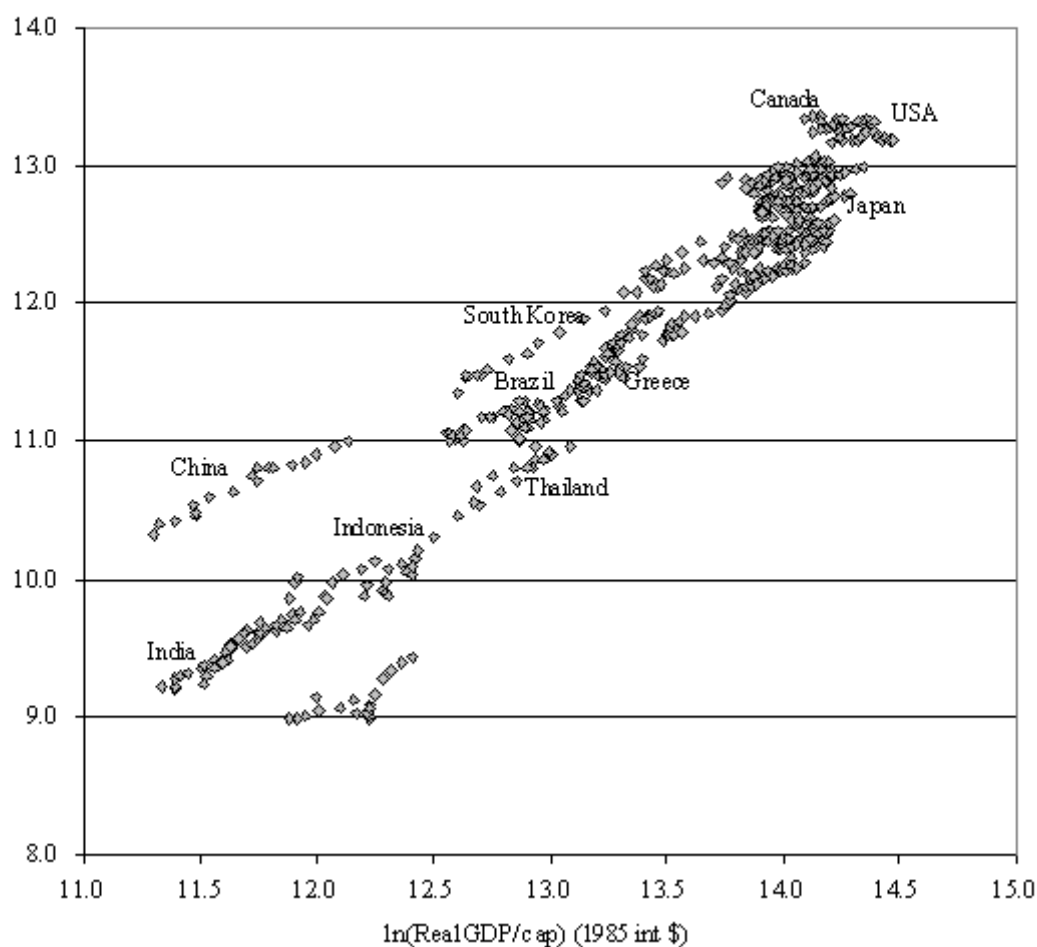
In principle, considering the arguments presented above, there is no reason to believe that the income elasticity of energy demand is constant (this is, however, a key assumption in most energy forecasting exercises). In fact, it is likely the case that as income rises the income elasticity of energy demand will decline. As income's effect diminishes, only energy prices and technology will significantly effect the total amount of energy demanded.

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In order to capture the idea that elasticity declines as income rises, we assume a very simple non-linear relationship between income and energy demand. Furthermore, we assume that energy consumption follows a commonly used partial adjustment mechanism. The equation to be estimated is of the following form.

$$(1) \quad ec_{i,t,j} = \alpha_i + \beta_1 y_{i,t} + \beta_2 y_{i,t}^2 + \beta_3 p_{i,t,j} + \beta_4 pop_{i,t} + (1 - \gamma)ec_{i,t-1,j} + \varepsilon_t$$

where

- $ec_{i,t,j}$ = energy consumption in sector j

$y_{i,t}$ = real GDP

$p_{i,t,j}$ = the real price of energy in sector j

$pop_{i,t}$ = population

γ = the speed of adjustment

α_i = a country specific effect

ε_t = white noise

with all variables in natural logarithms and defined for country i at time t where indicated. The long run income elasticity of energy demand implied by equation (1), defined as $\dfrac{\beta_1 + 2\beta_2 y_{i,t}}{\gamma}$, will decrease as income increases as long as $\beta_1 > 0$ and $\beta_2 < 0$. In addition, the use of a quadratic function implies that there exists some level of income at which this elasticity becomes negative. It is important to point out that the use of a quadratic function is only an approximation to what may very well be a more complicated functional form. Its use facilitates a description of the data over the observable range, and is intended to capture the idea that countries can reduce their energy intensities through structural change and more

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efficient allocation of resources. Beyond the turning point, or apex, of the quadratic, we would expect the income elasticity to be zero.

The data for real GDP, a purchasing power parity measure that is denominated in 1985 international dollars, and population come from the Penn World Tables 5.6. When making cross-country comparisons, these GDP data have an advantage over simple exchange rate converted denominations because they are adjusted for differences in the standard of living in various countries (hence, the term 'purchasing power parity'). The data for energy consumption was collected from various sources documenting energy balances for the years in the sample. The real price variables were constructed by dividing the price index for delivered energy in each sector by the general price index. The price data were collected from national statistical publications and UN sources. Due to the constraints of data availability, the time period covered is 1978 through 1995.

Equation (1) is estimated using a fixed effect model (FEM) for all three of the previously identified sectors. The results of the estimation procedure are reported in the statistical appendix. The primary criticism of using the FEM is the assumption that the coefficient vector is the same for all countries. However, given the reasonably short individual time series, it is difficult to say with any certainty whether or not the long run trends are similar. The assertion that they are similar, in fact, is a key assumption of this analysis. The procedure is used merely to identify a long run pattern of development that is common to all countries of the world (see Figure 6). The estimation of long run energy coefficients using only cross-section data has been applied on numerous occasions throughout the literature. However, since the energy-income relationship is dynamic, we feel the information of the time-series cannot reasonably be ignored.

The relationship between energy demand and output is simultaneous insomuch as increases in one motivate increases in the other. Energy is a necessary input into the production of most goods and services (the value of which is GDP). As income increases, the demand for these goods and services expands, thus raising the demand for energy inputs. Hence, GDP growth results in increasing energy demand, but, because energy inputs are required, insufficient energy resource supplies can retard economic growth. The majority of energy studies ignore the simultaneity of the energy-GDP relationship by simply allowing GDP to be an exogenous component of the energy demand system. Although we will not specify a macroeconomic production relationship for GDP and energy, we do allow GDP to be endogenous.

IV. Forecasting China's Energy Demand

There are distinct traits within the Chinese experience that distinguish it from the rest of the countries in the sample. Energy demand in transport has historically been lower than what is typical in other countries at similar levels of per capita income, and energy demand in the industrial and other sector has been higher (see Figure 6). This is indicative of the typical command economy, which emphasizes investment in heavy industry to the detriment of investment in light (consumer goods) industry. China severely restricted the production of automobiles and transport infrastructure, emphasizing the utilization of bicycles as the chief mode of personal transportation. In addition, the use of somewhat arbitrary fixed prices masked the true costs of energy inputs, and the de-emphasis of profits as a determinant of managerial performance, resulted in very inefficient energy use in industrial practices. The rate at which these sectors 'correct' to the average global development trend will have a significant impact on Chinese energy demand.

Is there evidence that any correction will take place? As far as the transportation sector is concerned, a World Bank study claims that it would be in the best interest of Chinese

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policy-makers to take action aimed at curbing the growth of motor vehicle stocks. The expansion of the transport infrastructure will be too costly to accommodate a continuation of the recent rapid rise in traffic volume. In addition, motor vehicle pollution in cities is increasing because many vehicles are outdated and almost all of the fuel consumed is leaded. Therefore, the report advises that planners encourage the use of bicycles as a chief means of passenger movement. A potential instrument for this type of policy is the levying of taxes on automobile imports/sales and/or the levying of taxes on motor fuel sales. Given the existing infrastructure and environmental obstacles, it seems unlikely that a correction is rapidly forthcoming. Rather, the process must involve massive infrastructure investment as well as the replacement of outdated transport equipment, both of which could take quite a long time.

The industrial sector, if properly motivated, can expect a downward 'correction' to the global development trend. As the Chinese economy liberalizes, managers will place greater emphasis on profits. Inevitably, this results in the extinction of inefficient processes, which leads to a reduction in the energy intensity of production. In addition, the effect of moving from very energy intensive heavy industry, the child of the command economy era, to less energy intensive consumer oriented production can create, in-and-of itself, a downward correction.

Using the results of our estimation, we can forecast energy demand growth in the prescribed sectors of China's economy. Given the relative magnitudes of the estimated parameters in each sector (see Appendix Table C), we see that energy demand in the transportation sector can be expected to grow the fastest. The slowest growth in energy demand will come from the industrial and other sector. The sum of the sector demands is final energy demand. In order to obtain primary energy requirement, which is the amount of energy necessary to facilitate a given level of final demand, we must make some assumptions about the transformation loss that will be incurred in the future. Transformation loss is the energy that

is used up in the production of delivered energy goods such as electricity and domestically produced petroleum products. Transformation loss can vary between countries. Factors that can affect this value are the composition of the primary fuel requirement, and the technologies used in the production of final energy products (electricity and petroleum products, for example). Therefore, transformation losses may change over time if there is a change in either of these factors. For the purposes of forecasting, the loss is assumed to hold to its observed value in 1995, about 21% of primary requirement. Historically (1973–1995), this number has been approximately constant, with only minor variation around the assumed value.

Table 3: Energy Demand Forecasts for China to 2020						
				Energy Demand *(a)*		
	Real GDP	Residential		Industrial		
	per capita	and		and		
Year	growth *(b)*	Commercial	Transportation	Other	Final	Primary *(c)*	DOE *(d)*
1995	…	136.5	42.5	544.5	723.5	915.8	…
	2.5	214.4	89.9	805.9	1110.2	1405.3	…
2010	5.0	230.4	106.4	922.1	1258.9	1593.5	…
	7.2	243.0	122.2	1035.9	1401.1	1773.5	1797.0

	2.5	240.5	102.6	901.5	1244.6	1575.4	…
2015	5.0	264.7	129.7	1092.8	1487.2	1882.5	…
	7.2	282.3	156.4	1290.6	1729.3	2189.0	2229.0
	2.5	267.7	116.2	1008.0	1391.9	1761.9	…
2020	5.0	299.8	155.9	1295.3	1751.0	2216.5	…
	7.2	320.3	196.1	1609.6	2126.0	2691.1	2764.0

Notes:

(a) Units are in Million Tons of Oil Equivalent

(b) Population is assumed to grow at 0.7% per annum. (World Bank Development Indicators, 1998)

(c) Historically, Transformation losses are around 21%. Thus, to obtain Primary, we assume this value.

(d) DOE refers to Department of Energy reference case projection for Primary Energy Consumption.

The forecasts generated in Table 3 show the demand for energy by sector under various development scenarios. Specifically, alternative assumptions about the rate of economic growth are made holding the real price of energy constant at 1995 levels. We take as our reference case the scenario in which per capita real GDP growth averages 5.0% per annum.

Also illustrated are the much more conservative growth scenario of 2.5% per capita GDP

expansion and the Department of Energy (DOE) reference case. The DOE projections are for

7.9% absolute real GDP growth, but, using the World Bank's projection for population

expansion (0.7% per annum), this calculates to 7.2% per capita growth. Our forecasts become

increasingly different from the DOE's forecast as the time horizon is extended. This is to be

expected due to the use of a quadratic formulation in our analysis. Figure 7 is an illustration

of our reference case forecast in Table 3.

Figure 7: Chinese Energy Demand to 2020
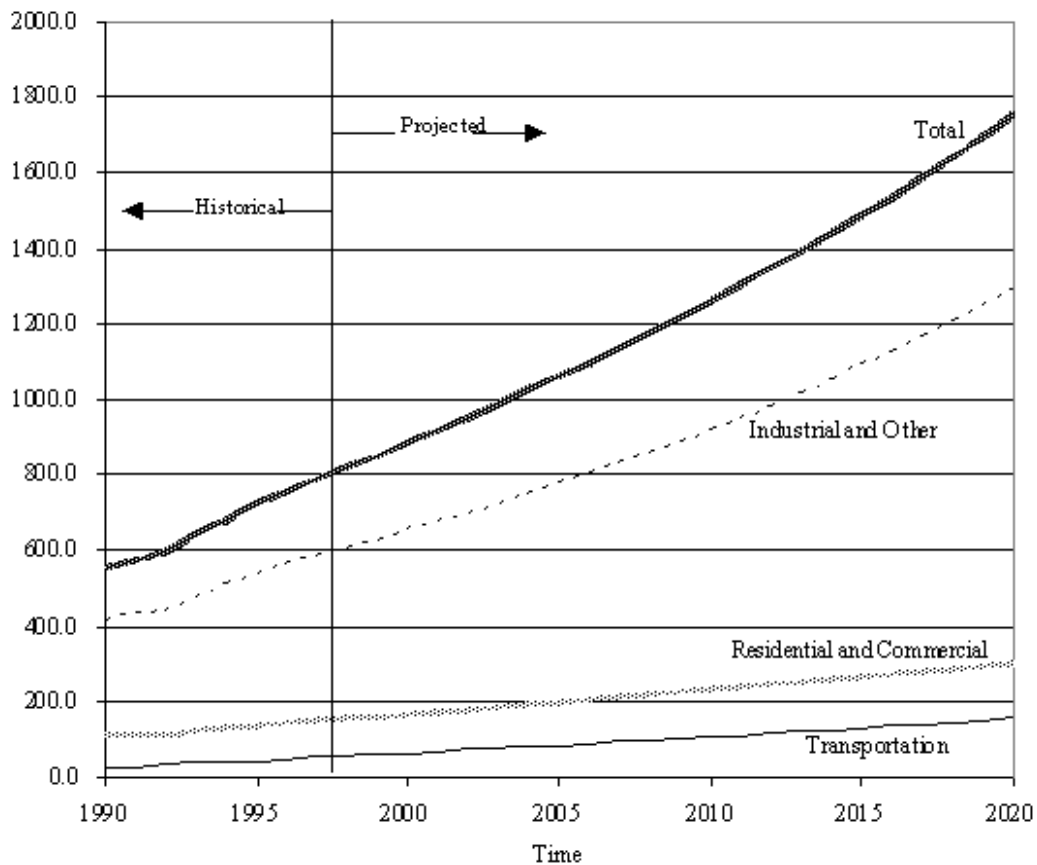
In all growth scenarios, the transportation sector takes up an increasing proportion of the total

energy demanded. This is reflective of the growth of consumer demand for transportation

services that occurs as economic development progresses. As discussed above, factors that

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will effect this growth are the future development of infrastructure and the extent to which environmental concerns are addressed.

What do these forecasts mean for future Chinese oil requirements? In Table 4, we have illustrated some forecasts for Chinese oil demand to the year 2020. The oil demand numbers are generated under the assumption that the fuel mix within each sector remains constant at 1995 levels. Again, we must make some assumptions about the amount of oil lost in transformation in order to get the primary requirement. Therefore, we assume the 1995 value for all projections. Note that these forecasts do not allow for the possibility of environmentally motivated substitutions away from coal, nor do they account for the fact that increases in energy demand in transportation will be largely dominated by the growth of private transportation. These would both have the effect of increasing the share of oil in total energy demand.

Dependence on exhaustible energy resources is crucial in determining a nation's development pattern due to the implication that increasing scarcity leads to increasing prices. As the price of various fuels increase substitution to cheaper resources will occur thereby altering the composition of energy demand. Likewise, environmental concerns are capable of reducing particular types of energy use through both public awareness and international carbon-tax policies (the proposed emissions reduction policies adopted at Kyoto (1997) are an example of such a policy). As implicit prices, such as those associated with pollution, increase, substitution to cleaner fuels will be encouraged.

The extent to which explicit and implicit prices either offset or reinforce each other will be crucial in determining the composition of energy demand. There is considerable evidence that energy price increases reduce real GDP growth in the short run, but the long run effects are less clear. The adoption of conservation policies and the encouragement of technological

innovation in response to higher explicit and implicit prices can both potentially have enormous impacts on the future energy consumption patterns of all nations, not just China.

Table 4: Projected Chinese Oil Requirements by Sector										
	1995		**2010**			**2015**			**2020**	
		2.5%	**5.0%**	**7.2%**	**2.5%**	**5.0%**	**7.2%**	**2.5%**	**5.0%**	**7.2%**
Residential and										
Commercial										
million tons	6.39	10.03	10.78	11.37	11.25	12.39	13.21	12.53	14.03	14.99
increase of		*3.63*	*4.38*	*4.97*	*4.85*	*5.99*	*6.81*	*6.13*	*7.63*	*8.59*
Transportation										
million tons	26.28	55.59	65.80	75.57	63.45	80.21	96.72	71.86	96.41	121.27
increase of		*29.29*	*39.50*	*49.27*	*37.15*	*53.91*	*70.42*	*45.56*	*70.11*	*94.97*
Industrial										
and Other										
million tons	103.08	152.56	174.56	196.11	170.66	206.88	244.32	190.82	245.21	304.71
increase of		*49.46*	*71.46*	*93.01*	*67.56*	*103.78*	*141.22*	*87.72*	*142.11*	*201.61*
Total Final										

million tons	135.75	218.19	251.14	283.05	245.37	299.47	354.25	275.21	355.65	440.97
increase of		*72.19*	*105.14*	*137.05*	*99.37*	*153.47*	*208.25*	*129.21*	*209.65*	*294.97*
Primary *(a)*										
million tons	167.59	269.37	310.05	349.44	302.92	369.72	437.35	339.77	439.08	544.41
increase of		*111.57*	*152.25*	*191.64*	*145.12*	*211.92*	*279.55*	*181.97*	*281.28*	*386.61*
barrels/day *(b)*	**3.35**	**5.39**	**6.20**	**6.99**	**6.06**	**7.39**	**8.75**	**6.80**	**8.78**	**10.89**
increase of		***2.04***	***2.85***	***3.64***	***2.71***	***4.04***	***5.40***	***3.45***	***5.43***	***7.54***
Notes:										
(a) Oil losses from transformation were approximately 19% of primary requirement in 1995.										
(b) Units are in millions.										

Bearing this in mind, the oil demand forecasts presented in Table 4 should be treated as conservative estimates due to the fact that we assume the composition of energy demand by sector remains constant at the 1995 values. Environmentally motivated substitutions away from the use of coal to alternative resources, and the fact that much of the growth in transportation energy will come from private use, could both have drastic effects on the overall composition of energy demand. With increasing domestic need, as well as international pressure, to abate pollution, steps toward cleaner energy, through either technology or substitution, should be expected.

The extent to which consumer demands dictate the use of non-coal resources will also drive movements to the consumption of fuels such as oil and natural gas. For example, with the largest percentage increase in energy demand expected to come from the transportation sector, an increase in the demand for private transport services will cause that sector to become increasingly oil intensive. This, either taken alone or coupled with environmental factors, can have enormous effects on oil consumption by the year 2010, not to mention 2020.

V. Concluding Remarks

The patterns of economic development, in particular, the ways in which consumer and producer demands change as per capita income increases, will have a direct effect on the composition and growth of energy demand. The initial stages of economic growth are characterized by the build-up of industries that are geared toward the development of infrastructure as well as the changing structure of consumer demand. A continued rise in consumer income leads to higher demand for energy consuming goods and services thereby raising the energy intensity of the consumer bundle. As the composition of industrial output becomes increasingly dominated by the production of consumer goods, the energy intensity of the industrial sector falls.

One difficulty in forecasting the future energy demand for developing nations is the prediction of future composition of production and consumption. We attempt to solve this problem by using a panel of countries from all levels of development to trace a map of China's probable development path. This gives us a basis upon which to form expectations about the future energy consumption of China.

The results of our analysis show that, even under modest growth scenarios, energy demand in China will increase substantially. Furthermore, the largest percentage increases will come from the demand for transportation services. As consumer incomes increase, passenger

vehicle ownership can be expected to increase. The utilization of these vehicles will result in large increases in the demand for energy, in particular, the demand for oil.

This brings us to the issue of energy security in China. It will depend heavily upon China's ability to 'play politics' with the nations of Middle East and, perhaps more importantly, the neighboring countries through whose waters and lands the oil must be transported. Moreover, the ability to overcome inefficient market structures and mechanisms, which have slowed domestic exploration and development of oil resources, will have a significant impact on the security issue. Since such a large portion of oil demand must be satiated with imports, the geo-political environment of Asia can be expected to change dramatically in the coming years.

The issue of future energy security leaves China with some difficult decisions. Among the questions to be answered are:

- Should oil and natural gas resources in Western China be developed despite the huge requirement of capital investment and geological risk?

- Should the reliance on Persian Gulf and other crude oil suppliers be increased despite the potential for political problems, which could cut into imports thereby strangling the Chinese economy?

- Should a major oil (and possibly natural gas) overland pipeline from Kazakhstan be constructed?

- Should the necessary infrastructure be put into place to allow the importation of natural gas from east Siberia or liquefied natural gas (LNG) from Southeast Asia and the Middle East?

While the costs associated with pipelines versus tankers are essentially exercises in accounting, the potential costs associated with dependence upon long-time political rivals are unclear. Therefore, the expected costs and benefits of the different possible solutions must be weighed against one another.

Using our conservative estimates of future Chinese oil demand, we see that future energy growth translates into substantial import requirements. If we allow oil to take up an increasing portion of total energy import requirements will be even larger. Accordingly, there will be increasing pressures to secure a stable flow of imported oil resources. An inability to do so will invariably interrupt the development process.

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Appendix A

The countries included in the development path estimation are:

Central and South America

Brazil

Mexico

North America and Europe

USA	Spain
Canada	Portugal
UK	France
Ireland	Netherlands
Italy	Belgium
Greece	Denmark
Turkey	Norway
Austria	Sweden
Finland	

Central and South Asia

China	Japan
India	Australia
Malaysia	Sri Lanka
Thailand	Pakistan
South Korea	Indonesia