Demand for ground transportation fuel and pricing policy in Asian Tigers

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Demand for Ground Transportation Fuel and Pricing Policy in Asian Tigers: A Comparative Study of Korea and Taiwan

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This paper examines the demand for gasoline and diesel in the ground transportation sectors of South Korea and Taiwan, comparing the effects of their different pricing policies and stages of economic growth. To account for substitutability between the two fuels, the model proposed here uses a system of equations estimated simultaneously with time-series data from 1973-1992. Results yield demand elasticities that confirm previous research showing that oil product demand is generally price inelastic, while income elasticities (reflecting a longer period of economic growth than previous studies in the Asian region) are lower than those previously reported. The estimated demand functions are then used to generate forecasts for both countries and, in particular, for an assumed reduction in a 180% tax on gasoline in Korea. Forecasted increases in demand by the year 2010 range from 40 to 180%, while the tax analysis suggests that Korea’s pricing policy has reduced total demand and promoted the use of diesel over gasoline.

INTRODUCTION

The world energy market is increasingly dominated by countries in the Asia-Pacific region. For example, oil demand in the Asia-Pacific region already exceeds that of Western Europe and will soon surpass North America. More than half of this regional demand is met by imports, which come primarily from the Middle East. Thus, in order to understand the world energy market, it is important that policy makers assess the nature and characteristics of the demand

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for petroleum and its products in Asia. This will help them develop pricing and taxation policies, negotiate free trade agreements, determine future investment needs and address accompanying environmental problems arising from the combustion of fossil fuels.

South Korea (henceforth called Korea) and Taiwan have been two of the most rapidly growing economies in the Asia-Pacific region. Both began experiencing sharply accelerated GDP growth rates in the 1960s. Less populous and with a smaller geographical area, Taiwan’s per capita income exceeds that of Korea, which has a larger economy in real dollar terms. Trends in energy intensity, or the amount of energy consumed per dollar of GDP, have differed somewhat for the two countries and could be indicative of slightly different patterns of development. Generally, as countries develop, their energy intensity increases for a period of time, before decreasing slightly and becoming stable (Nilsson, 1993). Between 1987 and 1992, Taiwan’s energy intensity dropped from 0.285 to 0.265 (toe/1,000 U.S. dollars of real GDP). During the same period, energy intensity in Korea increased from 0.310 to 0.362. It is worth noting that Korea also started its growth path from a much higher base of energy use (Petroleum Economist, 1992).

Differences between Korea and Taiwan are highlighted by the recent banking crisis in Asia which has disrupted economic growth and energy consumption in Korea (where annual gasoline and diesel use is expected to decline by over 100,000 barrels per day), while having a negligible impact on energy demand in Taiwan. While the time period examined in this paper does not include this recent crisis, the average energy consumption growth rates now projected for Korea over the long term are still within the range of high, medium and low economic growth scenarios examined here. Moreover, the price and income elasticities obtained here could be used in future work that focuses primarily on examining the impacts of the financial downturn on energy consumption.

Both Korea and Taiwan lack indigenous fossil fuel resources and rely heavily on imports for about 80% of total energy supply. These Asian tigers are also two of the heaviest energy price regulators within the Asian-Pacific region (Fesharaki, 1994). Expanding transport sectors in the two countries account for much of the fast growth in primary energy consumption for Taiwan and Korea—in fact, transport is the fastest growing component of world energy demand (The Economist, 1995). The spread of private vehicles and a rising desire for mobility together with commercial transportation drive gasoline and diesel consumption. Increases in gasoline and diesel demand affect the market for petroleum products as well as oil production and refining activity: the impacts are especially influenced by changing environmental regulation of sulfur levels in diesel and the contents of gasoline blends.
This paper will examine demand for gasoline and diesel in the transport sectors of Taiwan and Korea. Results for the two countries will be used to derive demand elasticities, make forecasts for consumption of the two fuels until the year 2010, and consider the supply-demand implications of alternative pricing policies. The next section reviews energy balances for these two Asian tigers, setting the contextual framework for transport energy demand and highlighting relevant similarities and differences between Korea and Taiwan. Following this, the methodology is developed along with a description of the data used in this study. Results from a time-series regression estimation are then presented as well as tests of model validity and demand forecasts. Finally, the concluding section examines policy implications of the analysis.

BACKGROUND

Energy Consumption in Korea

Korea and Taiwan are not very different from either Asia or the rest of the world in terms of sources of energy consumption. However, Korea imports essentially 100% of its oil, primarily from the Middle East. Anxious to reduce oil dependence, Korea has actively promoted the use of substitutes, particularly in the power sector where non-fossil fuel alternatives are more feasible. For instance, nuclear power supplies over 35% of the country's electricity compared with a share of 20% in the U.S. Imported natural gas has also been an important substitute.

The transportation sector, however, is heavily reliant on petroleum. Figure 1 shows the rapid growth in energy consumption by the transport sector. If energy trends in the U.S. or the OECD countries provide even a rough indication of what to expect, and Korea recovers from the current financial crisis as is widely expected by industry analysts, the transport sector of Korea could nearly double its share of energy (predominantly oil) use as the economy increasingly resembles that of a more developed country (see Figure 2).

Ground transportation in Korea is fueled by twice as much diesel as gasoline (Figure 3). About 5-10% of the diesel demand in recent years was met by low sulfur imports. Yet, Korea has actually been a net exporter of diesel, exporting higher sulfur products partly in exchange for lower sulfur imports which enable it to meet environmentally-based product specifications. Demand for Korea's high sulfur products in parts of Asia where less stringent environmental standards are currently in place will probably diminish in the future as diesel standards progressively tighten throughout the region.
Oil industry analysts argue that Korea’s heavy reliance on diesel stems from a national tax and price policy that maintained the highest gasoline-diesel price differential in the Asia-Pacific region (Fesharaki, 1994). Only in Singapore and Japan have consumers paid more in gasoline taxes. Retail gasoline prices in Korea have been among the highest in the region, surpassed only by Japan. Petroleum taxes in Korea at the end of the time-series were made up of three components: i) a 5% import duty on crude and products; ii) a Special Excise Tax (SET) levied on gasoline, diesel and LPG; and iii) a 10% value added tax (VAT) on all goods. In February 1994, the SET for gasoline was increased from 150 to 180% while that for diesel rose from 20 to 25%. Possible reasons for this tax differential are discussed below in the section on price sensitivity.

Efforts to deregulate the energy sector began in 1983 with the lifting of price controls on jet fuel and solvents. In March 1994, a floating oil system was initiated which allows domestic oil prices to vary once a month. As of January 1997, price controls on domestic gasoline and diesel were lifted, and the government intends to deregulate further in the near future (Fesharaki, 1994, p. 50). Meanwhile, as long as tax policy distorts market prices and maintains a large gasoline-diesel price differential, transportation fuel demand will continue to be greatly impacted.
Energy Consumption in Taiwan

With its smaller economy, Taiwan uses less oil today than Korea and its aggregate energy consumption is similar to that of Belgium or Turkey. Like Korea, however, virtually all of its oil is imported from the Middle East, and it too has actively sought to diversify its energy consumption, especially by promoting nuclear power and natural gas use in the electricity sector.

Taiwan’s transport sector has grown rapidly in energy consumption as shown in Figure 1, but the share of gasoline in transport surpassed diesel in 1980 and has been increasing ever since (see Figure 3). Given this difference with Korea, Taiwan has been much more reliant on gasoline imports, meeting one-third of its demand in 1996 with imported products, mostly from Singapore. Like Korea, Taiwan also exports high-sulfur petroleum fuels, and imports a relatively smaller amount with a lower sulfur content.

As in Korea, retail gasoline prices in Taiwan are among the highest in the region, but Taiwan does not maintain a large gasoline-diesel price differential through taxation. Its special energy excise tax rose in 1994 from 75 to 85% for gasoline and from 60 to 75% for diesel. A general value added tax has been levied at 5% since 1986. Although Taiwan began allowing the operation of private retail service stations in 1988, their sole supplier is a state-owned company (a privately owned refinery is under construction). Also, unlike Korea and other major price regulators in the region, the Taiwanese government has been slower in outlining plans to deregulate.
Figure 3. Gas and Diesel Shares of Ground Transport Energy Use

Taiwan

Korea
Comparison

Korea and Taiwan have several basic similarities and differences relevant to their energy, and specifically transportation, sectors. Both lack indigenous fossil fuels and have policies designed to avoid over-reliance on imported oil. Soaring costs of imports, for example, forced both countries in 1991 to release stocks from their strategic reserves (Petroleum Economist, 1992). On the other hand, these two countries differ in geographical area and economic size, and in their patterns of development as reflected in their energy consumption patterns and pricing policies.

Several other factors influence more directly a comparison of gasoline and diesel consumption in the transport sectors of Korea and Taiwan. Compared to Taiwan, Korea has moderate coal resources, which together with its rapidly expanding petrochemicals industry provide a sharp contrast to the case of Taiwan. It is important to observe how gasoline and diesel play very different roles in transportation in each country. Korea uses twice as much diesel as gasoline, a trend more common in developing economies, while Taiwan consumes an ever greater share of gasoline, following the general trend of industrialized economies. This is a result of a major difference in pricing policy—Korean taxes on gasoline are three to four times those on diesel, while Taiwanese consumers pay only twice as much tax for gasoline as for diesel. The model developed below will be used to test the sensitivity of transport fuel demand to alternative price policies.

METHODOLOGY AND DATA

The demand for transport fuels is derived from the demand for vehicle transport, for which gasoline, diesel, and motor vehicles are inputs in the production of transport services. Some studies propose estimating gasoline demand as a function of the existing stock of vehicles, their utilization (i.e., kilometers driven) and fuel efficiency (i.e., gasoline used per kilometer driven) (Greene, 1979; and Leung and Vesenka, 1987). A more elaborate version of this approach considers factors which explain geographical variance in demand through variables representing physiography, climate, level of traffic congestion and tourist travel, etc. (Greene, 1979).

Unfortunately, using these models in forecasting would require one to first obtain forecasts of all the exogenous variables involved. Moreover, even the data needed to estimate these models—such as the fuel efficiency for different types of vehicles and distances driven—can be difficult if not impossible to gather. Instead, researchers often rely on the argument that “both utilization and efficiency factors are reflected in income and gasoline price [variables]” (Al-Faris, 1992, p. 215). Demand is generally estimated as a
function of income and price, however much they inherently represent variations in vehicle utilization or fuel efficiency.

Still, the range of functional approaches and variables used reflects a host of additional considerations. For instance, the use of a lagged endogenous variable is popular because of data limitations and because it facilitates estimation of both long- and short-run demand elasticities. However, it often introduces collinearity if an income variable is also present. This causes instability and has a greater impact on elasticity estimates of long-run price compared to long-run income (Dahl, 1994).

To date, very little work has been done on transport sector fuel demand in the economically important and fast-growing Asia-Pacific region. McRae (1994) recently estimated gasoline demand and corresponding elasticities for eleven developing countries in Asia using a vehicle stock variable, but he did not consider the interaction between diesel and gasoline consumption. Neither did Garbacz (1989) who estimated gasoline and diesel demand for Taiwan, both with and without a vehicle stock variable. A study by the World Bank (Gately and Streifel, 1997) examined petroleum product demand in 37 developing countries without distinguishing the final demands (such as transportation, heating, etc.) from which fuel demand is derived. The authors consider and compare several functional forms, but do not incorporate competition between fuels.

Dahl’s (1994) survey of the literature on oil product demand shows, for instance, how including vehicle stock in a model with a lagged endogenous variable “dramatically lowers price and income elasticities” (Dahl, 1994, p. 51). It is worth noting that counter to Dahl’s theory, McRae (who does use a stock variable) estimates income elasticity for gasoline demand in Taiwan to be 0.81 which is higher than Garbacz’s results (with no stock variable) of 0.55 and 0.33 for the linear and logarithmic models, respectively. Since Dahl’s observations are of interest, results from the model used here are compared below to these earlier results. However, both of the approaches above overlook the substitutability of gasoline and diesel in transportation, a fundamental influence on demand. Thus, estimating systems of demand equations simultaneously should yield higher price elasticities.

Miklius et al. (1986) confirm this in their study of seven developing countries in Asia using a standard market share model. They estimate two equations simultaneously—one for total consumption of gasoline and diesel combined, and one for the share of gasoline (or diesel) out of total consumption. In this and other market share models (Greene, 1993), the market shares (those of gasoline and diesel in this case) must sum to one. To avoid a singular system of equations, one of the market shares is dropped (either gasoline or diesel) and is estimated later by using the constraint (the share of diesel, for example, is equal to one minus the share of gasoline). Using this approach, Miklius et al.
report significantly higher elasticities. They also use the model to forecast demand for individual countries.

Unfortunately, several aspects of their approach make it difficult to evaluate the accuracy of their forecasts. First, the data collected at the time did not always distinguish between end-uses of diesel fuel. While some countries use diesel primarily for transportation, the industrial sector also consumes diesel, and in Korea, a sizable portion is used in agriculture, mostly for irrigation. Since Miklius et al. pooled data for seven countries, their model probably reflects some indeterminable combination of diesel use in transport plus diesel use in other sectors. Thus, one cannot compare their predictions with actual demand. Although the simultaneous equation approach to estimating fuel demand taken by Miklius et al. seems more appropriate, it has been overlooked in the literature, perhaps in favor of simpler demand models and estimation techniques. In this paper, we adopt the Miklius et al. approach by using a multi-equation demand system. We use this to draw comparisons between gasoline and diesel consumption patterns in Korea and Taiwan and thus provide further test of the validity of this important modeling technique.

Applied individually to Korea and Taiwan, the model used here has two parts. The total demand of gasoline and diesel together (TC) is estimated as a log-linear function of: i) the weighted average of real diesel and gasoline prices (P); ii) real per capita gross domestic product (GDP); and iii) the total consumption of both fuels in the preceding year (TCP). The regression equation is written as follows:

\[
\ln TC = b_0 + b_1 \ln P + b_2 \ln GDP + b_3 \ln TC_P
\]

(1)

where

\[
P = \{DC/TC \cdot DP\} + \{GC/TC \cdot GP\}
\]

(2)

and

\[
DC = \text{Per capita diesel consumption}
\]

\[
GC = \text{Per capita gasoline consumption}
\]

\[
TC = DC + GC
\]

\[
DP = \text{Real diesel price, and}
\]

\[
GP = \text{Real gasoline price.}
\]

In addition, the market share of one of the two fuels (either gasoline or diesel) out of total consumption (i.e., gasoline and diesel) is estimated as a function of that fuel's real price, the real price of its substitute, real per capita domestic product, and the share of that fuel in the previous year. Because the shares of gasoline and diesel together sum to one, only one of the two shares needs to be estimated. In this estimation, prices of the two fuels are incorporated as a difference (i.e., \( GP - DP \)) in order to avoid problems created by using two
separate prices moving in a parallel fashion. The estimated regression equation for gasoline, for example, is as follows:

\[ \ln(GC/TC) = a_0 + a_1 \cdot \ln(GP-DP) + a_2 \cdot \ln GDP + a_3 \cdot \ln(GC/TC), \]  

and therefore,

\[ DC/TC = 100 \cdot \exp[\ln(GC/TC)]. \]  

Use of the log-linear form in both equations enables easy derivation of both short- and long-run elasticities of demand. The system is estimated with fuel consumption data from the International Energy Agency (IEA) Energy Statistics and Balances (obtained on diskette), while prices and GDP as well as deflators and population data are obtained from the Asian Development Bank (Energy Indicators of Developing Member Countries of the Asian Development Bank). The estimation is performed by using the iterative nonlinear three-stage least squares procedure available in SHAZAM software (version 6.2).

RESULTS AND FORECASTS

Estimation results for Taiwan and Korea using data from 1973-1992 appear in Table 1. Almost all coefficients have the correct sign and are significant at the 95% confidence level. High R² statistics for all equations indicate goodness of fit. Attempts to include an industrialization ratio variable are not reported since it does not produce significant results; this information is most likely captured by the GDP variable.

The only non-significant coefficient is the income (GDP) variable in the share equation for Korea; the Miklius et al. study reported a similar result. Note that in the total demand equation for Taiwan, the income coefficient is also not significant to the 95% confidence level, but is significant at the 90% confidence level. Given these results, one cannot say with confidence whether income has a role in determining the gasoline-diesel split for less developed countries such as Korea. Such countries may have more flexibility or choice in the type of infrastructure (especially vehicle stocks and refining capabilities) to accommodate gasoline or diesel consumption, so income may be less influential. In fact, for the estimated systems reported in Table 1, the income coefficient is larger in the total demand equation than it is in the share equation. In other words, within a country (or region, in the case of Miklius et al.), income has a relatively greater influence on aggregate transport fuel demand than on whether that fuel is gasoline or diesel.
Table 1. Estimated Total Consumption and Market Share Equations*

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Weighted Average Price (P)</th>
<th>Gas-Diesel Price Diff. (GP-DP)</th>
<th>Real GDP /Capita (GDP)</th>
<th>Lagged TC</th>
<th>Lagged Market Share</th>
<th>R-squared</th>
<th>System R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAIWAN TC (total demand)</td>
<td>0.848</td>
<td>-0.124</td>
<td>0.233</td>
<td>0.761</td>
<td>0.9966</td>
<td>0.9995</td>
<td></td>
</tr>
<tr>
<td>GC/TC (gasoline share)</td>
<td>-0.297</td>
<td>-0.043</td>
<td>0.065</td>
<td>0.588</td>
<td>0.9528</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KOREA TC (total demand)</td>
<td>2.653</td>
<td>-0.385</td>
<td>0.439</td>
<td>0.556</td>
<td>0.9779</td>
<td>0.9970</td>
<td></td>
</tr>
<tr>
<td>GC/TC (gasoline share)</td>
<td>1.550</td>
<td>-0.185</td>
<td>0.044</td>
<td>0.691</td>
<td>0.7916</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*t-ratios in parentheses, \( n = 20 \) (number of observations)
The corresponding coefficients from the total consumption equation also provide direct estimates of short-run price and income elasticities for overall ground transport fuel demand. The long-run elasticity is then calculated as the short-run elasticity divided by 1 minus the elasticity or coefficient of the lagged dependent variable. Along with results from previous research, these elasticities are summarized in Table 2.

Our elasticity results support Dahl’s (1994) conclusion that oil product demand is generally price inelastic. Counter to Dahl’s generalization, on the other hand, demand does not appear to be very income elastic in our study. Since our model does not contain a vehicle stock variable, one would expect that estimated demand elasticities may be somewhat higher than those estimated in similar studies using this variable. However, the fact that income elasticities are, for the most part, lower than those previously reported might indicate that the extended time series of this study reflects other factors such as the advancing development and energy maturity of these two Asian tigers. This is supported by results from McRae (1994), who used a shorter time series within the same period and estimated a higher income elasticity for gasoline in Taiwan. Thus, income elasticity for Taiwan, where energy intensity has stabilized, is lower than in Korea where energy intensity is still increasing. As pointed out by a referee, increasing income in Korea may imply a greater transition to motorized vehicle use than in Taiwan, which is a more mature and more motorized economy. In this case, incorporation of vehicular data in the analysis would decrease the income elasticity for Korea more than it would for Taiwan.

Results reported here, however, differ with the generalization put forth by McRae (1994) after examining gasoline demand in eleven Asian countries. He asserts that price elasticities are lower in low-income Asian countries versus middle-income Asian countries, because energy is necessary to development in the low-income countries which are therefore less sensitive to price change. He identifies both Taiwan and Korea as middle-income countries, but does not compare price elasticities among these countries. (The price coefficient for Taiwan is not significant in his country-by-country regression results.) Perhaps among middle-income Asian countries such as Taiwan and Korea, differences in income do not help determine differences in price elasticity. This may explain why, in the results presented here, price elasticities are lower in the higher income country (Taiwan) and higher in lower-income Korea.

Interestingly, aggregate demand elasticities reported here for Korea and Taiwan (except for short-run price elasticity in Taiwan) are larger in the short-run and smaller in the long-run than those estimated by Miklius et al. for seven countries. Apart from Korea, the other countries in their pool—Bangladesh, India, Indonesia, Philippines, Thailand and Sri Lanka—have lower incomes, hence smaller long-run elasticities for income are expected. The difference in results for the long-run elasticities might also reflect the use of a longer time
Table 2. Estimated Elasticities

<table>
<thead>
<tr>
<th></th>
<th>TAIWAN</th>
<th>KOREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banaszak, et al. (1999)</td>
<td>aggregate demand</td>
<td></td>
</tr>
<tr>
<td>sample years 1973-92</td>
<td>short-run:</td>
<td>short-run:</td>
</tr>
<tr>
<td>2-equation system</td>
<td>-0.124 (weighted)</td>
<td>-0.385 (weighted)</td>
</tr>
<tr>
<td></td>
<td>0.233 (GDP)</td>
<td>0.439 (GDP)</td>
</tr>
<tr>
<td></td>
<td>long-run:</td>
<td>long-run:</td>
</tr>
<tr>
<td></td>
<td>-0.519</td>
<td>-0.866</td>
</tr>
<tr>
<td></td>
<td>0.977</td>
<td>0.989</td>
</tr>
<tr>
<td>Garbacz (1989)</td>
<td>aggregate demand</td>
<td></td>
</tr>
<tr>
<td>sample years 1954-85</td>
<td>short-run:</td>
<td>short-run:</td>
</tr>
<tr>
<td>1 equation</td>
<td>-0.338 (Price)</td>
<td>-0.496 (Price)</td>
</tr>
<tr>
<td></td>
<td>0.490 (Income)</td>
<td>0.810 (Income)</td>
</tr>
<tr>
<td></td>
<td>long-run:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1.650</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.460</td>
<td></td>
</tr>
<tr>
<td>McRae (1994)</td>
<td>gasoline demand only</td>
<td></td>
</tr>
<tr>
<td>sample years 1973-87</td>
<td>short-run:</td>
<td>short-run:</td>
</tr>
<tr>
<td>1 equation, stock variable</td>
<td>(insignificant)</td>
<td>-0.496 (Price)</td>
</tr>
<tr>
<td></td>
<td>0.810 (Income)</td>
<td>(insignificant)</td>
</tr>
<tr>
<td>7-COUNTRY POOL</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>TAIWAN</th>
<th>KOREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miklius, et al. (1986)</td>
<td>aggregate demand</td>
<td></td>
</tr>
<tr>
<td>sample years 1974-81</td>
<td>short-run:</td>
<td>short-run:</td>
</tr>
<tr>
<td>2-equation system</td>
<td>-0.132 (weighted)</td>
<td>-0.132 (weighted)</td>
</tr>
<tr>
<td></td>
<td>0.077 (GDP)</td>
<td>0.077 (GDP)</td>
</tr>
<tr>
<td></td>
<td>long-run:</td>
<td>long-run:</td>
</tr>
<tr>
<td></td>
<td>-2.722</td>
<td>-2.722</td>
</tr>
<tr>
<td></td>
<td>1.588</td>
<td>1.588</td>
</tr>
</tbody>
</table>
series which more accurately captures full adjustments in consumption. Greater short-run elasticities may also have been influenced by the extended time series if in recent years the promotion of public transportation has led to substitutability and increased fuel demand responsiveness to both price and income.

Model Validation

In addition to the high R² statistics reported in Table 1, several criteria can be used to evaluate the multi-equation model, particularly with regard to its forecasting ability. For within sample validation, the estimated equations are used to predict all endogenous variables (total consumption and fuel shares for Taiwan and Korea) for the sample period, producing quite robust predictions compared to actual values. The Root Mean Square Error (RMSE) was found to be fairly low for all of the equations. Labeled as a measure of forecast quality, Theil’s U₂ can range from 0 to infinity, where 0 represents a perfect forecast and 1 is a no-change forecast. The values for Theil’s U₂ range from 0.28 to 0.7 and are lower for total consumption than for the share variable.

The within sample predictions are also evaluated for the number of turning point errors—or instances where the sign of the actual change between periods differs from the sign of the predicted change. The average percent error of prediction for turning points is lower for Taiwan than Korea and lower for total demand than for fuel share. All average percent errors range from 7% to less than 1%. Thus, what appears to be good tracking between actual and predicted values is confirmed by low average percent errors of prediction, which suggests that the model may be useful for forecasting purposes.

Table 3. Parameter Forecasts: Average Annual Growth Rates(%)*

<table>
<thead>
<tr>
<th>GDP (per capita)</th>
<th>PRICES - LOW</th>
<th>PRICES - HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gasoline</td>
<td>Diesel</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993-2000</td>
<td>3.5</td>
<td>3.3</td>
</tr>
<tr>
<td>2000-2010</td>
<td>2</td>
<td>2.2</td>
</tr>
<tr>
<td>Bass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993-2000</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>2000-2010</td>
<td>5</td>
<td>2.2</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993-2000</td>
<td>8</td>
<td>3.3</td>
</tr>
<tr>
<td>2000-2010</td>
<td>5</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*based on Pacific Energy Outlook, East-West Center, Tables 2.1, 2.3

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Forecast

Estimation of the above demand equations is used to make forecasts for the period 1993-2010. While these forecasts predate Asia's recent financial crisis, they are still useful in making a number of interesting comparisons. In the first step, forecasts of the exogenous variables (GDP and fuel prices) are developed from the Pacific Energy Outlook published by the East-West Center. Three alternative rates of growth in GDP are considered—a base case, low growth and high growth. Each case is forecast under two increasing fuel price scenarios, since constant and falling prices for gasoline and diesel are both highly unlikely. Table 3 summarizes the growth rates of these independent variables.

As summarized in Table 4, the forecast results produce trends that conform to expectations. For example, the highest increase in total consumption occurs with the highest predicted growth in GDP and the lowest increase in prices. Likewise, the lowest increase in total consumption follows from low growth in GDP and high growth in prices. These two extreme scenarios are illustrated along with the base case in Figure 4. The effect of high GDP growth relative to the base case on total consumption is approximately the same in both countries, increasing final demand in 2010 by about 13%.

In both countries, total consumption in 2010 is affected more by different GDP growth rates than by differing price scenarios. At the same time, GDP growth rates have a smaller impact (in percentage terms) on the demand shares of gasoline or diesel. In Taiwan, the GDP effect on the share of each fuel used is greater than a shift in shares due to a change in prices. In Korea, on the other hand, the shift in shares of gasoline or diesel consumed changes more with different price scenarios than with GDP growth. This difference between Korea and Taiwan is explained partly by the assumptions on the price scenarios which predict shifts in the gasoline-diesel price differential. These shifts lead to a greater price scenario impact in Korea where the gasoline-diesel price differential is currently much larger than in Taiwan.

Forecasts derived from the model are lower than those made around the same time by the Program on Resources: Energy and Minerals at the East-West Center in Honolulu (unpublished). In the case of Taiwan, growth rates in gasoline consumption predicted by the high GDP, low prices scenario are roughly similar to those of the East-West Center. Diesel consumption cannot be compared because East-West Center predictions do not identify transport use separately. In Korea, forecasts for gasoline demand only become comparable to those made by the East-West Center when a decrease in gasoline taxes is considered (see below).
<table>
<thead>
<tr>
<th>Year</th>
<th>Total Consumption</th>
<th>Gasoline Consumption</th>
<th>Diesel Consumption</th>
<th>Year</th>
<th>Total Consumption</th>
<th>Gasoline Consumption</th>
<th>Diesel Consumption</th>
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<tbody>
<tr>
<td><strong>SOUTH KOREA</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>TAIWAN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Case (low GDP, high prices)</td>
<td></td>
<td></td>
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<td>Low Case (low GDP, high prices)</td>
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<tr>
<td>2000</td>
<td>290.46</td>
<td>76.60</td>
<td>213.87</td>
<td>2000</td>
<td>444.95</td>
<td>301.08</td>
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<td>297.20</td>
<td>71.24</td>
<td>225.96</td>
<td>2005</td>
<td>469.14</td>
<td>316.15</td>
<td>152.99</td>
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<tr>
<td>2010</td>
<td>311.73</td>
<td>70.62</td>
<td>241.11</td>
<td>2010</td>
<td>492.25</td>
<td>329.41</td>
<td>162.83</td>
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<tr>
<td>Base Case (base GDP, low prices)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2000</td>
<td>360.38</td>
<td>99.68</td>
<td>260.70</td>
<td>2000</td>
<td>516.09</td>
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<td>2005</td>
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<td>314.91</td>
<td>2005</td>
<td>622.64</td>
<td>440.74</td>
<td>181.91</td>
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<tr>
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<td>128.92</td>
<td>386.06</td>
<td>2010</td>
<td>750.31</td>
<td>539.77</td>
<td>210.55</td>
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<td>High Case (high GDP, low prices)</td>
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<td>High Case (high GDP, low prices)</td>
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<td>2000</td>
<td>563.92</td>
<td>398.96</td>
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<tr>
<td>2005</td>
<td>483.58</td>
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<td>353.99</td>
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<tr>
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<td>148.61</td>
<td>434.16</td>
<td>2010</td>
<td>847.91</td>
<td>622.64</td>
<td>225.27</td>
</tr>
</tbody>
</table>
Figure 4. Total Consumption Forecasts

Taiwan

Korea
Price Sensitivity

The estimated model is used here to forecast how both total demand and fuel shares would be affected by a change in Korea's pricing policy. Let us assume that with deregulation, Korea lowers its Special Excise Tax (SET) on gasoline from 180% to 60%. This brings Korea closer to APEC averages and to Taiwan, both in terms of total tax on gasoline and tax-induced gasoline-diesel price differentials. Two possibilities are considered: i) a one-time, immediate SET reduction to 60% in 1996; and ii) a gradual decrease in SET—at the rate of 30% per year—to 60%.

Under both tax reduction scenarios, total fuel demand by 2010 is higher than all other forecast cases, except for the extreme case of high GDP growth and relatively lower prices. As expected, the share of gasoline in fuel consumption increases dramatically in both cases, although by 2010, it actually decreases slightly. Nevertheless, reducing the gasoline SET in either scenario increases the share of this fuel from the 22-25% range to around 45% while total gasoline demand increases by 90-100%.

It appears, then, that Korea's tax policy both restricts total transport fuel demand and promotes the use of diesel over gasoline. Also, the Korean government appears to respond to externalities associated with fossil fuel use, since it uses tax revenues to finance not only price stabilization and stockpiling but also an oil-quality check system and social infrastructure and development projects (Fesharaki, 1994). The latter may include public transportation, such as the plan for building a high-speed railway which has now been deferred because of the current economic crisis.

On the other hand, it remains a bit of a mystery why diesel is favored so heavily over gasoline as a road transport fuel. Less developed countries may initially favor diesel because of its use in the agricultural sector, e.g., in operating farm machinery. The agricultural sector may be larger in Korea than in Taiwan, but it is far from being the largest in the region. Historically, gasoline may also have been viewed as a luxury fuel (associated with private vehicle ownership) and thus subject to heavier taxes. Yet, given the projected relative rise in diesel prices and the strain on regional supply that price increases reflect, the Korean government may need to re-examine its tax policies.

CONCLUSIONS

This paper has used a multi-equation model to estimate transport sector demand for two substitutable fuels, gasoline and diesel, in Korea and Taiwan. The results demonstrate that income has a relatively greater (at least 3-4 fold) effect on aggregate transport fuel demand than on whether that fuel is gasoline or diesel. In addition, estimated demand elasticities conform with previous
research showing oil product demand to be generally price inelastic. Supporting
the hypothesis that income elasticities are lower in higher income countries,
GDP elasticities in this study (which includes recent, high-income years for
Korea and Taiwan) are lower than those previously reported, and they are lower
for Taiwan than for Korea.

The forecasts derived from this model suggest that total demand and
fuel shares respond differentially to changes in GDP and prices. Given the
assumptions made regarding growth in income and prices, by the year 2010,
total transport fuel demand could increase anywhere from 65 to 180% in Taiwan
and 40 to 160% in Korea. With an expected drop in economic growth rates for
Korea, transport fuel demand projections for Korea may be in the lower end of
that range. However, substantial increases (as much as a doubling) in transport
demand for gasoline and diesel have several implications for these two Asian
tigers. To meet this anticipated increase in demand, an expansion of refining
capacity was recently completed in Korea and is presently underway in Taiwan.
In Korea, the crisis has forced refiners to operate at reduced capacity while they
wait for fuel consumption and economic growth to resume. New capacity is also
having a significant impact on petroleum product markets throughout the region,
although the added refining capacity is not sufficiently sophisticated to maximize
production of gasoline and diesel—lighter products in a barrel of oil.

Regardless of expansion in refining capacity, any growth in fuel
consumption would exacerbate the issue of reliance on imported oil
(predominantly from the Middle East) in Taiwan and Korea. This is a source of
concern for government and policy makers in particular, who are worried about
the energy security and environmental implications of sizable oil imports. Fuel
substitution is not currently an economically competitive option for road
vehicles, although improvements in technology, including the development of
fuel cells, could change this picture radically in the next decade or so.

Government tax policies that aim to constrain fuel demand may have
unforeseen negative consequences. For example, Korea, with its tax-induced
reliance on diesel over gasoline, could soon find itself trying to meet diesel
needs in an international market where the price of diesel has risen above that
of gasoline (Fesharaki, 1995). Tax revenues, then, might better be used towards
developing alternatives to transport fuels such as through public transportation
projects. Expanding the model used here to include public transportation as a
third substitute in the demand for transportation could provide added insight into
this policy option. Finally, because a range of development patterns and fuel
pricing policies coexist in the Asia-Pacific region, an expansion of this study to
a larger sample of countries could enable further analysis of the influence of
alternative policy instruments as well as the testing of hypotheses concerning the
elasticity of transport fuel demand for developing countries in general. It is clear
from this research and others cited here that although the Asia-Pacific region is
the fastest growing energy market in the world, surprisingly few studies have focused on understanding the determinants of fuel demand in the countries of this region, which consists of economies positioned at radically different sections of the income-energy growth curve. Understanding the energy consumption patterns of the advanced economies in the region could provide insights into the nature of energy demand in heavily populated countries such as China and India that are only now beginning to graduate towards energy-intensive transportation and lifestyle choices.

The recent tightness in the global economy and in particular the banking crisis in Asia may have serious impacts on domestic demand for gasoline and diesel. Although current expectations suggest that long-run oil demand growth rates will still be in the low end of our forecast range, a global recession (as has been predicted by several analysts) is certain to push oil demand below the low range of our forecasts. If economic slowdown results in negative rates of economic growth, the lower income elasticities reported in this paper suggest that the effect on consumption of transportation fuels may be limited and may have more to do with government regulatory policies. On the other hand, economic slowdown and decline in consumption can cause a decline in oil prices, which in turn could stimulate consumption.

Further research could also focus on incorporating several variables whose omission may have introduced biases in the estimation of the price and income elasticities reported in this paper. For example, vehicle stocks as well as vehicle export and import policies may play a significant role in the fuel consumption decision. As pointed out by a referee, since the government is the major player in the energy sector of these two countries, policies such as fuel economy standards, road construction and provision of public transportation may have impacted consumption of transportation fuels significantly. Fuel use could be disaggregated by commercial and personal use in order to reveal the differential effect of government pricing policies on end-use patterns. As pointed out by a referee, commercial fuel use tends to be much less price elastic than personal use. Depending on the relative weights of end-uses, the use of aggregate consumption (as in this study) may have introduced biases in the regression coefficients. The results of this study could also be further tested with other models, such as a polynomial distributed (Almon) lag model.

An especially interesting area of further research may be the environmental impacts of fuel pricing and taxation policies. For example, Korea's promotion of diesel use over gasoline implies a higher emission of particulate matter emissions such as dioxins and NOX. However, if a significant use of diesel is in public transportation, then the emissions per passenger mile may be lower than that of gasoline. These emission trade-offs will become critically important with the expected ratification of a Climate Treaty which will entail significant emission reductions for both Korea and Taiwan.
REFERENCES


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