THE JAMES A. BAKER III
INSTITUTE FOR PUBLIC POLICY
OF
RICE UNIVERSITY

JAPANESE ENERGY SECURITY AND CHANGING GLOBAL ENERGY MARKETS:

An Analysis of Northeast Asian Energy Cooperation and Japan's Evolving Leadership Role in the Region

JAPANESE ENERGY DEMAND TO 2015

KENNETH B. MEDLOCK III
DEPARTMENT OF ECONOMICS
RICE UNIVERSITY

AND

RONALD SOLIGO
PROFESSOR OF ECONOMICS
RICE UNIVERSITY

PREPARED IN CONJUNCTION WITH AN ENERGY STUDY SPONSORED BY
THE CENTER FOR INTERNATIONAL POLITICAL ECONOMY
AND
THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY
RICE UNIVERSITY – MAY 2000

Introduction

The expected future growth of energy demand plays an important role in shaping domestic energy policies. Concern over growing national dependence on international energy sources builds pressure to develop domestic resource stocks, promote conservation or develop alternative technologies not dependent on imported energy. In order to construct a realistic plan for managing future energy needs and sources of supply, it is important to obtain an accurate estimate of those future requirements. This study focuses on the growth of end-use energy demand in Japan, and the composition of primary fuel supplies needed to meet that demand. Given the fact that Japan is almost completely import dependent for fossil fuel resources, it is likely that government policies will play the most significant role in the growth of end-use energy demand.

Medlock and Soligo (2000) have shown that growth in consumer end-use demand is the principle driver of increases in energy consumption in high-income countries. As consumer wealth increases, the demand for services provided by durable goods and automobiles increases. The production of these services requires energy input in the form of motor fuel and electricity; therefore, the demand for energy will increase with income *ceteris paribus*. In the transportation sector, the increased demand for motor fuel translates into an increase in the demand for crude oil. For Japan, this increases dependence on imports, a potentially undesirable outcome. The production of services from other household durable goods such as air conditioning and heating requires electricity that can be generated by dams and nuclear plants, as well as by imported oil and gas. In the longer run, the development of alternative primary energy sources, such as hydro-power, nuclear power, hybrid, and fuel cell technologies, could curb Japan's reliance on fossil fuels in both areas. However, if alternatives are not viable in the short run, likely policy actions to minimize exposure will be aimed at direct decreases in energy demand through taxes and energy conservation.

Apart from consumption and production patterns and concerns over energy security, environmental policies could also shape the composition of primary fuel demand. Considering its role in the Kyoto negotiations, this will likely be the case in Japan. As cleaner energy resources are sought out, the appeal of natural gas increases relative to oil and coal. A major barrier to fuel switching (aside from higher costs) is insufficient transport infrastructure for alternative fuels. The only short-term solution to meeting pre-specified pollution targets, therefore, would be a direct reduction of energy consumption. This could be a costly policy.

Economic Development and End-Use Energy Demand

As an economy develops, it undergoes a series of structural changes.[1] During the initial stages of economic growth, the share of agriculture in total output falls and the share of industry rises. This is the industrialization phase of development. In the later stages of development the demand for services begins to increase rapidly, increasing its share of GDP. This latter stage is often referred to as the 'post-industrialized' society.

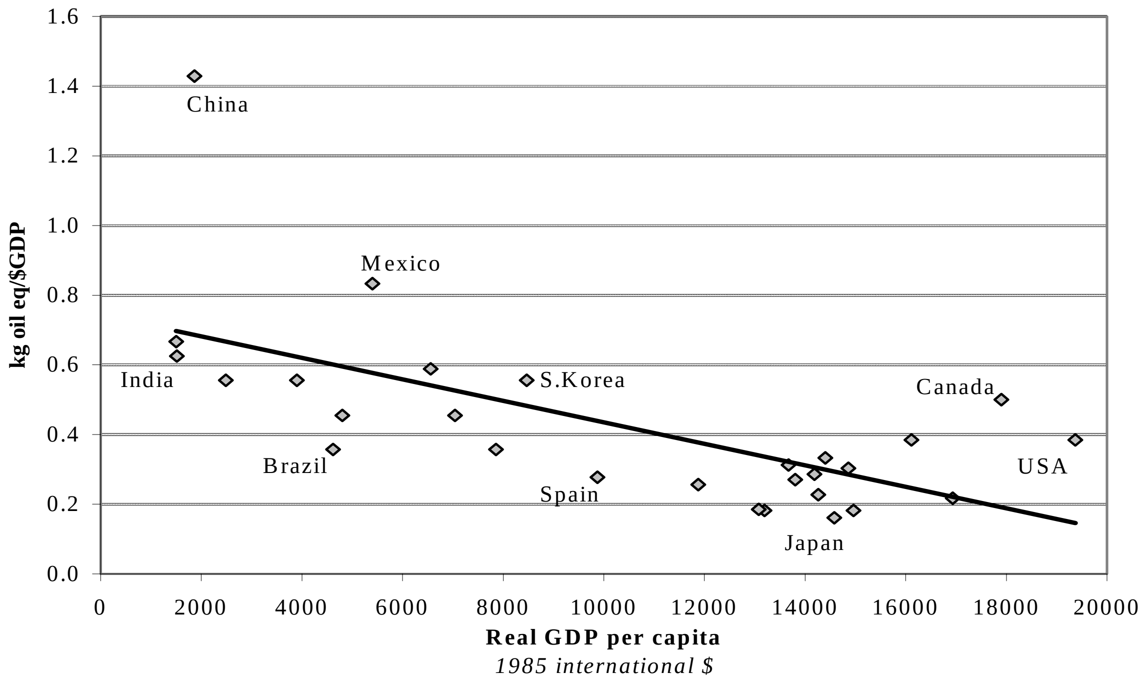
The changing structure of production and consumption accompanying the process of development are important in determining the growth and composition of end-use energy demand. The growth of heavy industry (infrastructure development) during the industrialization phase leads to enormous increases in energy consumption. Accordingly, the energy intensity of GDP (defined as energy input per dollar of GDP) increases as the share of industry in GDP increases. As development continues, however, demand for financial services, communications, transportation, and consumer goods (light manufacturers) grows rapidly. As a result, the share of services and consumer goods increases, eventually accounting for over one-half of total output. To the extent that light industry (the production of consumer goods) and services require less energy input per of unit output than heavy industry, there is a reduction in overall energy intensity (see figure 1 below).[2]

Although economic development leads to declining growth rates of per capita energy demand in the industrial sector, there is substantial growth in energy demand in the transportation and residential and commercial sectors. As per capita incomes rise, consumers devote a larger proportion of their income to durable goods such as air-conditioners, furnaces, refrigerators, and automobiles. Since these items require some energy input to produce a flow of services, energy demand increases. The growth of energy demand in these sectors, however, slows as incomes continue to rise because there are constraints (time, comfort, etc.) that limit the amount of energy that

[1] These have been documented by authors such as Kuznets (1971) and Chenery and Syrquin (1975), so only require brief mention here.

can be consumed for transport and residential and commercial uses. That is, there exists a *saturation* effect in the demand for services that require energy input.

Figure 1 – Energy Intensities of Selected Nations (1995)



In a recent study of the effect of economic development on end-use energy demand, Medlock and Soligo (2000) found that energy demand grows at different rates in different, broadly-defined, end-use sectors (industrial, transport, and residential and commercial).[3] Specifically, they found that per capita industrial energy demand rises very rapidly at the outset of development, accounting for most energy use. The growth of energy demand in industry, however, quickly declines, and energy use in the other sectors eventually takes a majority share of total end-use energy consumption. In fact, energy demand in the transportation sector continues to grow well into the post-industrial phase of development, accounting for more than half of all energy use. A simulation of energy demand by sector for an *average* country based on these results is depicted in figure 2.[4]

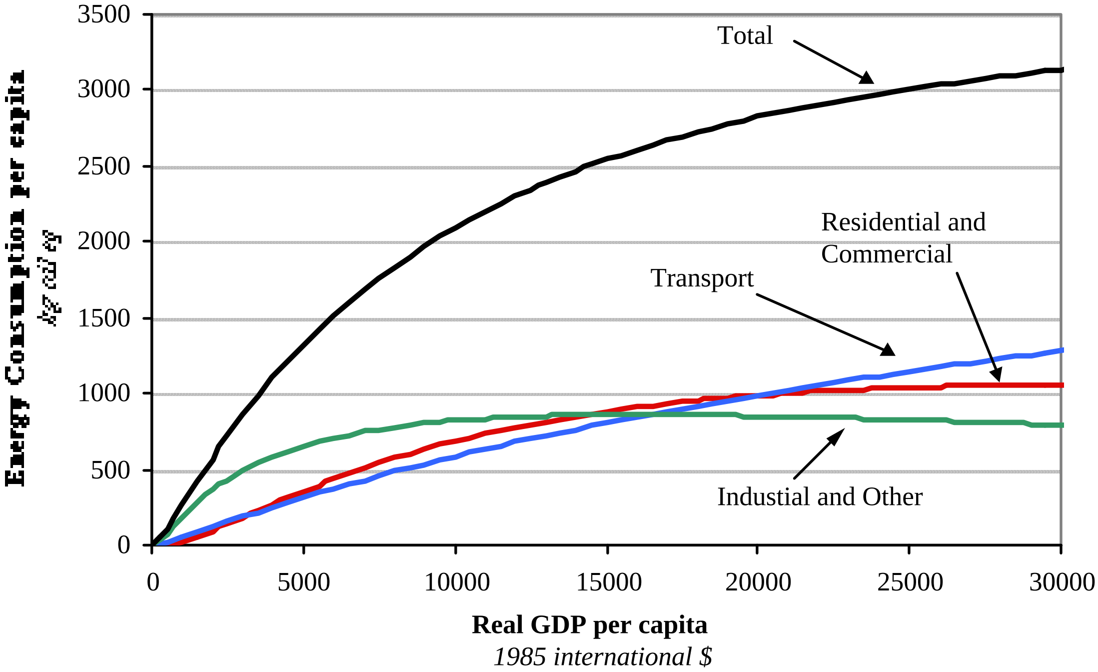
---

[2] This phenomenon is often referred to as *dematerialization*.

[3] They used a panel of 28 different countries from all levels of development covering the period 1978-1995. A complete list of the countries in the sample is given in Appendix 1.

[4] Figure 2 is a recreation of that found in Medlock and Soligo (2000). The paths were generated using the long-run estimated coefficients (see Appendix 2). Prices are assumed fixed, and an average intercept coefficient is used.

Figure 2 – Simulated Per Capita End-Use Energy Demand



Given these patterns of development, we can expect energy demand in transport to become an increasing share of developed countries' energy bundles. The trends evident in figure 2, however, represent average *global* trends. They do not necessarily hold for any one country. It is important to consider this, therefore, when making inferences about the future energy needs for any single country such as Japan.

End-Use Energy Demand in Japan

Historical Trends

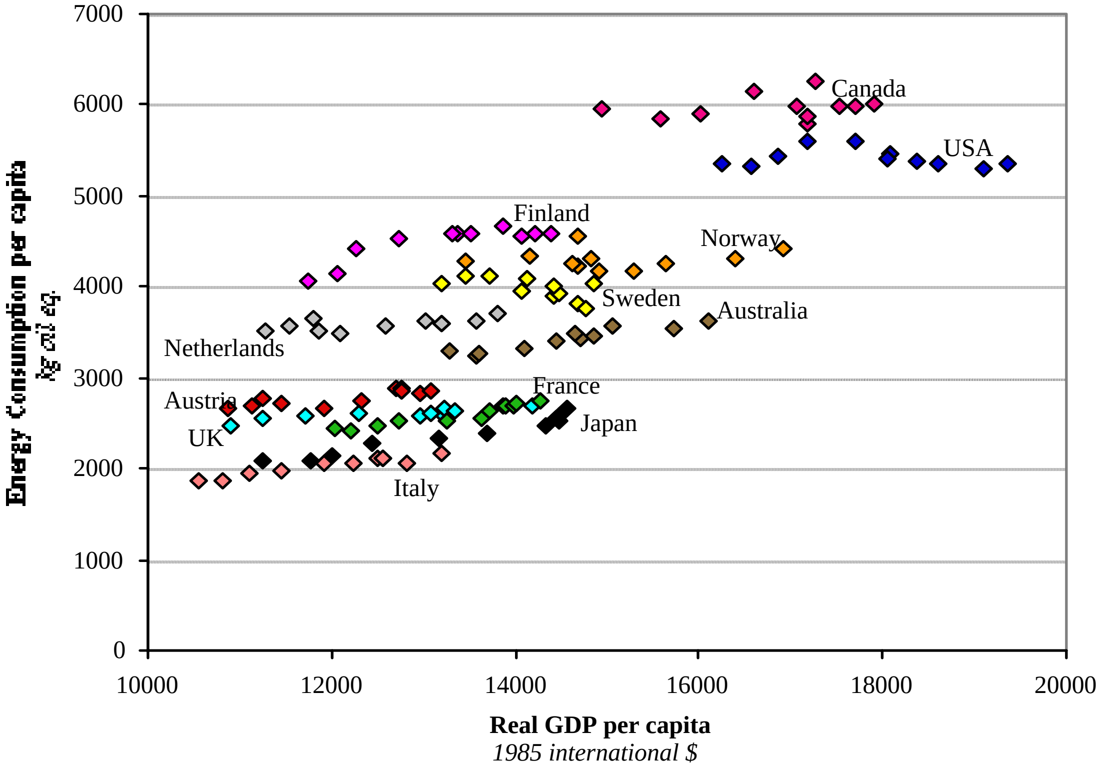
As shown in figure 3, energy consumption in Japan has been lower than in most other industrialized countries at similar levels of per capita income. This can be attributed, in large part, to the fact that a lack of domestic natural resources has placed a premium on highly energy efficient practices. The Japanese government's use of import duties, end-user taxes, and environmental regulations and the existence of physical constraints[5] have lead to energy prices that are among the highest in the OECD. As a result, heavier industries, such as aluminum smelting, have moved from

---

[5] The lack of natural gas pipelines into Japan, for example, dictates the importation of more expensive LNG.

Japan to nations where energy is less costly. Furthermore, a large emphasis is placed on electricity conservation as well as transport fuel efficiency. Taken together, these factors result in a relatively low level of total end-use energy consumption per capita for a given level of per capita income.

Figure 3 – Final Energy Demand per Capita for Selected OECD Nations (1985-1995)

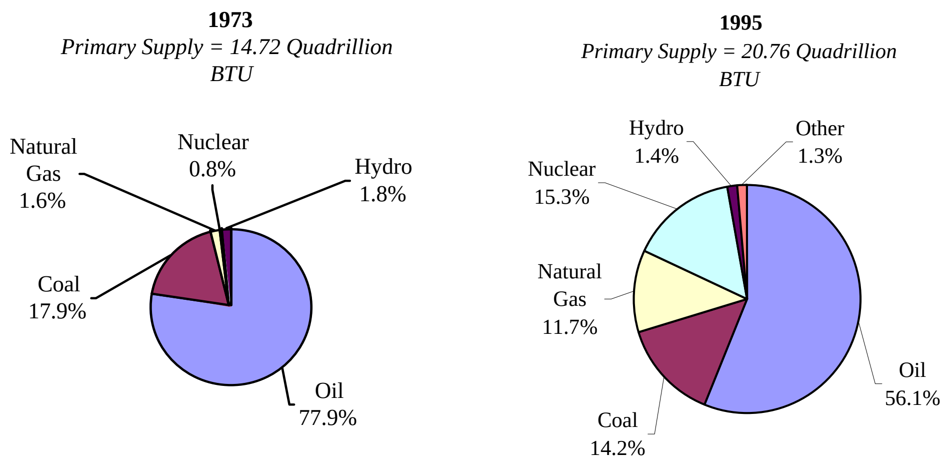


Despite growth in energy demand, Japanese energy policies have dictated the composition of primary fuel supplies to meet secondary requirements. Figure 4 shows the composition of primary energy supply in 1973 and 1995. The share of oil in total primary supply fell from 77.9% in 1973 to 56.1% in 1995. The share replacement has come from an increase in the use of natural gas (the cleanest of the fossil fuels), and a large increase in the use of nuclear power. A strong dedication to a clean environment has limited the use of coal to 14.2% of total primary energy supply in 1995. This is in stark contrast to the rest of the world, where the average share of coal in total energy was 24.5%.[6]

[6] Based on authors' calculations from the US Energy Information Administration's database.

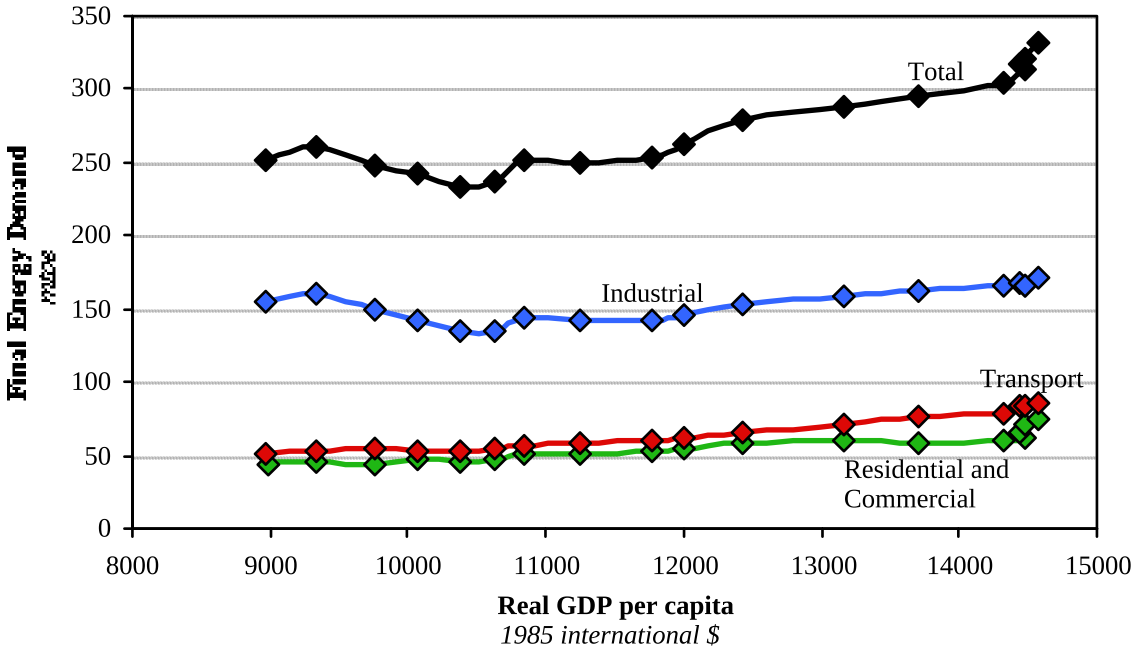
The decline in the share of oil in primary energy supply can be attributed to a number of factors. First, energy security concerns have no doubt played a role in effort to keep dependence on foreign oil supplies from rising. Second, growth in the use of nuclear and natural gas have mitigated the extent to which oil requirements had to increase. Increases in oil prices through the early 1980's necessitated a move to alternative energy sources. A 9.5% decline in oil demand from 1980 to 1983 has been offset by an increase of 30.7% from 1985 through 1997, a period in which, coincidentally, oil prices fell from an average of $27.45/barrel to $18.80/barrel.

Figure 4 – Japanese Primary Energy Supply by Source, 1973 and 1995



The use of nuclear power is nowhere more evident than in the electricity-generating sector. By 1995, nuclear power accounted for 30.2% of all electricity generation in Japan, compared to 17.1% for the rest of the world. This is an astounding difference, and is indicative of the emphasis on finding alternatives to fossil fuels. However, following Japan's worst ever nuclear facility accident in September 1999 at Tokaimura, public concern about the safety of nuclear power has halted the development of proposed new facilities. Ten major electric power companies have announced intentions to build a maximum of 13 such plants by 2010, instead of 20 as earlier planned - although some of the reduction is also in response to the long Japanese recession and the resulting lower-than-expected rate of electricity growth. Without these facilities, rising energy demand will force Japanese energy consumers to find innovative ways to avoid an increasing reliance on foreign energy resources. Potential solutions lie in the development of more energy efficient technologies, such as the gas-electric hybrid automobile, or alternative technologies, such as solar power or the fuel cell.

Figure 5 – Japanese End-Use Energy Demand by Sector



The sector composition of end-use energy demand in Japan has also been influenced by government policy. High end-use prices have kept energy demand in the transport sector and residential and commercial sector from growing faster than industrial energy use. This is different from what is observed, on average, in other countries. For the average country the energy consumed in the transport sector rises faster relative to other sectors until it accounts for the majority of final energy demand (see previous section). This has not been the case in Japan (see figure 5). Premium gasoline prices in Japan are among the highest in the OECD. In 1994, the price in Japan was 233.8% higher than in the U.S., and 44.8% higher than in the U.K..[7] This translates to high user costs for private transport. Furthermore, in the residential sector prices are approximately 90% and 141% higher than in the U.K. and U.S., respectively. A history of such trends has resulted in the development of a large public transport sector and an emphasis on public awareness for energy conservation.

[7] Calculated by authors using data from the EIA's International Energy Annual.

In the electricity sector, end-user prices are kept high for a number of reasons, including a lack of a national power grid. This limits any potential competition among power suppliers, granting each some degree of monopoly power. Coupled with strict regulations and high input fuel costs, the result is lower demand than is observed in other countries at similar levels of per capita income. Nevertheless, any increase in stocks of durable goods, or utilization of current stocks, will result in an increase in electricity demand in the residential and commercial sector. As per capita income increases in Japan, such a trend is likely to occur as consumer budgets become more heavily weighted towards durable goods and transportation.

Projections to 2015

What can we expect in the future? When considering the structure of the Japanese economy, it is apparent that the same sort of structural changes are occurring as in the rest of the world. For example, the share of services in total output in Japan increased from 54% in 1980 to 60% in 1995 while the share of industry fell from 42% to 38% during the same period.[8] This structural change lead to a decline in energy intensity from 0.22 kg oil equivalent per 1985 international $ GDP to 0.18 kg oil equivalent per 1985 international $ GDP. As the Japanese economy becomes increasingly service oriented, this trend can be expected to continue. Future increases in energy demand, therefore, will continue to be smaller proportions of increases in GDP.

As production shifts toward services, energy in the industrial sector will account for a smaller portion of Japan's primary energy requirement. This means that gains from conservation and efficiency will have to come increasingly from the transport and residential and commercial sectors in order to make a meaningful impact. In other words, there will be decreasing returns to overall energy conservation on investments aimed at increasing efficiency in the industrial sector because energy use in that sector is becoming a smaller proportion of total energy demand.

We use the estimates from Medlock and Soligo (2000) (see Appendix 2) to predict the growth of energy demand in each of the end-use sectors (see table 1). The model utilizes the growth patterns of a panel of 28 countries from all levels of

---

[8] World Bank Development Indicators, 1997.

development to ascertain the expected future patterns of energy demand growth. Explicit in the construction is the notion that there are individual country characteristics that differentiate one country from another. Implicit in the construction is the notion that these differences do not change over time, i.e.- certain policies that effect energy growth are consistent throughout time (public transport policy, for example). The one exception is policies that directly influence price (tax measures), as end-user prices are explicitly included.

These forecasts are based on the following assumptions. First, as a base case, we assume that the average annual growth rate of real GDP per capita will be 2.5% per annum until 2015. This is, approximately, the average annual growth rate from 1980-1995. We also consider two alternative rates of growth 1.5% (low case) and 3.5% (high case). Second, we assume that end-user prices remain constant at their 1995 levels. Third, population is assumed to grow at 0.1% per annum (see World Development Indicators, 1998).[9] Finally, we assume that energy efficiency, at each level of per capita income, will remain constant at current levels. Each of these assumptions is subject to criticism, especially in light of recent developments. In particular, the assumption of per capita

Table 1 – Energy Demand Forecasts to 2015

	1995	**Projected - 2015**		
Consuming Sector		**Low** *1.5%*	**Base** *2.5%*	**High** *3.5%*
Residential and Commercial	74.7	156.1	161.4	165.3
Transportation	85.9	131.3	145.6	160.5
Industrial and Other	170.6	177.2	174.1	169.0
Total Final Consumption	331.2	464.6	481.0	494.8
Total Primary Consumption	480.0	673.3	697.5	717.1
Real GDP per capita	$14,578	$19,634	$24,358	$29,007

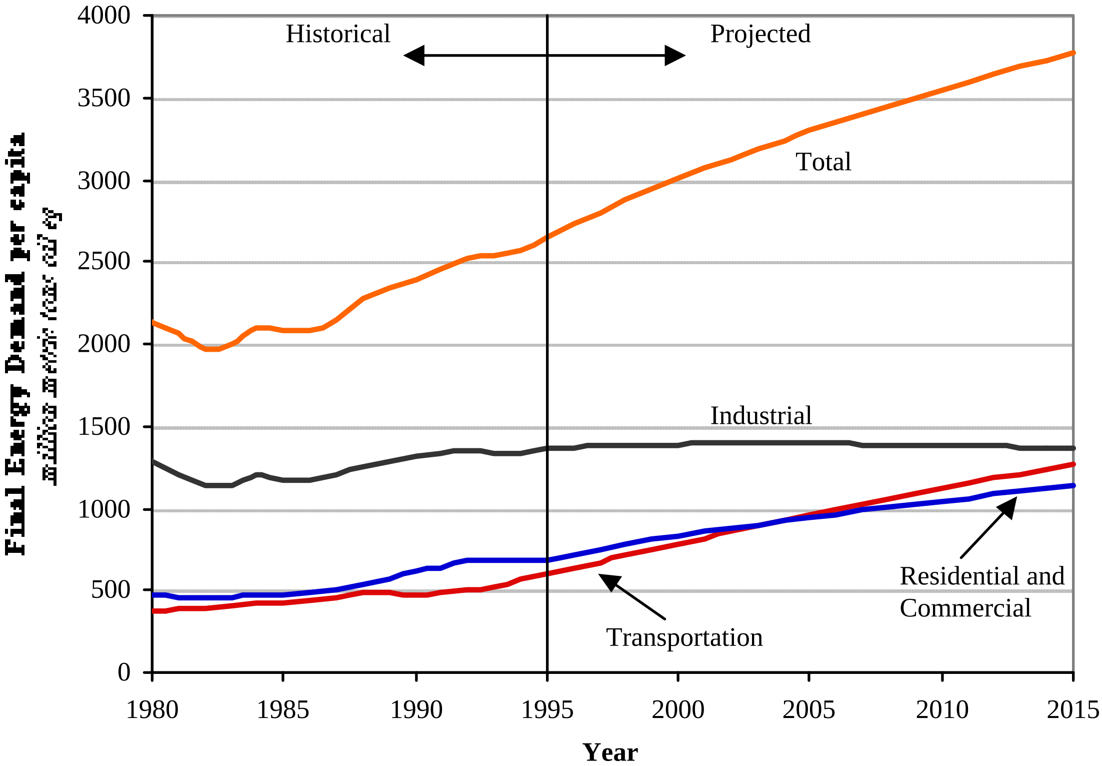
Notes:
(a) Energy units are million metric tons of oil equivalent. Real GDP per capita is 1985 international $.
(b) Transformation losses in 1995 were 30%. Thus, to obtain Primary, we assume this value.

GDP growth of 2.5% as the base case may be very optimistic given the stagnation of the Japanese economy over the past decade. For example, Japanese

[9] The EIA assumes a population growth rate of 0.0% in their projections for Japan.

GDP (not per capita) grew at only 1.4% from 1990-96, down from 4.0% from 1980-90 (World Development Indicators, 1998). The forecasts will, however, provide us with some indication of what to expect.

Figure 6 – Base Case Forecasts to 2015



The base case forecasts to 2015 presented in table 1 are depicted in figure 6. The development trends discussed above are evident here. In the base case, total final energy demand is expected to grow an average of 1.9% per year. The industrial sector demand, however, is projected to grow by only 0.1% per year, while growth in the transport sector and residential and commercial sector are projected to be 2.7% per year and 3.9% per year, respectively.

These projections, of course, ignore the potential effects that price increases could have on the growth of energy demand in each sector. The data in Appendix 2 shows the long run price elasticity for each sector as follows: the residential and commercial, -1.3; transportation, -0.5; and industrial, -0.27. Given these magnitudes, price increases will have the largest impact in the long term in the residential and commercial and the transportation sector. Furthermore, the state of technology is held constant in our calculations. Increases in fuel efficiency will no doubt result in a reduction in energy demand. In fact, based on these projections, it may be of greater benefit, and urgency, to channel resources into increasing fuel efficiency in the residential and commercial and transportation sectors than in the industrial sector.

The rapid growth in energy demand in the residential and commercial sector and the transportation sector are indicative of the effect that increasing consumer wealth has on the stock of durable goods in an economy. Recently, a great deal of literature has been dedicated to the investigation of the effect of economic development on the demand for motor vehicles. Medlock and Soligo (2000b), for example, used a panel of 28 countries to forecast the growth of motor vehicle stocks to 2015. For Japan, they project passenger vehicle stocks to increase from 357 cars per 1000 people to 454 cars per 1000 people. In a related exercise, Dargay and Gately (1998) project Japanese vehicle demand to increase to 550 cars per 1000 people in 2015. While there is considerable disparity between these projections, they both indicate a considerable increase in the demand for passenger mobility. This, in almost any scenario, implies an increasing demand for transport fuel.

The forecasts in table 1 indicate that the majority of future energy demand growth will come from the "consumer" side of the economy. In addition, these forecasts provide an indication of the future composition of primary energy supply. For example, given information on the fuel composition of total demand (i.e.- share of coal, natural gas, and oil) in each end-use sector, it is possible to make inferences about future primary fuel demand. In conducting this exercise, we will be concerned only with oil demand. Using data on energy balances, it is possible to discern the share of oil used in electricity generation in each sector. Then, adding that oil requirement to direct use within each sector, we can construct, by sector, the "electricity-adjusted" share of oil used in each sector. We then use the forecasts in table 1 to project future oil demand, by sector, for the Japanese economy. In particular, we consider two alternative scenarios for each of the growth rates indicated in table 1. We first assume oil demand will remain at the 1995 share of total energy demand in each sector (see table 2). Then, we allow the share of oil in total demand in each sector to decline at historical rates (see table 3). This will provide us with insight into the effect that fuel switching could have on oil demand, and allow for a reasonable projection of total oil requirements using historical patterns of oil displacement.

Table 2 – Projected Oil Requirements (Scenario 1)

	Historical **1995**	Projected **2015**		
		1.5%	**2.5%**	**3.5%**
Residential and Commercial				
million metric tons	38.078	79.616	82.295	84.286
increase of		*41.516*	*44.195*	*46.186*
million barrels per day	0.759	1.588	1.641	1.681
increase of		*0.829*	*0.882*	*0.922*
Transportation				
million metric tons	83.361	127.326	141.232	155.694
increase of		*43.926*	*57.832*	*72.294*
million barrels per day	1.663	2.540	2.817	3.105
increase of		*0.877*	*1.154*	*1.442*
Industrial and Other				
million metric tons	102.369	106.330	104.432	101.425
increase of		*3.930*	*2.032*	*-0.975*
million barrels per day	2.042	2.121	2.083	2.023
increase of		*0.079*	*0.041*	*-0.019*
Total Final				
million metric tons	223.807	313.272	327.959	341.405
increase of		*89.472*	*104.159*	*117.605*
million barrels per day	4.464	6.248	6.541	6.809
increase of		*1.784*	*2.077*	*2.345*
Total Primary				
million metric tons	272.935	382.039	399.951	416.347
increase of		*109.104*	*127.016*	*143.412*
million barrels per day	5.444	7.620	7.977	8.304
increase of		*2.176*	*2.533*	*2.860*

Notes:

(a) Conversion used for tons to barrels is 7.33 barrels/ton

(b) Oil losses from transformation were approximately 22% of primary requirement in 1995. We assume this value to obtain primary requirement.

(c) Adjusted for electricity generation, the share of oil in each sector was assumed to be the following:

	1995	2015
Residential and Commercial	51.0	51.0
Transportation	97.0	97.0
Industrial and Other	60.0	60.0

Where the 1995 values are calculated from available data.

Table 3 – Projected Oil Requirements (Scenario 2)

	Historical 1995	Projected 2015 1.5%	2.5%	3.5%
Residential and Commercial				
million metric tons	38.078	57.663	59.604	61.046
increase of		*19.563*	*21.504*	*22.946*
million barrels per day	0.759	1.150	1.189	1.218
increase of		*0.391*	*0.430*	*0.459*
Transportation				
million metric tons	83.361	127.326	141.232	155.694
increase of		*43.926*	*57.832*	*72.294*
million barrels per day	1.663	2.540	2.817	3.105
increase of		*0.877*	*1.154*	*1.442*
Industrial and Other				
million metric tons	102.369	77.012	75.637	73.459
increase of		*-25.388*	*-26.763*	*-28.941*
million barrels per day	2.042	1.536	1.509	1.465
increase of		*-0.506*	*-0.533*	*-0.577*
Total Final				
million metric tons	223.807	262.002	276.473	290.199
increase of		*38.202*	*52.673*	*66.399*
million barrels per day	4.464	5.226	5.514	5.788
increase of		*0.762*	*1.050*	*1.324*
Total Primary				
million metric tons	272.935	319.514	337.163	353.901
increase of		*46.591*	*64.240*	*80.978*
million barrels per day	5.444	6.373	6.725	7.059
increase of		*0.929*	*1.281*	*1.615*

Notes:

(a) Conversion used for tons to barrels is 7.33 barrels/ton

(b) Oil losses from transformation were approximately 22% of primary requirement in 1995. We assume this value to obtain primary requirement.

(c) Adjusted for electricity generation, the share of oil in each sector was assumed to be the following:

	1995	2015
Residential and Commercial	51.0	36.9
Transportation	97.0	97.0
Industrial and Other	60.0	43.5

Where the 1995 values and an average annual oil displacement rate of 1.9% are calculated from available data.

We have illustrated the results of both scenarios 1 and 2 in figures 7 and 8. Each path beyond 1995 is a smoothed line to the projected values of primary oil requirement, and corresponds to the assumed growth rates of per capita GDP as indicated in tables 2 and 3.

Figure 7 – Scenario 1

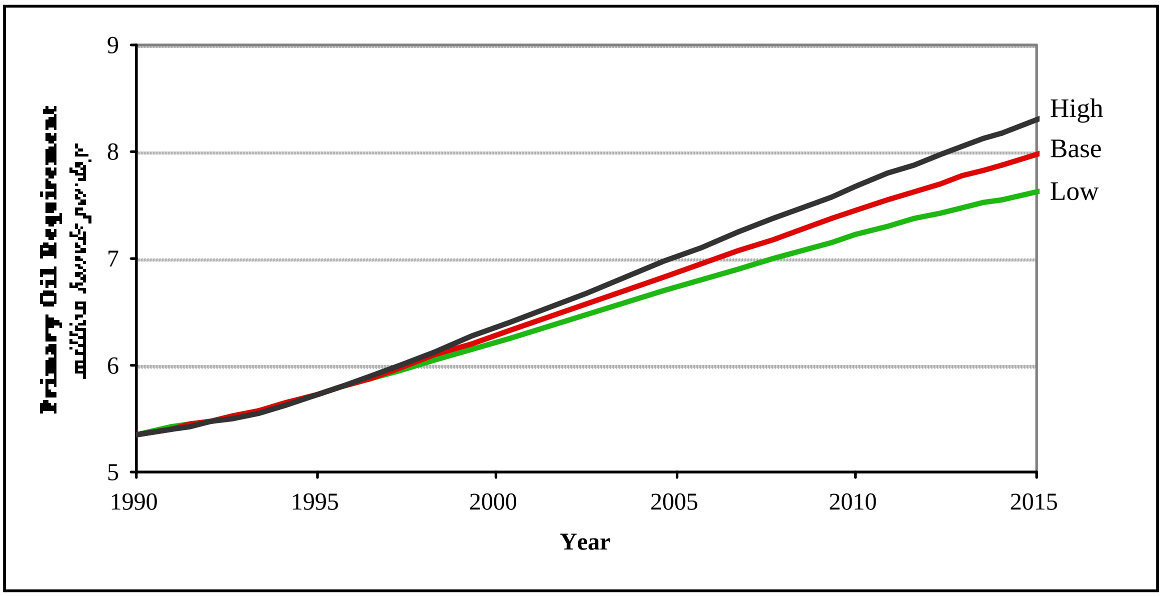
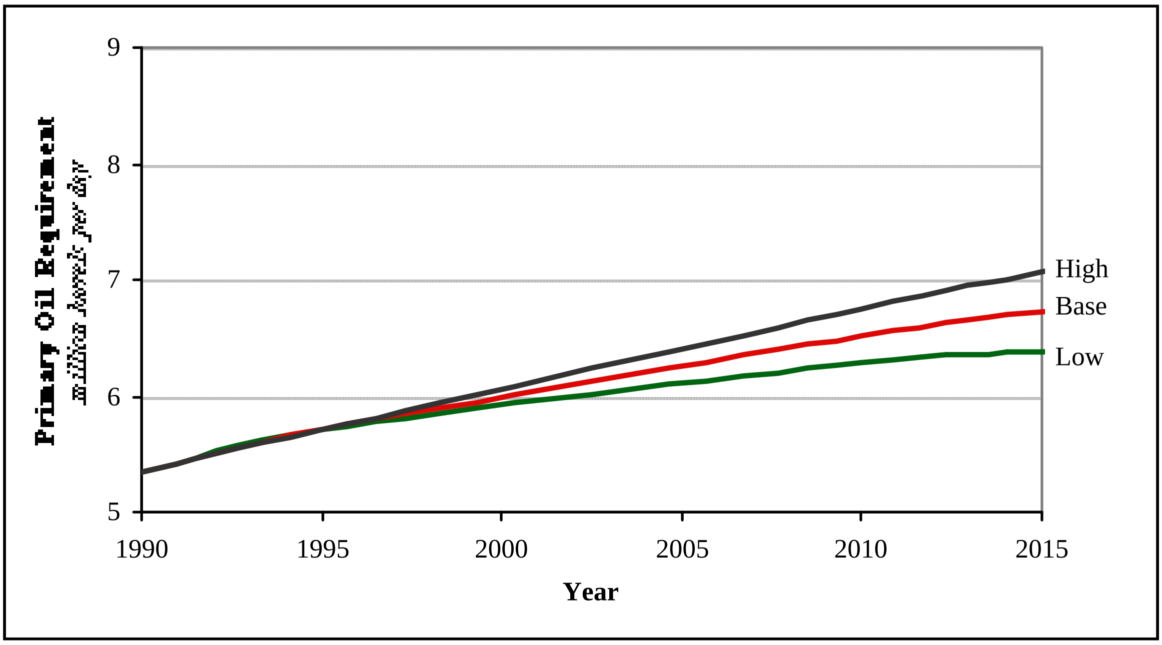


Figure 8 – Scenario 2



The results from this exercise indicate that Japan's ability to switch to alternative fuels will greatly impact its dependence on foreign oil. In Scenario 1, in the base case (2.5% growth), Japanese oil demand is projected to increase by 2.8 million barrels per day. This represents an approximate 50% increase from 1995, and is quite significant when considering energy security issues. In Scenario 2, however, this increase is much less pronounced, only 1.28 million barrels per day, due to fuel switching in the residential and commercial and industrial sectors. The assumption that oil's share of total energy in transport remains unchanged in both scenarios is based on the nature of fuels used for mobility. If the development of alternative modes of transport, such as fuel cells or electricity, is sufficiently rapid, then the increase in Japanese oil demand will be even smaller. Implicitly in Scenario 2 we have allowed for technological change in the residential and commercial and industrial sectors.

Implications

The above forecasts, in any of the indicated scenarios, have important implications for both energy security and environmental goals. Dependence on imported energy has been a primary concern of the Japanese government throughout the post World War period. Japan has few domestic energy resources, and, in 1998, imported more 80% of its primary energy requirement. This represents a decline in the share of international energy dependence in the past few decades reflecting a number of policies, including the development of nuclear power and the discouragement of private use of automobiles. Absent any energy efficiency gains or alternative fuels, however, any increase in energy demand will result in an increasing dependence on foreign resources. Given current projections of economic growth of the developing world, Japan will be competing for scarce resources with an increasing population. The extent to which this will drive up energy prices could impact economic growth.[10]

Given current technologies, transport services are dependent on (imported) oil. The projected growth of the transportation sector dictates that oil demand could increase dramatically. Under scenario 1 (see table 2), oil use in the transportation sector will increase by 69.4% between 1995 and 2015 increasing the share of the transport sector in total oil use from 37.2% to 43.1% of final consumption. Oil use in the residential and commercial sector is predicted to increase by 116.1%, assuming the share of various energy sources remain at the 1995 levels. The share of total oil used by this sector increases from 17.0% to 25.1% of final consumption. By comparison, oil demand in the industrial and other sector will only increase by less than one half of 1%. The result of these trends will be to raise the share of oil in total energy consumption.

Even at the current level of import dependence, Japan is vulnerable to supply disruptions. And while all countries, given the global nature of the international energy market, will be subject to oil price variability, Japan is particularly vulnerable to short term supply interruption because of its dependence on oil for such a high proportion of its energy needs. The geographic source of supply also affects Japanese vulnerability. Japan currently imports over 75% of its oil from OPEC countries, primarily from the Persian Gulf producers. This represents a substantial increase from 1988 when only 57% of Japanese demand was met from the Persian Gulf. Even more significantly, two countries, the UAE and Saudi Arabia account for 65% of Japanese imports.

Since Japan is relatively isolated from both major producers and consumers of oil, the flow of oil to Japan will take longer to adjust to short term disruptions in supply than other major users such as Europe and North America where distances from most sources of supply are relatively short. Tankers will be able to be redirected and the flow of oil altered in less time than it would take in the Far East. The time required to recognize the problem, place orders from alternative sources, and have tankers make the trip to Japan could easily take a month. To deal with the risk of disruptions and to accommodate such lags in adjustment, Japan maintains precautionary oil stocks.

There are several policy options available to Japan to reduce the cost of energy supply shocks.[11] First, Japan can continue to diversify its energy mix, especially in

---

[10] The macroeconomic effect of increasing energy prices is a well-investigated topic. Evidence suggests that the short run impact is negative, but the long run effects are less clear, as they can be mitigated by technological improvements.

[11] Costs of energy interruptions include the storage costs of precautionary stocks, the opportunity cost of the inventories and reductions in GDP that might arise if there were short-term reductions in available energy.

the production of electricity. Further development of nuclear power and hydroelectric power could significantly reduce Japanese exposure to oil supply disruptions. Scenario 2 shows that if oil's share in the residential and commercial sector falls from 51% to 36.9%, primarily by shifting electricity generation from oil to nuclear, then the growth in oil imports will be 1.28 million b/d rather than 2.53 million b/d.

On the other hand, if the high cost of nuclear power and public concern about the safety eliminate further expansion of nuclear energy, then we can expect Japanese oil demand to increase. In order to calculate the effect of cancelled nuclear power plants on total oil demand, we construct a Scenario 3. Here, we assume that oil is imported to account for the *loss* in nuclear power generation. Nuclear power, however, serves no purpose for transportation. Therefore, the increase in oil imports for transportation is unaffected. All of oil displacement (or *non*-displacement) occurs in the other two sectors, where electricity is consumed. In particular, if nuclear energy were to remain 21.0% of total primary demand in the industrial and residential and commercial sectors, then, based on our forecasts, nuclear power generation would have to expand by an estimated 81 billion kWh by 2010 and 114 billion kWh by 2015. If this expansion does not occur, Japanese oil demand would increase by 436,000 b/d in 2010 and 540,000 b/d in 2015 over and above the projected values in Scenario 1. This rounds out to an increase in total imports of 3.07 million b/d in 2015 in Scenario 1.

A second policy alternative is to diversify energy imports geographically. This policy also involves a shift in the fuel mix from oil to natural gas. In particular, the development of Russian gas for export to Japan would reduce dependence on the Middle East and reduce the associated risk of that dependence. While transport costs whether by pipeline or liquification, will be high, some of the cost of transport will be shifted to the Russian exporters[12].

A third alternative is to develop alternative energy sources, new technology that further increases the efficiency of existing fuels or to increase conservation efforts. Hydroelectric plants have the capacity to minimize some of the impact of the cancellation of nuclear facilities. Solar is one of the more promising new energy

[12] In an unregulated market Russian gas would have to compete with oil so that the Russian suppliers would have to absorb as much of the transport costs as is necessary to be competitive. Ironically, by requiring utilities to shift to natural gas for environmental of energy security reasons, the Japanese increase the bargaining power of the Russian gas suppliers, permitting them to shift more of the transport costs forward to Japanese buyers.

sources but current costs are prohibitive of widespread implementation. The recently introduced hybrid gas-electric automobiles are very fuel-efficient, and have the potential to more than double automotive fuel efficiency. The widespread diffusion of this technology would alter our projections of energy demand in the transport sector considerably. Fuel cells, both for use in motor vehicles as well as stationary power, are of interest primarily for environmental reasons. At present, however, this technology is also not competitive.

The construction of a national energy grid would also facilitate the development of hydroelectricity. Most of the hydroelectric capacity in Japan is currently available only in particular regions. The power generated by these facilities cannot currently be sold over long distances due to the structure of the electricity industry (see Hartley, in this study, for more on the electricity industry). Increased competition in wholesale and retail markets, facilitated by "connecting" the existing vertically integrated electricity industry, would encourage a greater amount of non-fossil fuel based electricity generation, provided hydro, nuclear, and other alternatives are cost competitive. As a result, aside from eliminating the economic inefficiency of monopoly markets, increased competition could actually decrease Japanese reliance on coal and oil for electricity generation.

The development of a national gas grid would facilitate Russian gas imports and enhance geographic diversification of energy supplies. In addition, a national gas network would reduce the amount of gas storage needed. Moreover, installation of suitable infrastructure to import natural gas from Russia would reduce the energy cost of consuming natural gas in Japan. Currently, liquefied natural gas (LNG) is imported via tankers to meet gas demand, a very costly procedure. Reducing the cost of natural gas, the cleanest of the fossil fuels, could encourage a switch away from oil and coal, an environmentally desirable benefit.

The role that Japan has taken in negotiating efforts to combat global warming indicates that it will most likely try to prevent any rapid increase of domestic consumption of fossil fuels domestically. Meeting carbon dioxide (CO_2) emissions limitations, as prescribed by the Kyoto Protocol, can be done in a number of different ways. These include the clean development mechanism (CDM), land-use changes, and tradable emissions quotas[13], as well as direct reduction through reducing fossil

[13] See MacCracken, et al (1999) for a good discussion of these issues.

fuel consumption. Already, Japan is making use of the CDM. Land-use changes, due to the geographic nature of Japan, will probably not count for very much in CO_2 emission reduction credit. The majority of reduction credit, therefore, will have to come from either tradable permits or direct domestic abatement. As a result, the role of technology could be large.

Given our projections for energy and oil demand, the message, from a policy perspective, is clear. Technological advancement is an important part of long-term energy security, and, therefore, should be strongly encouraged. If there is significant advance in alternative fuel technology, to the point where it is cost-effective, then neither energy security nor environmental goals will be compromised by an increasing demand for energy. These innovations, however, are more likely to take place in the longer term, beyond the time span of the above forecasts.[14] Meanwhile, Japan needs to pursue three principal policy goals:

- Continue to promote gains in energy efficiency
- Develop natural gas supplies from Russia, and
- Build national gas and electricity grids.

The more Japan succeeds in reaching these goals, the more resilient it will become to energy supply disruptions.

[14] See Hartley and Medlock (2000) for more on the environmental impacts of rates of innovation.

References

- Chenery, Hollis B. and Moises Syrquin. *Patterns of Development, 1950-1970*. London: Oxford University Press, (1975).

- Dargay, Joyce and Dermot Gately. "Income's Effect on Car and Vehicle Ownership Worldwide: 1960-2015," *Journal of Transport Economics and Policy* (1998).

- Eden, Richard, Michael Posner, Richard Bending, Edmund Crouch and Joe Stanislaw. *Energy Economics: Growth, Resources and Policies*. Cambridge University Press (1981).

- Hartley, Peter and Kenneth B. Medlock III. "The Urgency of CO_2 Controls." James A. Baker III Institute for Public Policy Working Paper (2000).

- Judson, Ruth A., Richard Schmalansee, and Thomas M. Stoker. "Economic Development and the Structure of the Demand for Commercial Energy," Energy Journal, Vol. 20, No. 2 (1999), pp. 29-57.

- Kuznets, Simon. *Economic Growth of Nations: Total Output and Production Structure*. Cambridge MA: The Belnapp Press of Harvard University Press (1971).

- MacCracken, Cristopher N, James A. Edmonds, Son H. Kim, and Ronald D. Sands. "The Economics of the Kyoto Protocol," *Energy Journal - Special Issue* (1999).

- Medlock III, Kenneth B. and Ronald Soligo. "Economic Development and End-Use Energy Demand." James A. Baker III Institute for Public Policy Working Paper (2000).

- ___________________________________. "Automobile Ownership and Economic Development: Forecasting Passenger Vehicle Stocks to 2015." James A. Baker III Institute for Public Policy Working Paper (2000b).

Data Sources

EnergyPrices and Taxes, IEA, various issues.
Energy Statistics of OECD Countries, IEA, various issues.
Energy Statistics and Balances of Non-OECD Countries, IEA, various issues.
Energy Statistics Yearbook, various editions. United Nations.
International Energy Annual, EIA, various years.
OECD Historical Statistics, 1960-1995.
Penn World Tables 5.6 (http://cansim.epas.utoronto.ca/).
Statistical Yearbooks for the various countries studied.
World Bank Development Indicators, 1997. World Bank

Appendix I

The countries, by geographic region, included in the study are:

Asia/Pacific -

Pakistan, India, China, Indonesia, Thailand, Malaysia, South Korea, Japan, Australia

Europe -

Turkey, Greece, Portugal, Spain, Ireland, Austria, Italy, Belgium, Netherlands, United Kingdom, France, Finland, Sweden, Denmark, Norway

North/South America -

Canada, United States, Mexico, Brazil

Appendix 2

Results from Medlock and Soligo (2000)

Note: Please see above reference for a discussion of the procedures involved in estimation as well as a complete discussion of the model formulation.

The model:

$$\ln ec_{t,j,i} = \alpha_{j,i} + \beta_1 \ln p_{t,j,i} + \beta_2 \ln y_{t,i} + \beta_3 \left[\ln y_{t,i}\right]^2 + (1-\gamma)\ln ec_{t-1,j,i} + \varepsilon_t$$

This generates an income elasticity of:

$$\frac{\beta_2 + 2\beta_3 \ln y_{t,j}}{\gamma}$$

This will decline as income increases provided $\beta_2 > 0$ and $\beta_3 < 0$.

Estimated coefficients (w/ standard errors in parenthesis):

Estimated Coefficient	Residential and Commercial	Transportation	Industrial and Other
α_i	---	---	---
β_1	-0.0939	-0.0938	-0.0664
	(0.0216)	(0.0124)	(0.0157)
β_2	0.4632	0.4958	0.9531
	(0.2034)	(0.1371)	(0.2228)
β_3	-0.0222	-0.0188	-0.0493
	(0.0114)	(0.0078)	(0.0126)
$1-\gamma$	0.9292	0.8196	0.7541
	(0.0318)	(0.0337)	(0.0326)
R^2	0.9266	0.9584	0.8907
LR Coefficient			
b_1	-1.3263	-0.5200	-0.2700
b_2	6.5424	2.7483	3.8760
b_3	-0.3136	-0.1042	-0.2005