An Analysis of the Rapid Growth in Japanese Energy Demand Since 1987

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The purpose of this paper is to identify the sources of the rapid growth in energy demand in Japan that has occurred since 1987. The analysis focuses on sectoral demands. In the industrial sector changes in total final energy consumption are broken down into three components, those brought about by energy conservation, those resulting from changes in the mix of industrial output and those brought about by changes in the overall level of industrial activity. Changes in the industrial demand for purchased electric power are similarly decomposed into four components. In the residential, commercial and transportation sectors the demands for individual categories of end-use energies are related to a series of relevant variables in a multiple linear regression framework. The estimated parameters are then used to decompose changes in consumption that occurred in 1987 and 1988 into separate components caused by different factors. The paper concludes with some brief comments on the likelihood that the trends reported on in this paper will continue.

Les auteurs cherchent à déterminer les sources de la croissance rapide de la demande d'énergie enregistrée au Japon depuis 1987 en analysant la demande sectorielle. Dans le secteur industriel, l'évolution de l'ensemble de la consommation finale d'énergie est divisée en trois composantes, à savoir les changements attribuables aux mesures d'économie d'énergie, ceux qui résultent de la composition modifiée de la production industrielle et ceux qui tiennent à la progression du niveau général de l'activité industrielle. L'évolution de la demande industrielle d'énergie électrique achetée est pareillement ventilée en quatre composantes. Quant aux secteurs résidentiel et commercial et à celui des transports, la demande d'énergie selon les types particuliers d'utilisation finale est liée à un ensemble de variables pertinentes dans une formule de régression linéaire multiple. Les paramètres estimés servent ensuite à décomposer l'évolution de la demande de 1987 et de 1988 en composantes distinctes liées à différents facteurs. En conclusion, les auteurs y vont de quelques brèves observations sur la probabilité du maintien des tendances signalées dans l'article.

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The demand for energy in Japan began to grow very rapidly in the spring of 1987 and the growth trend intensified as business activity expanded. Energy demand grew by 4.9% on a primary supply basis in fiscal 1987 and by 5.5% in fiscal 1988[1] due to an upswing which appears comparable to the "Izanagi" boom in the period around 1970. Strong growth in domestic consumption has been the major cause of the economic expansion and a slowdown in energy conservation, caused by lower oil and other energy prices, has combined with it to boost energy demand. The Japanese energy-GNP elasticity was close to unity during 1987 and 1988. The elasticity coefficient has not been at this level for two consecutive years since 1973.

Breaking the growth down into types of final energy demand, in 1987 electricity demand increased by 6.0%, oil demand by 4.7% and town gas demand by 4.4%. In 1988, though temperature changes and other factors reduced the rate of increase of electricity demand to 5.3%, oil and gas demand rose remarkably, by 6.9% and 7.2% respectively.

1 / In this paper, all measures referring to years should be understood to apply to the 12 months from April 1 through March 31 of the following year. Therefore the first fiscal quarter is from April to June, and the second quarter from July to September.

Table 1: Energy Supply and Demand and GNP in Japan (Levels and Percentage Growth Rates)

	1983	1984	1985	1986	1987	1988
Total Primary Energy Supply (Tcal)	3763100	3858980 (2.5)	3934490 (2.0)	3903140 (-0.8)	4094200 (4.9)	4320580 (5.5)
Total Final Energy Consumption (Tcal)	2603250	2674520 (2.7)	2706300 (1.2)	2716850 (0.4)	2846050 (4.8)	3008890 (5.7)
Gross National Product (Billions of yen - 1980 prices)	267700	281399 (5.1)	293982 (4.5)	301834 (2.7)	317589 (5.2)	333832 (5.1)
Primary Energy per Unit of GNP (kcal/thousand yen)	14057	13714 (-2.4)	13383 (-2.4)	12931 (-3.4)	12892 (-0.3)	12942 (0.4)

The surge in energy demand since 1987 has surpassed all short and medium term governmental projections, the government forecasters having assumed moderate growth trends as a legacy of the first oil crisis. The official forecast underestimated oil demand for 1987 by about 7%. Forecasters failed to draw a lesson from this considerable divergence and the projection for 1988 was also low, by about 5%.

What are the reasons for the recent rapid growth of energy demand in Japan?

The primary factor is the favourable nationwide state of the economy. The latest boom is particularly noteworthy because it involves growth in domestic demand that is quite energy intensive, which is a departure from the recent pattern. That is, although the recent growth in energy demand basically resulted from the business cycle, structural factors also played a part.

A second factor is associated with low energy prices. After a peak in 1981, crude oil prices fell continually as the market reacted to high prices. In the summer of 1986 they fell below $10 US per barrel. In 1986 CIF prices in Japan averaged $13.80, having dropped sharply by $23 from their peak. The rising value of the yen also played a role; crude oil prices in yen dropped to less than one-quarter of the fiscal 1981 level.

A third factor was a slowdown in energy conservation, which itself is related to falling energy prices. Many technically possible conservation efforts have already been made and the commitment to conserve more was weakened by low energy prices.

While the effects of average temperature on energy demand must also be considered, there were offsetting movements through time and this factor caused little significant change in energy demand in 1987 and 1988.

The description above provides an overview of the rapid growth in Japanese energy demand since 1987 and the factors causing it. The purpose of this paper is to provide a more detailed analysis that uses linearly-defined index numbers to quantify the contributions of various factors affecting demand in sub-sectors of the economy.

1. Industrial Sector

The following equation, which is used for the analysis of the industrial sector, decomposes three factors involved in changes in energy demand: energy conservation (i.e., changes in energy used per unit of output), changes in industrial structure (i.e., changes in the mix of goods produced) and changes in the overall level of industrial output.

$E = \Sigma E_i$ is defined as total final energy consumption in the industrial sector in a given year and is the sum of final energy consumption in each industry i. It can be rewritten as:

(1) $E = \Sigma\{(E_i/IIP_i) \times (IIP_i/IIP) \times IIP\}$, where
IIP is an index of overall industrial production;
IIP_i are indices of production in the i-th industry; and
i corresponds to food; textiles; pulp and paper; chemicals; ceramics, stone and clay; iron and steel; non-ferrous metals; machinery and other products.

Table 2: Final Energy Consumption by Sector (Levels in Tcal and Percentage Growth Rates)

	1983	1984	1985	1986	1987	1988
Industrial Sector	1394190	1464560 (5.0)	1458340 (-0.4)	1441130 (-1.2)	1510660 (4.8)	1600530 (5.9)
Residential & Commercial Sector	636950	635120 (-0.3)	659160 (3.8)	666190 (1.1)	701160 (5.2)	738410 (5.3)
Transportation	572120	574830 (0.5)	588800 (2.4)	609520 (3.5)	634230 (4.1)	669950 (5.6)
Total Final Energy Consumption	2603260	2674510 (2.7)	2706300 (1.2)	2716840 (0.4)	2846050 (4.8)	3008890 (5.7)

Then a one-period change in energy consumption, $\Delta E = E_{t+1} - E_t$, can be written by direct computation as:

(2) $\Delta E = \Sigma\{A + B + C + D\}$, where

$A = \Delta(E_i/IIP_i) \times (IIP_i/IIP) \times IIP$, the energy conservation factor;

$B = (E_i/IIP_i) \times \Delta(IIP_i/IIP) \times IIP$, the industrial structure factor;

$C = (E_i/IIP_i) \times (IIP_i/IIP) \times \Delta IIP$, the industrial activity factor; and

$D =$ (a series of second and third order interaction terms).

For small changes in energy consumption the D-term is negligibly small. When these interaction terms are omitted, equation (2) is equivalent to what we obtain when equation (1) is totally differentiated; i.e., small changes of E in equation (1) can be approximated by total differentiation. This formulation is used as an accounting framework for separating the three major types of changes that bring about a change in energy consumption in the industrial sector.

The same reasoning is applied to decompose the industrial demand for fuels and electric power into four different factors.[2] Here the basic equation is:

(3) $F = \Sigma F_i$

$= \Sigma\{E_i/IIP_i) \times (F_i/E_i) \times (IIP_i/IIP) \times IIP\}$,

where

F is the total consumption of fuels or purchased electric power in the industrial sector and

F_i is the consumption of fuels or purchased electric power in the i-th industry.

From this it follows that:

(4) $\Delta F = \Sigma\{\Delta(E_i/IIP_i) \times (.) \times (.) \times (.)$
$+ (.) \times \Delta(F_i/E_i) \times (.) \times (.)$
$+ (.) \times (.) \times \Delta(IIP_i/IIP) \times (.)$
$+ (.) \times (.) \times (.) \times \Delta IIP\}$

The first term is characterized as the energy conservation factor, the second term is the energy substitution (or conversion) factor, the third the industrial restructuring factor, and the fourth captures the effect of changes in industrial activity.

The results obtained by calculating these factors for the Japanese industrial sector in the years 1980 through 1988 are shown in Figures 1 and 2. In Figure 1 the height of each diamond-shaped point on the polygonal line indicates the difference between energy consumption in the current year and the previous year. The percentage change relative to the same period in the previous year is given by the unbracketed number near each point. The bar chart decomposes the difference for each year into factors shown in equation (2); the height of each bar shows the contribution of one of the factors to the change in energy demand. Bracketed numbers shown next to bars indicate percentage change in consumption due to that particular factor taken by itself.

The data in Figure 1 show clearly that, from 1980 through 1986, energy conservation (declines in the energy intensiveness of industrial output) and industrial restructuring (that involved declining weights for energy-intensive

2/ Only purchased electric power is accounted for.

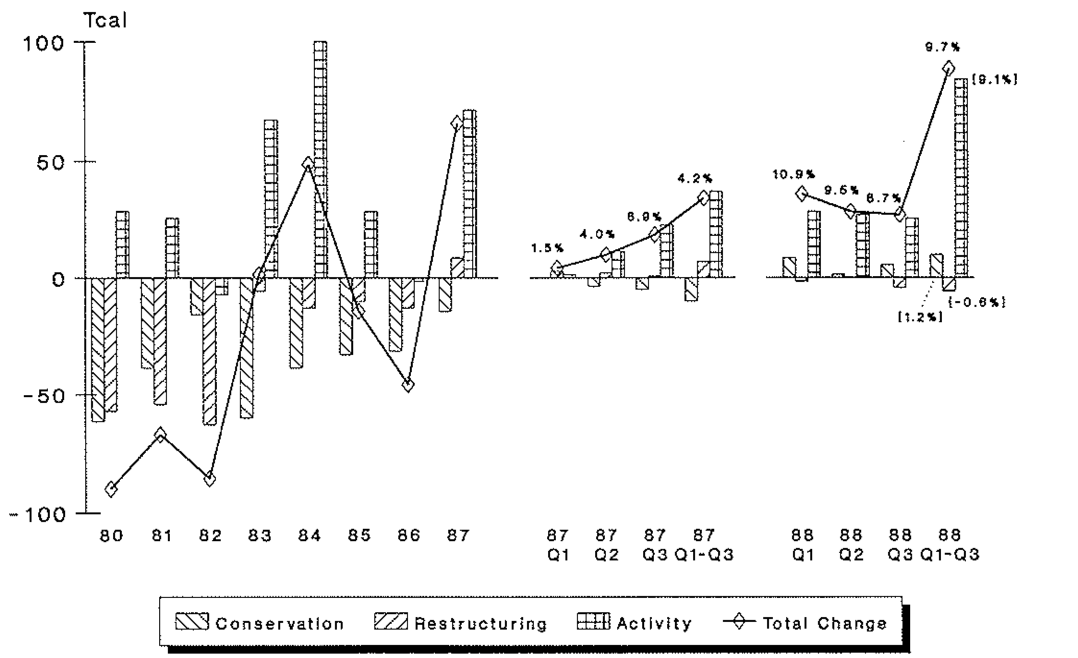

Figure 1: Industrial Sector — Sources of Changes in Final Energy Consumption

basic materials industries) were important factors in determining small or negative changes in final energy consumption in the industrial sector. In 1987, however, energy conservation made only a small contribution and industrial restructuring had a positive effect on energy consumption as a strong demand for basic materials increased the weights of energy intensive industries. As the economic recovery proceeded, industrial output increased and energy consumption began to expand steadily. Industrial energy demand in the April-December period of 1988 was 9.7% higher than in the same period in the previous year, largely due to the contribution of the industrial activity factor (which accounted for 9.1 of the 9.7 percentage points).

Figure 1 also shows that energy conservation turned into a plus factor (i.e., the energy intensiveness of IIP increased in 1988), though only a small one. In 1988 industrial restructuring again became a minus factor, because the machinery industry, which is less energy-intensive than basic materials, increased its activity.

Turning to Figures 2 and 3, they show that the consumption of electric power and fuel oil in the April-December period of 1988 rose by 5.1% and 15.4% respectively relative to the same period one year earlier. As in the case of total final energy consumption in the industrial sector, these two categories of consumption were affected most strongly by changes in industrial activity; energy conservation turned into a plus factor and industrial restructuring again became a minus factor in 1988. Note, however, that these two types of energy differed in terms of the role played by the energy substitution factor (the weight of the relevant energy type in total final energy consumption). Energy substitution had been a minus factor for changes in fuel oil consumption (the share of fuel oil in total final consumption had been declining) until low crude oil prices caused it to have a positive effect in fiscal 1988. By contrast, purchased electric power consumption had increased its share in total final consumption since the oil crisis, until crude oil prices slumped at the end of 1985 and continued to be low, causing purchased power to cost relatively more than private power generation.

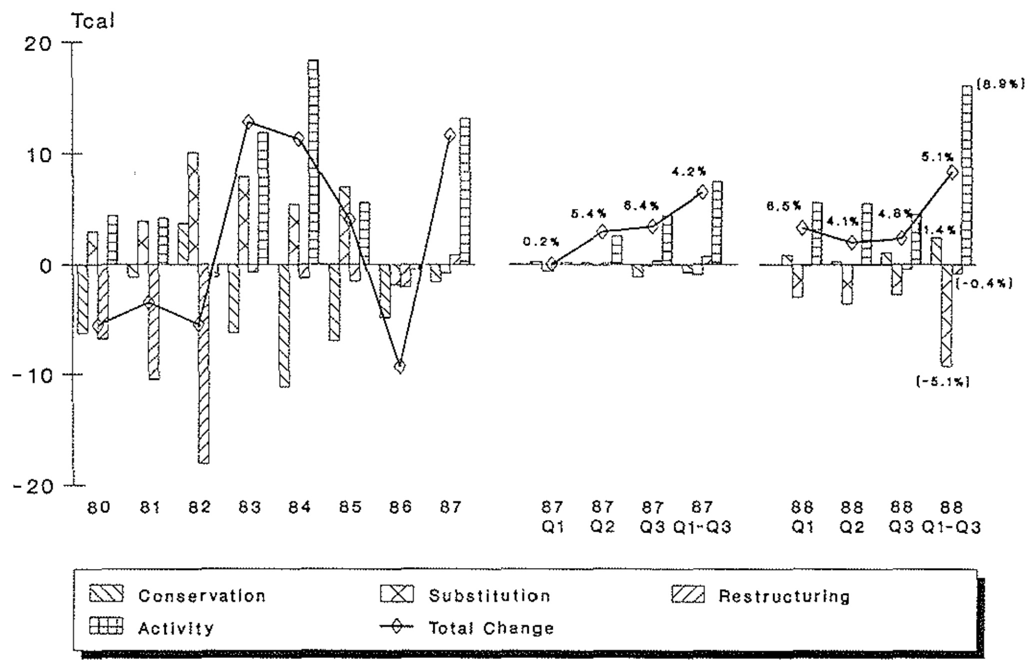

Figure 2: Industrial Sector — Sources of Changes in Electric Power Consumption

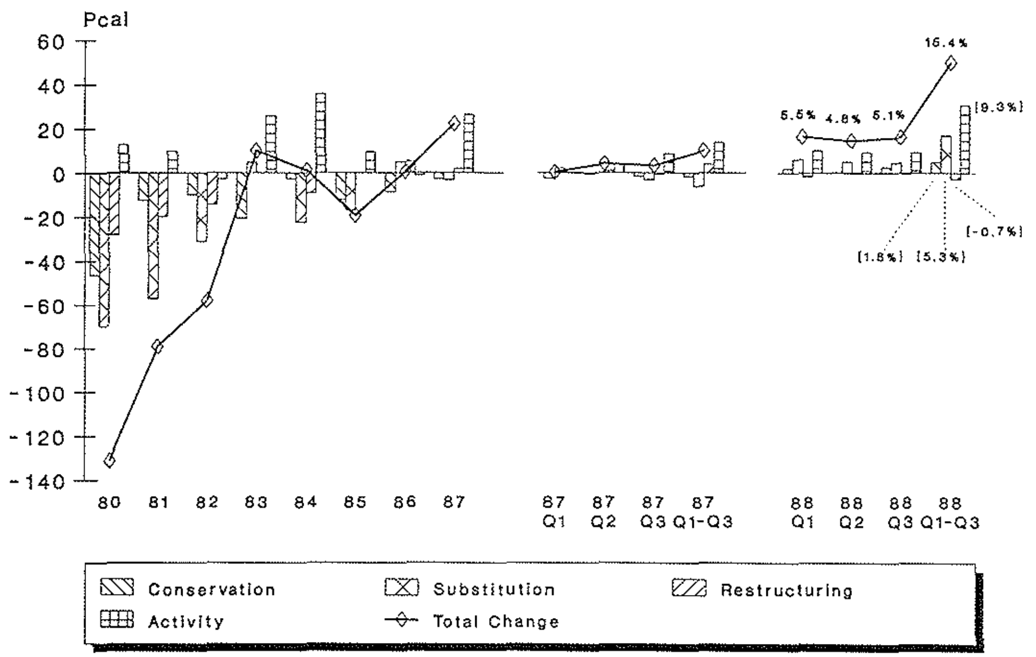

Figure 3: Industrial Sector — Sources of Changes in Fuel Oil Consumption

Therefore substitution towards electric power consumption has been a minus factor since 1986. (See Figure 2).

2. Residential and Commercial Sector

For each of the residential, commercial and transportation sectors, we used multiple regression techniques to estimate simple demand functions for various types of energy. The estimated linear functions, based on data starting in 1980, and the usual summary statistics associated with them are reported in the Appendix at the end of this paper.

For each energy type in a given sector the estimated function is used to quantify the various factors hypothesized to have brought about observed changes in energy demand in 1987 and 1988. For instance, regression 1 assumes that the amount of fuel oil used in the commercial sector (HASCM) depends upon a measure of outdoor air temperature (WARMDD), the price of fuel oil (WPIHA), the commercial demand for electric power (ELESCM), total consumer expenditure (C), and the total floor space of commercial buildings (FLOOR). The following parameters were estimated:

$$\begin{aligned} HASCM = 40.716 &+ 1.45989WARMDD \\ &- 2.45639WPIHA - 0.0105871ELESCM \\ &+ 0.0159955C + 0.77069FLOOR. \end{aligned}$$

In each of 1987 and 1988 the actual changes in these independent variables were used to calculate the change in fuel oil demand associated with it. The total actual change in each period (the line graph) and the portions attributable to each variable (the bars) are shown in Figure 4. (The part of the total change not explained by the regression change — the error term — is labelled "Other Factors".) A similar decomposition is shown for kerosene, electric power and town gas in Figures 5-8.

During the April-September period of 1988, demand for fuel oil was diminished by the negative effect of higher than usual temperatures (i.e., warming degree days decreased) and the negative effect of the energy substitution factor (i.e., more electricity was used as an alternative heat source). On the other hand, declining prices, and increases in business activity and the total

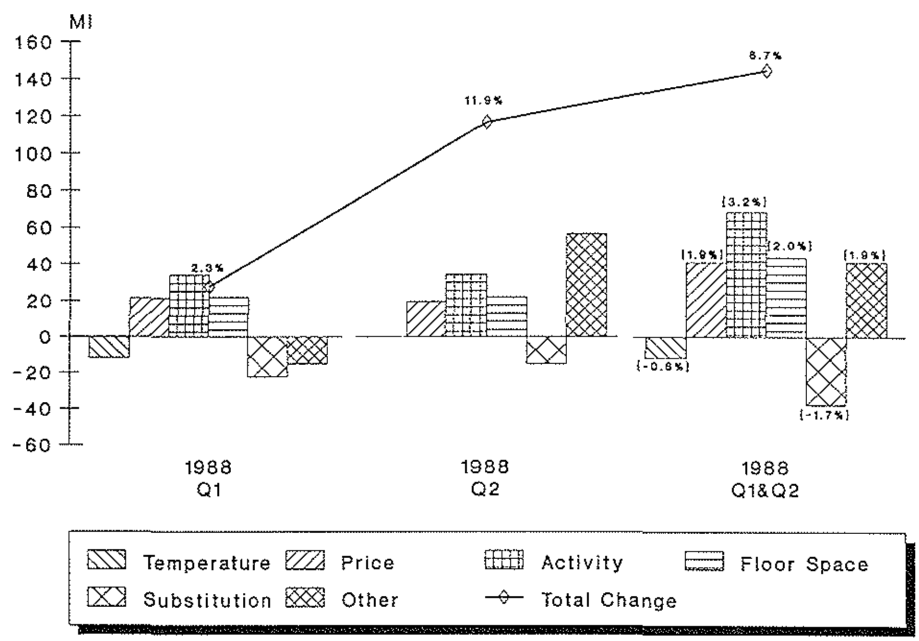

Figure 4: Commercial Sector — Sources of Changes in Fuel Oil Consumption

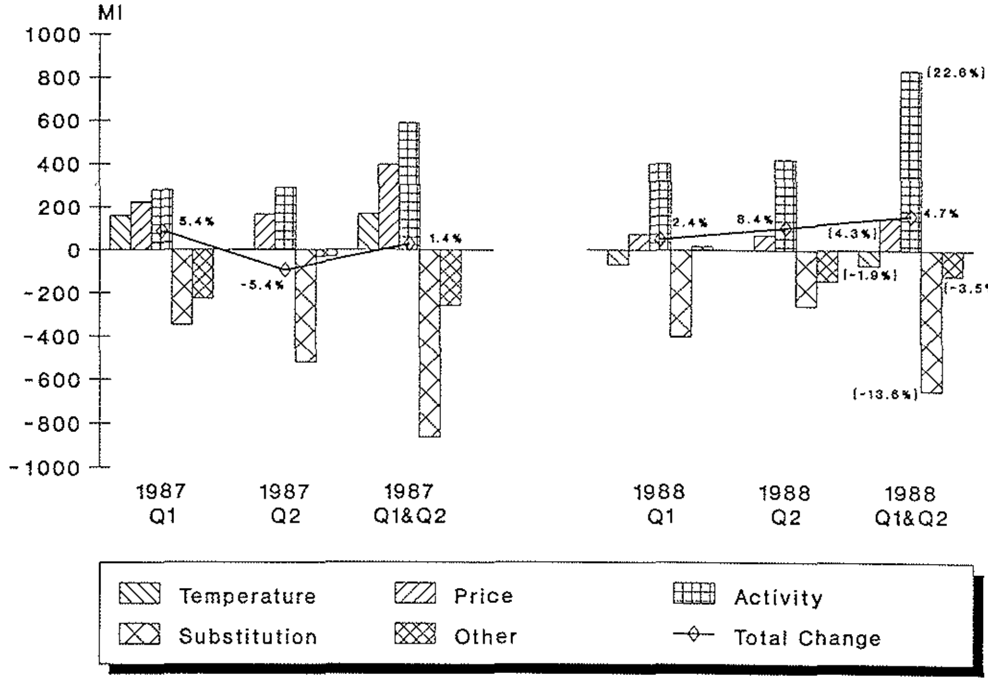

Figure 5: Residential/Commercial Sector — Sources of Changes in Kerosene Consumption

amount of floor space in commercial buildings boosted demand. As a result, the first half of fiscal 1988 showed an increase of 6.7% relative to the same period one year earlier.

In the case of kerosene (Figure 5), the effects of temperature and energy substitution were negative, while decreased prices and increased consumption expenditure were positive factors, causing the demand for kerosene to increase by 4.7% during the first half of fiscal 1988.

Turning to Figure 6, the combined household and housing factor (increases in the number of households and in housing investment) had a positive effect on residential demand for electric power, while a decrease in cooling demand due to an unusually cool summer made the temperature factor negative. The overall result was a 3.1% increase in residential electricity demand in the first half of fiscal 1988. The commercial demand for electric power (Fig. 7) increased by 5.1% during the first half of fiscal 1988 because the positive effect of increased consumption expenditure was more or less offset by the negative effect of temperature.

A cool summer served as a plus factor for the residential demand for town gas (Fig. 8) because water heating demand increased. The household and housing factor further added to the demand for town gas, leading to a large overall increase of 9.3% in the first half of fiscal 1988. The favourable effects of business activity and floor space factors combined to boost the commercial demand for town gas by 6.5% (not shown in a graph).

3. Transportation Sector

The analysis of energy demand changes in the transportation sector is based on the regression coefficients for equations 7 and 8 in the Appendix. The results of the decomposition of changes in the transportation demand for motor gasoline and diesel oil during the first half of each of 1987 and 1988 are shown in Figures 9 and 10.

Reflecting favourable business conditions, increases in the stock of passenger cars using motor gasoline and increases in the volume of passenger traffic played the leading role in in-

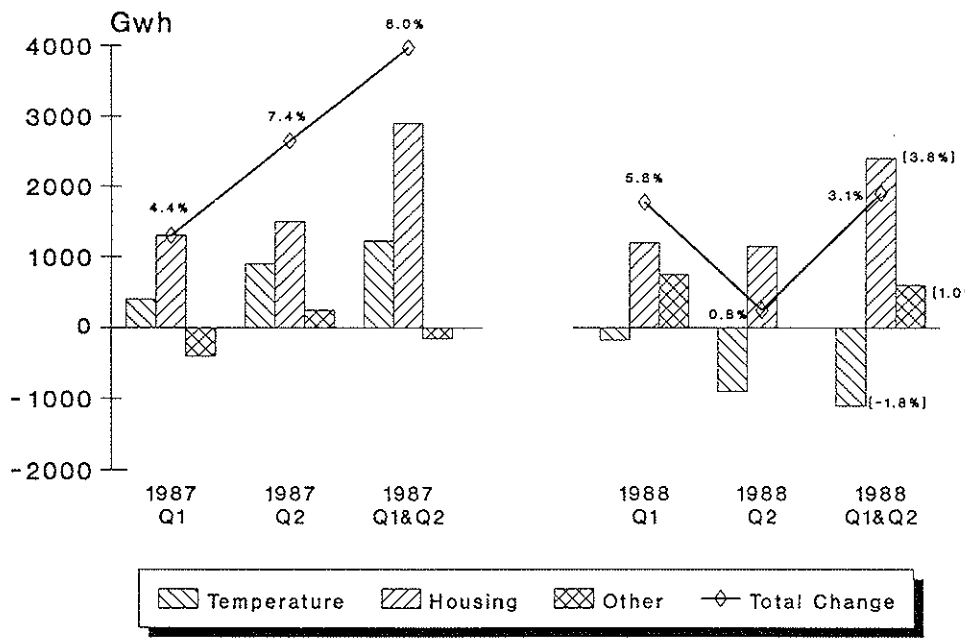

Figure 6: Residential Sector — Sources of Changes in Electric Power Consumption

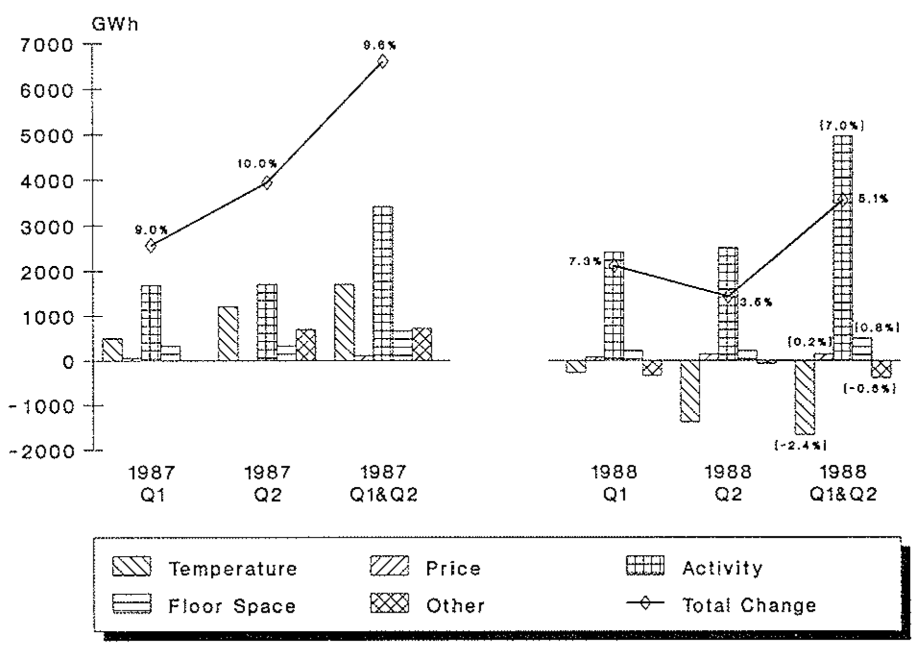

Figure 7: Commercial Sector — Sources of Changes in Electric Power Consumption

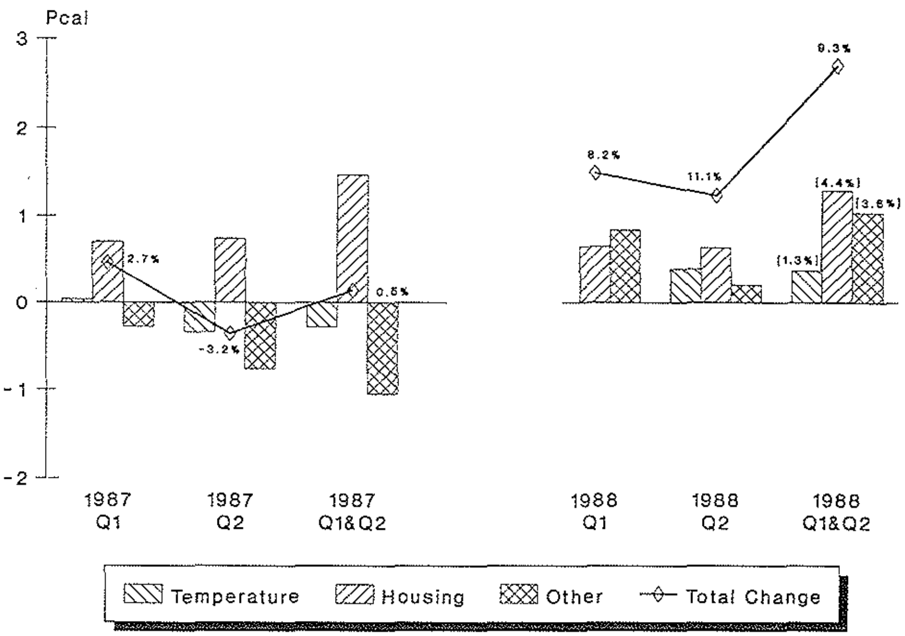

Figure 8: Residential Sector — Sources of Changes in Town Gas Consumption

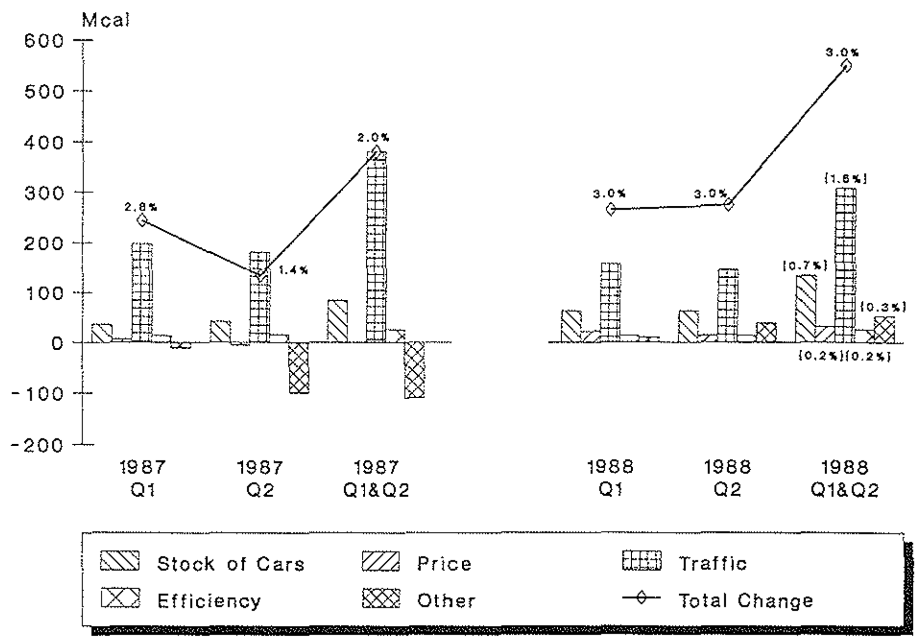

Figure 9: Transportation Sector — Sources of Changes in Gasoline Consumption

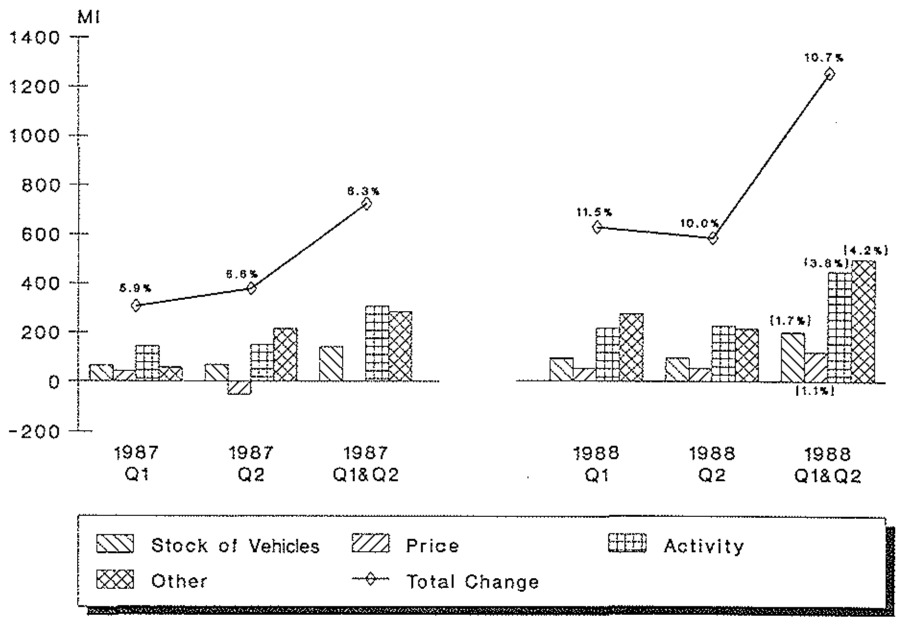

Figure 10: Transportation Sector — Sources of Changes in Diesel Oil Consumption

creasing the demand for gasoline by 3.0% during the first half of fiscal 1988. The fuel efficiency variable (the average 10-mode mileage of passenger cars produced for the domestic market)[3] added to demand, presumably because of a recent preference for large-size and/or luxury cars that leads to a lower average fuel efficiency of new cars.

The demand for diesel oil in the first half of fiscal 1988 increased by 10.7%. The positive factors were increases in the stock of trucks using diesel oil, lower diesel oil prices and expanded business activity. But none of these factors showed a greater percentage contribution than "other factors", which is the unexplained error term when the diesel oil regression is calculated for the first half of 1988. These unexplained factors accounted for some 40% of the 10.7% increase in demand.

4. Concluding Comments

The above analysis indicates that the surge in energy demand in Japan since 1987 has been brought about by a combination of low energy prices, higher levels of economic activity and a slow down in energy conservation. How long will this phenomenon continue and what implication does it have for government policy? To respond to this question, consider the prospects for each of the three factors identified above: energy prices, the level of economic activity and energy conservation.

There are two broadly defined views in regard to the prospects for future energy prices. In one view, world oil demand and supply will be tight again in the 1990s, due to increasing oil demand on the one hand and stagnating production of non-OPEC producers on the other. This will result in a strengthening of OPEC's monopolistic position and high prices for oil and other energies. In the other view, oil reserves are abundant and more additional reserves are available to be found than has been generally believed. In this

3/ "10-mode fuel consumption" refers to the fuel used per car in the first 135 seconds of driving during 10 stages of stop-and-go driving in congested city traffic.

view the price of oil will not go up in the 90's. If the former view is taken, it will be accelerated. We believe that the latter view is more likely to be correct.

Looking at the prospects for economic activity in Japan, several years ago the Japanese economy began to shift from an export orientation towards a domestic demand orientation. The major causes for this have been the high value of the yen and the pressure from other countries, led by the US, in favour of policies intended to reduce the Japanese trade surplus. A domestic demand oriented economy tends to be energy intensive in Japan, as it is most effectively realized through the accelerated development and improvement of social capital. This gives impetus to such energy intensive activities as construction of roads, bridges and sewage facilities and land reclamation. This shift, and the increased use of energy in the industrial sector shown in the above analysis, has been encouraged by the low energy prices in the years considered.

The structural change referred to in the preceding paragraph will lead to a higher overall energy intensity. The past trend of falling energy intensity in the industrial sector, due to lower weights of energy intensive industries, like the iron and steel, aluminum, cement and petrochemical industries, and increasing weights for less energy intensive high technology industries will continue, but this trend will be much slower in the future because it will be set back by the emerging industrial restructuring.

The slowing down of energy conservation and worsening fuel efficiency in the transportation sector will not be turned around easily so long as the price of oil remains low. As noted above, we believe that the price of oil is likely to stay relatively low over the longer term. Price increases due to events such as the Gulf crisis of the summer of 1990 are, of course, not excluded, but oil prices are likely to fall fairly quickly once the turmoil is over. Adding to the effect of low prices, according to some observers, energy consumption in the Japanese household sector has reached a mature stage with a sufficient provision of very efficient energy consuming equipment. We believe also that the expected increase of average house size will be accompanied by the increasing use of energy. Japan, unlike the developed countries of Europe and North America, remains in many respects more comparable to the developing countries. Poor social capital, low levels of housing space and rush hour traffic jams provide some of the evidence for this. A large energy input is required to improve this situation.

In sum, the surge in energy demand in the past two to three years in Japan has reflected this structural change in the Japanese economy and it has been supported by the low prices of oil. So long as the low prices remain, higher rates of growth in energy demand are likely to persist. The Japanese government is gradually recognizing this situation and is going to revise its long term energy forecast by raising the level of forecast energy demand for the first time since the oil crisis that began in 1973. The provision of sufficient energy supplies is now a very urgent task for the energy industries. Moreover, Japan is challenged like all countries to cope with the problems of the global environment. Curbing future energy demand in Japan for environmental goals in the context of the situation described above is not going to be easy. It will be necessary not only to develop more energy efficient technologies, the potential for which seems limited, but also to introduce significant changes in energy supply systems, transportation and its regulation, and in other aspects of daily life. The urgency and severity of these changes will depend on the kinds of decisions taken in the ongoing international negotiations on the global environment.

Appendix

The following are the regression functions estimated for the residential, commercial and transportation sectors.

1. Fuel oil A for commercial use

$$\mathrm{HASCM} = \underset{(0.22)}{40.716} + \underset{(33.53)}{1.45989}\mathrm{WARMDD} - \underset{(-4.14)}{2.45639}\mathrm{WPIHA} - \underset{(-2.97)}{0.0105871}\mathrm{ELESCM} + \underset{(2.56)}{0.0159955}\mathrm{C} + \underset{(2.38)}{0.77069}\mathrm{FLOOR}$$

$AR^2 = 0.97442$ SE = 77.79 DW = 1.505

HASCM: the commercial demand for fuel oil A
WARMDD: warming degree days (the number of degrees by which average temperature is below 14°C, summed over the number of days)
WPIHA: wholesale price index of fuel oil A
ELESCM: commercial demand for electric power
C: real private final consumption expenditure
FLOOR: total floor space of commercial buildings

2. Kerosene for residential and commercial use

$$\mathrm{KERRCS} = \underset{(0.46)}{392.074} + \underset{(23.70)}{8.25484}\mathrm{WARMDD} - \underset{(-3.13)}{8.81505}\mathrm{CPIKER} + \underset{(10.38)}{0.19412}\mathrm{C} - \underset{(-9.13)}{0.95707}\mathrm{ELRE} - \underset{(-1.88)}{0.36271}\mathrm{TGRE}$$

$AR^2 = 0.98193$ SE = 322.87 DW = 2.000

KERRCS: the residential and commercial demand for kerosene
CPIKER: consumer price index for kerosene
ELRE: the residential and commercial demand for electric power
TGRE: the residential and commercial demand for town gas

3. Electric power for residential use

$$\mathrm{ELHS} = -\underset{(-15.55)}{40676.4} + \underset{(5.61)}{12.8914}\mathrm{COOLDD} + \underset{(2.85)}{5.38408}\mathrm{WARMDD} + \underset{(3.59)}{0.59439}\mathrm{IH} + \underset{(28.70)}{1.76059}\mathrm{SETAI} - \underset{(-1.48)}{20.4583}\mathrm{Q1} - \underset{(-1.69)}{27.3708}\mathrm{Q2} - \underset{(-3.11)}{28.9736}\mathrm{Q3}$$

$AR^2 = 0.98194$ SE = 492.73 DW = 2.482

ELHS: the residential demand electric power
COOLDD: cooling degree days (measured relative to 24°C)
IH: real private housing investment
SETAI: number of households
Q1, Q2,
and Q3: seasonal dummy variables

4. Electric power for commercial use

$$\mathrm{ELESCM} = -\underset{(-14.55)}{28686.1} + \underset{(6.97)}{19.9318}\mathrm{COOLDD} + \underset{(9.43)}{4.24324}\mathrm{WARMDD} + \underset{(0.88)}{9.23339}\mathrm{FLOOR} + \underset{(3.91)}{1.14934}\mathrm{C} - \underset{(-0.70)}{10.7224}\mathrm{WPIELE} + \underset{(2.84)}{27.1030}\mathrm{Q2}$$

$$-\underset{(-3.99)}{59.2392}\mathrm{Q3}$$

$AR^2 = 0.99097$ SE = 593.50 DW = 2.367

WPIELE: wholesale price index of electric power.

5. Town gas for residential use

$$TGHS = -2475.27 + 0.87446WARMDD - 0.55804COOLDD + 0.10425SETAI + 0.0225290IH - 3.89412Q2 - 3.61624Q3$$

(-9.12) (19.57) (-1.91) (13.40) (1.09) (-4.72) (-13.84)

$AR^2 = 0.98249$ SE = 62.55 DW = 1.868

TGHS: the residential demand for town gas

6. Town Gas for commercial use

$$GASSCM = -392.683 + 0.36285WARMDD + 0.65735FLOOR + 0.0086573C - 0.44097WPIGAS - 1.55495Q3$$

(-6.62) (26.15) (2.91) (1.34) (-1.16) (-4.93)

$AR^2 = 0.98378$ SE = 19.46 DW = 3.078

GASSCM: the commercial demand for town gas
WPIGAS: wholesale price index of town gas

7. Motor gasoline for transportation

$$GASOTN = 5362.22 + 0.0790733SGCAR - 3.22094CPIGSO - 48.2643NENPI + 0.0195479NINKL + 6.05489Q2 + 6.19224Q3$$

(9.39) (2.04) (-0.99) (-0.68) (3.72) (13.95) (15.80)

$AR^2 = 0.96660$ SE = 94.30 DW = 1.998

GASOTN: the demand for motor gasoline in transportation
SGCAR: stock of cars using gasoline
CPIGSO: consumer price index of gasoline
NENPI: average 10-mode gas milage of passenger cars (new cars) produced for the domestic market.
NINKL: volume of passenger traffic (person-kilometres)

8. Diesel oil for transportation

$$DSTN = 870.505 + 0.25174SDTRCK + 0.10288C - 6.03833WPILIT$$

(2.63) (4.48) (9.45) (-5.63)

$AR^2 = 0.95581$ SE = 138.55 DW = 1.288

DSTN: the demand for diesel oil in transportation
SDTRCK: stock of trucks using diesel oil
WPILIT: wholesale price index of gas oil