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Forecast errors in IEA-countries' energy consumption

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Abstract

Every year *Energy Policy of IEA Countries* includes a forecast of the energy consumption in the member countries. Forecasts concerning the years 1985, 1990 and 1995 can now be compared to the actual values. The second oil crisis resulted in big positive forecast errors. The oil price drop in 1986 did not have a similar opposite effect. A correction for economic growth reduces forecast errors during the second oil crisis but not elsewhere. Industry has a relatively big positive forecast error while transportation has a negative forecast error. Even when the forecast error is small, the results are not so "nice" because the small value is often the sum of large positive and negative errors. Almost no significant correlation is found between forecast errors in the 3 years. Correspondingly, no significant correlation coefficient is found between forecast errors in the 3 main energy sectors. Therefore, a relatively small forecast error is not caused by a relatively small forecast error in all 3 sectors.

Keywords: Energy consumption; Forecast; IEA

1. Introduction

Every year the annual publication (Review) Energy Policies and Programmes of IEA Countries (since 1989 Energy Policies of IEA Countries) includes a forecast of energy consumption in member countries. Forecasts concerning the years 1985, 1990 and 1995 can now be compared to actual values.

The t Review is typically published in year $t+1$ and the forecasts are based on actual values from year $t-1$. In this paper the analysis is based on "review years". The 1978 Review is the first publication including forecasts from all member countries. Therefore, the analysis covers only member countries in 1978. However, small countries like Island and Luxembourg are excluded. Australia is also excluded because in 1978 the country did not make forecasts for the same years as the other member countries.

Forecasts are submitted by member countries and are based upon public energy plans etc. which to a certain degree express the desired target for energy consumption. If consumption increases more than expected, higher energy taxes can be imposed to stop the undesirable development so relatively small forecast errors can partly be explained by a political willingness to change energy policy quickly if unexpected events occur.

The oil crises speeded up the development of national energy plans with the purpose of being less dependent on oil import from OPEC countries. Therefore, oil consumption was in focus in years after the oil crisis. Today, reduction of greenhouse gas emission is also important when national energy plans are prepared. Anyhow, it is interesting to observe the level of forecast error and compare with other countries.

Section 2 deals with how to measure forecast errors, Section 3 with the expected development in forecast errors, Section 4 with average forecast errors and Section 5 with forecast errors in all countries.

2. Error concepts

In the following, t refers to review year and n to forecast year (1985, 1990 or 1995). The forecast value is $\hat{E}_t(n)$ and actual energy consumption is $E(n)$. Then:

$$\text{Forecast error(proportional)} = [\hat{E}_t(n) - E(n)]/E(n). \quad (1)$$

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Of course, forecast errors can be positive (overshooting) as well as negative (undershooting). Because of big differences between energy consumption in member countries errors have to be related to actual observations:

If the forecast error is 0.2, then of course an overshooting by 20% has taken place.[1] OECD (1974) includes energy forecasts from 1971 to 1985. The proportional forecast error in 1985 is 0.41 (TPES, total primary energy supply) in the USA and 0.89 in Japan. The errors are positive because of the two oil crises, which put a brake on energy consumption.

The error is much higher in Japan than in the USA which is to a great extent caused by the fact that economic growth in Japan became much smaller than expected compared to economic growth in the USA. During the period 1971–1985, GDP was expected to increase by 188% in Japan and by 78% in the USA. The actual figures were only 74% and 52%, respectively.[2]

Wrong growth rate assumptions are taken into account by calculating the GDP-corrected TPES:

$$ {}_{\mathrm{corr}}\hat{E}_t(n) = GDP_{t-1}x(GDP(n)/GDP_{t-1})x\hat{I}_t(n). \quad (2) $$

Energy Policies of IEA Countries include GDP_{t-1} and the expected energy intensity $\hat{I}_t(n)$. $(GDP(n)/GDP_{t-1})^3$ is actual growth from year $t-1$ to year n.

Corresponding to (1):

$$ \text{Forecast error (corr)} = [{}_{\mathrm{corr}}\hat{E}_t(n) - E(n)]/E(n). \quad (3) $$

(3) indicates only TPES with actual growth rates if the income elasticity is close to 1. Brennand and Walker (1990) estimate the average income elasticity in 10 OECD countries at 1.3 with variations between −0.2 and 3.4. Barker et al. (1995) concludes that aggregated income elasticity is close to 1 but with a considerable variation.[4] Because of the big variation, (3) only makes a rough method to correct for the difference between forecast and actual economic growth rates.

Basically, the error term in (3) is caused by the difference between $\hat{I}_t(n)$ and $I(n)$. This difference depends on whether energy prices, autonomous efficiency improvements, public energy policy etc. develop as expected.

The forecast error is applied in Section 4 to calculate average forecast errors. In Section 5, focusing on the individual countries, the purpose is to find out whether some countries continuously have smaller errors than other countries. In that respect, Root Mean Square (RMS) is applied.

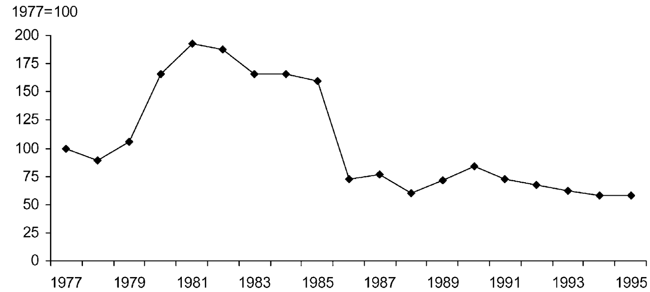

Fig. 1. OECD's average crude oil import price deflated by OECD's export price index for manufacturing goods 1977–95, 1977 = 100.

$$ \text{Forecast error} = \left(\sqrt{\sum\nolimits_{t=n-6}^{n-2} \left[\hat{E}_t - E(n)/E(n)\right]^2}\right)/5. \quad (4) $$

According to (4) the forecast error is squared with the effect that positive and negative errors are treated alike. It also implies that big errors count relatively more than small errors.

An average is calculated including review years from $n-6$ until $n-2$. In that way, reviews from 1979 until 1993 are included continuously without any overlap in review years.[5]

From a political point of view, perhaps negative forecast errors are considered more seriously than positive forecast errors because a negative error is equal to an unexpected high growth rate in energy demand and pollution.

3. Expected development of error terms

Ceteris paribus errors decrease as t approaches n. Furthermore, errors must to a great extent, as mentioned earlier, depend on the difference between expected and actual energy prices. Here we only focus on crude oil prices. However, crude oil prices have fluctuated much more than energy prices at the consumer level but the direction has to a great extent been the same.

The actual oil price doubled during the second oil crisis and was nearly halved in 1986, cf. Fig. 1. The oil crisis in 1990/91 caused by Iraq annexing Kuwait did not increase the oil price much on a yearly basis.

We do not know the assumptions of the oil price development in member countries, energy plans etc. but we do know something about the general opinion of future oil price. Before the second oil crisis only

[1] Bails and Peppers (1993) use the term percent error.

[2] Economic Outlook and Energy Prospects to 1985 p. 43. GDP in 1991$.

[3] Source: OECD, various issues.

[4] Energy price elasticities also differ to a great extent between the OECD countries.

[5] $t = 1979-1983 (n = 1985)$, $t = 1984-1988 (n = 1990)$, $t = 1989-1993 (n = 1995)$.

moderate oil price increases were expected.[6] During the second oil crisis the future oil price was increased significantly and afterwards decreased when actual oil price dropped. All the time the future oil price was actual oil price plus some positive growth rate. So, in spite of the fact that the oil price has doubled between 1978 and 1981 further oil price increases were expected. For instance, according to The International Energy Workshop (IEW) the real oil price was expected to increase by 30% from the beginning of the 1980th until 1990.[7]

Because of the unexpected big oil price increase from 1978/79 until 1985 positive forecast errors must be expected in review years around 1979 for forecast year 1985. Likewise, negative errors in forecast year 1990 can be expected in review years from 1980 until 1985 because of the unexpected oil price drop in 1986. In fact, it appears later on that errors were usually positive during that period. To a great extent this can be explained by unexpected low economic growth rates. That even the GDP-corrected forecast error is positive is to a certain extent caused by the fact that price elasticity is bigger numerically during periods of price increases than during periods of price decreases (irreversibility of energy demand).[8] Therefore, energy price increases during the second oil crisis have decreased energy consumption more than energy price decreases have subsequently increased energy consumption. Furthermore, long-run income and price elasticities are much bigger than short-run elasticities. Therefore, the effect of the second oil crisis is still at work in the late 1980s.

As mentioned earlier, there are big differences between income elasticities as well as between price elasticities in OECD countries. Therefore, unexpected events as regards economic growth and energy price development must result in differences in forecast errors. In other words, a considerable standard deviation has to be expected. Big differences in energy taxes may also involve variation in forecast errors.

4. Mean forecast errors and standard deviations

In this section, forecast errors correspond to (1) and (3), respectively.

4.1. Total primary energy supply (TPES)

1978 is the first review year including forecasts for 1985/1990 and 1984 first review year including forecasts for 1995.[9]

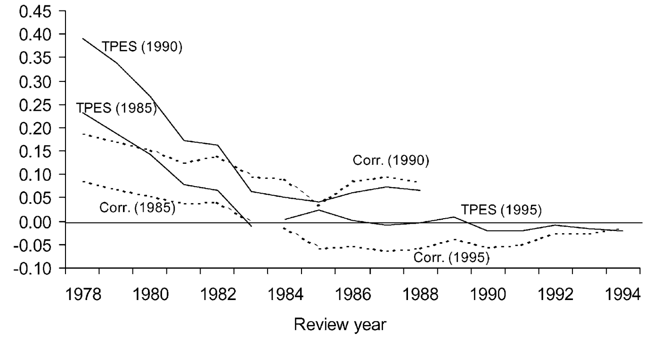

Fig. 2. Average proportional forecast errors, $\mathrm{TPES}_t(n)$ and $\mathrm{Corr}_t(n)$.

For purposes of simplicity, $\mathrm{TPES}_t(n)$ stands for proportional forecast error measured on total primary energy supply (TPES).[10] Correspondingly, $\mathrm{Corr}_t(n)$ stands for forecast error according to (3), $\mathrm{Oil}_t(n)$ forecast error measured on oil consumption etc.

As expected, we observe a considerable positive value of $\mathrm{TPES}_{78\text{–}79}(1985)$(see Fig. 2). However, we also observe $\mathrm{TPES}_{78\text{–}79}(1985)$ and $\mathrm{Corr}_{78\text{–}79}(1985)$ being much smaller than $\mathrm{TPES}_{78\text{–}79}(1990)$ and $\mathrm{Corr}_{78\text{–}79}(1990)$, respectively even though the crude oil price was halved between 1985 and 1990. We also notice $\mathrm{Corr}_t(1985)$ and $\mathrm{Corr}_t(1990)$ being positive. As mentioned in Section 3, this can to a certain extent be explained by irreversibility of energy demand, long-run elasticities being much bigger than short-run elasticities etc. Anyhow, it is remarkable that the oil price drop in 1986 does not seem to have any essential effect on forecast errors.

$\mathrm{Corr}_{78\text{–}80}(1985)$ and $\mathrm{Corr}_{78\text{–}80}(1990)$ are much smaller than $\mathrm{TPES}_{78\text{–}80}(1985)$ and $\mathrm{TPES}_{78\text{–}80}(1990)$, respectively. Consequently, economic growth expectations have to a great extent been exaggerated. Since 1983, the GDP-correction does not improve forecasts.

$\mathrm{TPES}_{86\text{–}88}(1990)$ and $\mathrm{Corr}_{86\text{–}88}(1990)$ are also considerable. This may be caused by the oil crisis in 1990. The crisis decreased energy consumption on a short-run basis resulting in a positive forecast error.[11]

$\mathrm{TPES}_t(1995)$ is small but forecast errors in projections published in World Energy Outlook (WEO)[12] are even smaller. $\mathrm{TPES}_{93}(1995)$ is thus -0.016 in my paper and only -0.004 in WEO93. The corresponding figures for $\mathrm{TPES}_{94}(1995)$ are -0.022, respectively -0.010. The comparisons are not so good, however, because in my paper the forecast error is an unweighted average based upon projections from only some of the OECD

[6] National Energy Plan ll (1979); Annual Report to Congress (1978); Annual Energy Outlook (1983); Andersen & Co (1984).

[7] Schrattenholzer and Marchant (1996).

[8] Barker et al. (1995) pp. 306 ff.

[9] 1982 Review includes forecasts concerning 1995, but 1983 Review does not. Therefore, 1982 has been excluded from the analyses.

[10] Equal to total primary energy requirements (TPER).

[11] An increasing trend in energy consumption was in 1990 replaced by a decrease of 1%. Source: International Energy Agency (IEA), various issues.

[12] World Energy Outlook, 2000, p. 341. The projections are based upon the IEA's World Energy Model.

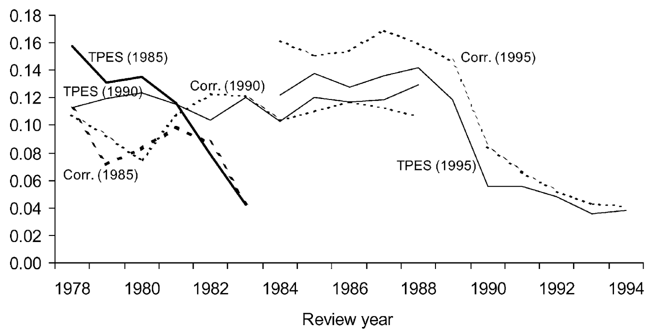

Fig. 3. Proportional forecast errors, standard deviations, $\mathrm{TPES}_t(n)$ and $\mathrm{Corr}_t(n)$.

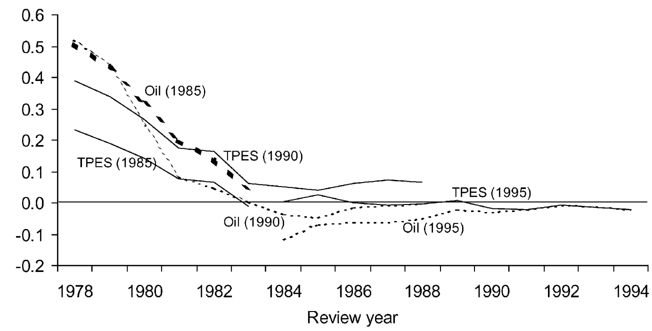

Fig. 4. Average proportional forecast errors, $\mathrm{Oil}_t(n)$ and $\mathrm{TPES}_t(n)$.

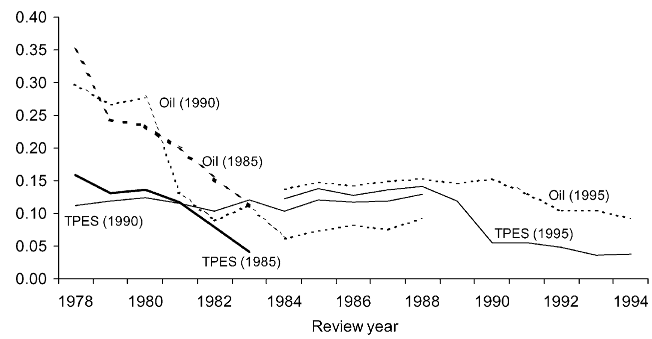

Fig. 5. Proportional forecast errors, standard deviations, $\mathrm{TPES}_t(n)$ and $\mathrm{Oil}_t(n)$.

countries while the error term in WEO concerns OECD as a whole. A small average forecast error can of course be caused by big positive and negative forecast errors. Whether this is the case, can be revealed by the standard deviation, cf. Fig. 3.

Standard deviations of $\mathrm{TPES}_{84\text{–}89}(1995)$ are considerable. Evidently, small values of $\mathrm{TPES}_{84\text{–}89}(1995)$, cf. Fig. 2, are the result of positive forecast errors and corresponding negative forecast errors. For example, Norway's $\mathrm{TPES}_{88}(1995)$ is 0.35 and Japan's -0.16, very much different from an average close to zero.

Since 1989 forecast errors converge. Of course, one has to expect decreasing standard deviations as t approaches n because forecast errors should converge to zero, but this is not the case considering $\mathrm{TPES}_t(1990)$ and $\mathrm{Corr}_t(1990)$. Norway's $\mathrm{TPES}_{88}(1990)$ is 0.34 and Ireland's -0.12. The forecast error of Norway has not changed for several years. Clearly, forecasts are not changed currently. Only new energy plans and the like may change forecasts. Consequently, we find some curious results.

Finally, we observe the standard deviations of $\mathrm{Corr}_{78\text{–}80}(1985)$ and $\mathrm{Corr}_{79\text{–}80}(1990)$ being smaller than the standard deviations of $\mathrm{TPES}_{78\text{–}80}(1985)$ and $\mathrm{TPES}_{79\text{–}80}(1990)$, respectively. The GDP-correction decreases deviations. Surprisingly, this is not the case after 1982. After all, we observe considerable standard deviations, to a great extent caused by big differences in income and price elasticities.

4.2. Oil consumption

During the second oil crisis crude oil prices increased more than other energy prices. Therefore because of the substitution effect, errors in forecasting oil consumption are presumably bigger than errors in forecasting TPES. This is the case for $\mathrm{Oil}_t(1985)$ but not for $\mathrm{Oil}_{81\text{–}88}(1990)$ and $\mathrm{Oil}_t(1995)$. $\mathrm{Oil}_t(1995)$ is even negative (see Fig. 4).

This somehow unexpected development of $\mathrm{Oil}_t(n)$ is caused by $\mathrm{Transport}_t(n)$ being negative, cf. the next section. In the transport sector practically no substitution has taken place. Oil is still covering over 90% of the energy consumption and unexpected high growth rates in transportation demand have resulted in negative forecast errors.

The fact that $\mathrm{Oil}_{78\text{–}79}(1990)$ is not substantially bigger than $\mathrm{TPES}_{78\text{–}79}(1990)$ can also be classified with the small value of $\mathrm{Transport}_{78\text{–}79}(1990)$.

Cooper (1992) estimates oil consumption income elasticity at 1.1[13] varying from 0.28 to 1.74. Barker et al. (1995) find long-run gasoline income elasticities in 21 OECD varying from 0.45 (Switzerland) to 2.03 (Greece) and short-run gasoline income elasticities varying from 0.04 (Germany) to 0.96 (Spain). Short run price elasticity varies from 0.05 (Switzerland) to -0.57 (the Netherlands) and long-run price elasticity varies from 0.09 (Switzerland) to -2.29 (the Netherlands). Because of the substantial elasticity differences, a considerable standard deviation during the second oil crisis is expected. In fact, this is the case, cf. Fig. 5.

4.3. Total final consumption (TFC)

TPES is the sum of TFC plus transformation and distribution losses. TFC includes only three sectors. According to Fig. 6, the substantial overshooting in reviews around the second oil crisis is to a great extent caused by big positive forecast errors in the industry sector.

[13] Average for 15 of the countries included in this paper.

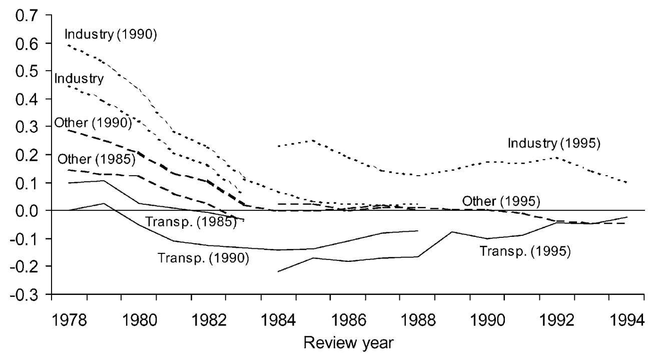

Fig. 6. Average proportional forecast errors in 3 sectors.

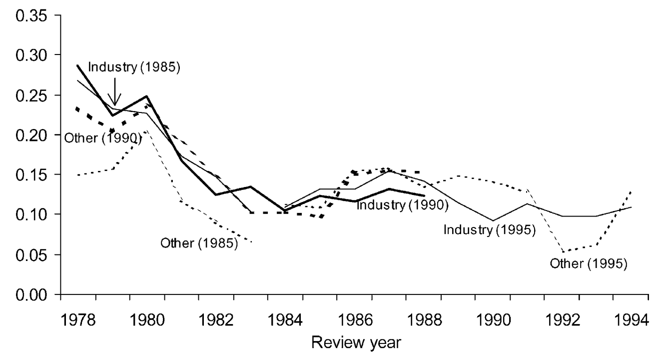

Fig. 8. Standard deviations, Industry$_t(n)$ and Other$_t(n)$.

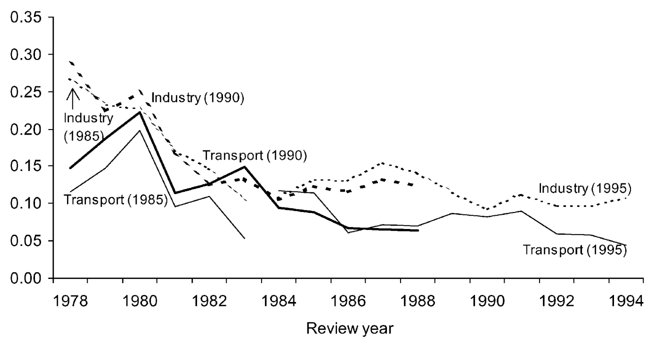

Fig. 7. Standard deviations, Transport$_t(n)$ and Industry$_t(n)$.

Even Industry$_t$(1995) is positive and considerable, presumably caused by an unexpected, low growth rate in the industrial sector. On the other hand, we notice a corresponding negative value of Transport$_t$(1995) and because Other$_t$(1995) is close to zero, TPES$_t$(1995) is also close to zero (see Fig. 2).

Thinking of big oil price increases during the second oil crisis, the negative values of Transport$_t$(1990) and Transport$_t$(1995) are a surprise. Concerning gasoline demand in 21 OECD countries Barker et al. (1995) find 1.19 and −1.28 as long-run income elasticity and long-run price elasticity, respectively. Therefore, the negative value of Transport$_t(n)$ cannot be explained by relatively small elasticities but rather by a general tendency to underestimate the demand for transportation.

As mentioned before, big differences in gasoline demand elasticities cause considerable standard deviations in forecast errors in the transport sector. In the industrial sector too, demand is characterized by huge differences in elasticities.[14] In fact, standard deviations are bigger in the industrial sector than in the transport sector, while standard deviations in other sectors are at the same level as standard deviations in the industrial sector except during the second oil crisis, cf. Figs. 7 and 8.

Surprisingly, one notices considerable standard deviations even when t is close to n. OTHER$_t$(1995) being close to zero is thus the result of considerable positive forecast errors being counterbalanced by negative forecast errors. Therefore, OTHER$_t$(1995) is not small because individual forecast errors are small.

5. RMS

In this section, forecast errors are measured according to (4) when it is established which countries have relatively small forecast errors and which have relatively big forecast errors. However, the main purpose is to test for correlation between individual forecast errors.

5.1. TPES

As above, TPES$_t(n)$ stands for forecast error measured on total primary energy supply, but in this section, TPES$_t(n)$ constitutes an average including review years from $n-6$ to $n-2$.

In most countries TPES$_{79–83}$(1985) is considerable bigger than TPES$_{89–93}$(1995), but there are exceptions (NZ, S, CDN and N) (see Fig. 9). Therefore, we find a negative correlation coefficient between TPES$_{79–83}$(1985) and TPES$_{89–93}$(1995). However, the coefficient is not significantly different from zero. Countries with relatively small forecast errors in 1985 do not have relatively small forecast errors in 1995, too. Moreover, relatively big forecast errors in 1985 correspond to relatively small forecast errors in 1990, cf. the significantly negative correlation coefficient between TPES$_{79–83}$(1985) and TPES$_{84–88}$(1990). On the other hand, a significant positive correlation coefficient exists between TPES$_{84–88}$(1990) and TPES$_{89–93}$(1995). So, relatively small forecast errors in 1990 correspond to relatively small forecast errors in 1995.

Considering forecast year 1990, Norway and Canada are nearly outliers. Both Canada, New Zealand

[14] Analyzing 15 OECD countries, the long-run income elasticity varies from 0.22 (USA) to 1.46 (Belgium) and the long-run price elasticity varies from 0.06 (Austria) to −0.35 (Denmark), cf Barker et al. (1995).

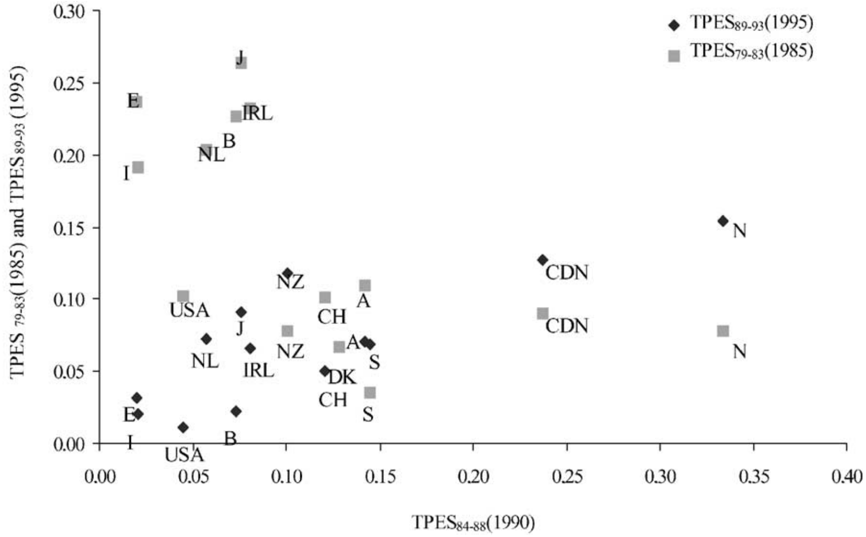

Fig. 9. RMS, $TPES_t(n)$. Note: Correlation coefficients: $TPES_{79-83}(1985)/TPES_{84-88}(1990)$: −0.59*, $TPES_{79-83}(1985)/TPES_{89-93}(1995)$: −0.37, $TPES_{84-88}(1990)/TPES_{89-93}(1995)$: 0.81*. *significant at 5% level. A(Austria), B(Belgium), CDN(Canada), DK(Denmark), IRL(Ireland), I(Italy), J(Japan), NL(the Netherlands), NZ(New Zealand), N(Norway), E(Spain), S(Sweden), CH(Switzerland). No forecast values can be found for West Germany in 1995 and for the UK in 1990 (review year 1988).

and Norway have a substantial $TPES_{89}(1995)$[15] and afterwards a considerable decrease in forecast errors.

5.2. Oil consumption

The effect of the second oil crisis appears more clearly in oil consumption than in TPES.

On average, $Oil_{79-83}(1985)$ is thus much bigger than $Oil_{84-88}(1990)$ and $Oil_{89-93}(1995)$, and $Oil_{79-83}(1985)$ is considerably bigger than $TPES_{79-83}(1985)$, cf. Figs. 2 and 3. This is to be expected because of oil prices increasing much more than energy prices in general during the second oil crisis.

None of the correlation coefficients are significantly different from zero. The Netherlands (NL) and Ireland (IRL) are highest in 1985, Japan (J) and Sweden (S) are highest in 1990 and New Zealand (NZ) and Norway (N) highest in 1995. The high value of IRL in 1985 is caused by the fact that the forecast value is not reduced substantially until 1983, 0.54 being the proportional forecast error in 1982 and −0.07 in 1983 (see Fig. 10).

Analyzing further, one would prefer splitting oil consumption up into oil consumption in the transport sector (substitution possibilities are poor) and oil consumption in other sectors (substitution possibilities are good). Unfortunately, this splitting up is not possible including all years since 1978.

[15] Only 1989 as review year.

5.3. Energy consumption in the transport sector

Forecast errors in the transport sector develop differently than forecast errors elsewhere. On average, $Transport_{79-83}(1985)$ is for instance smaller than $Transport_{84-88}(1990)$ (see Fig. 11).

Once more, there are no significant correlation coefficients between errors in the three forecast years. Ireland has a relatively high error in 1985, a relatively low error in 1990 and again a relatively high error in 1995. The relatively high error in Norway in 1985 is caused by a curious development in forecast values. In 1979 (review year) we find 4.2 Mtoe as forecast value for 1985, in 1980 1.9 Mtoe and in 1981 3.9 Mtoe. Perhaps the 1980 figure is a misprint. Sudden shifts in a forecast value can also be found in the Spanish figures. From 1980 to 1981 the proportional forecast error changes from 0.30 to −0.02.

5.4. Energy consumption in industry

Once again, there are insignificant correlation coefficients. A relatively small forecast error in one forecast year is not followed by a relatively small forecast error in the next forecast year (see Fig. 12). In 1990, Denmark is an outlier presumably because of a relatively low economic growth rate in the period 1987–1990 due to a tax reform etc.

In 1985, Ireland's forecast error is high because the forecast was not revised until 1983. From 1982 to 1983 the proportional forecast error changed from 0.43 to

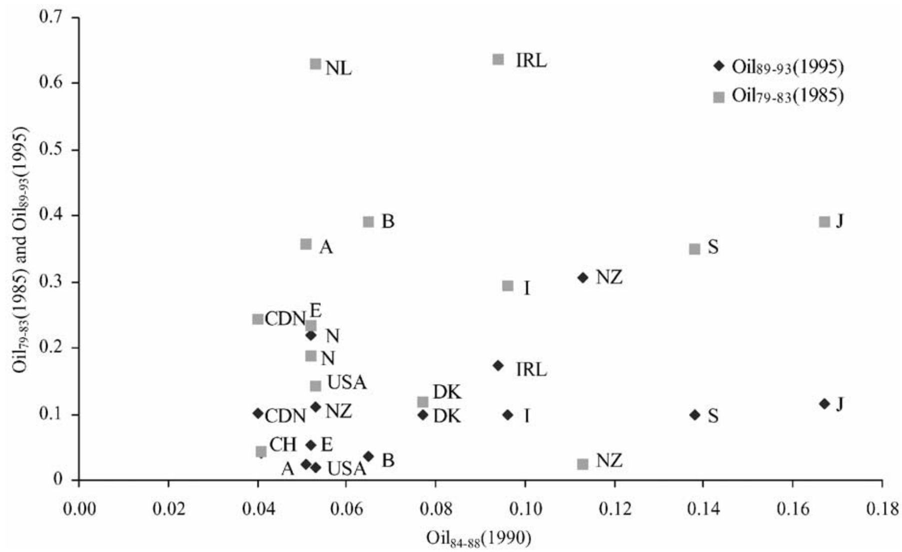

Fig. 10. RMS, $Oil_t(n)$. Note: Correlation coefficients: $Oil_{79–83}(1985)/Oil_{84–88}(1990)$: 0.17, $Oil_{79–83}(1985)/Oil_{89–93}(1995)$: −0.19, $/Oil_{84–88}(1990)/Oil_{89–}$

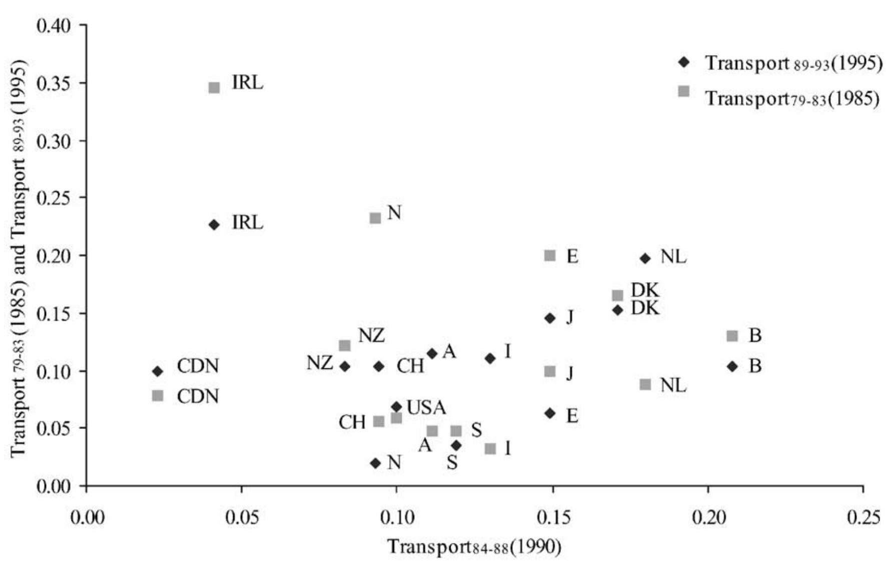

Fig. 11. RMS, $Transport_t(n)$. Note: Correlation coefficients: $Transport_{79–83}(1985)/Transport_{84–88}(1990)$: −0.17, $Transport_{79–83}(1985)/Transport_{89–93}(1995)$: 0.29, $Transport_{84–88}(1990)/Transport_{89–93}(1995)$: 0.05.

−0.17. Norway is a special case because of proportional forecast errors being negative in review years 1981 and 1982.

5.5. Energy consumption in other sectors

The correlation coefficient between $Other_{84–88}(1990)$ and $Other_{89–93}(1995)$ is positive and significantly different from zero. However, Fig. 12 also shows that New Zealand (NZ) is an outlier. Ignoring NZ, the correlation coefficient between $Other_{84–88}(1990)$ and $Other_{89–93}(1995)$ is insignificant (0.17) and the correlation coefficient between $Other_{84–88}(1990)$ and $Other_{79–83}(1985)$ turns out to be negative (−0.57*) (see Fig. 13).

The development of forecast values in NZ is peculiar, the forecast being 2 Mtoe (forecast year 1990) in 1984 and 1985 (review years), 1.3 Mtoe in 1986 and 1.1 Mtoe in 1987 and 1988. The actual value is 2.33 Mtoe.

So, the forecast error is increasing as t approaches n which of course is not to be expected.

The considerable forecast error in 1995 is due to a late revision. It was not until 1992 that the forecast value was changed from 1.2 Mtoe in 1991 to 2.4 Mtoe. The actual value is 2.43 Mtoe.

The big forecast error in Norway in 1985 is caused by big forecast errors in 1979 and 1980. In 1981 the forecast value is changed from 10 Mtoe to 6 Mtoe, actual value is 5.5 Mtoe.

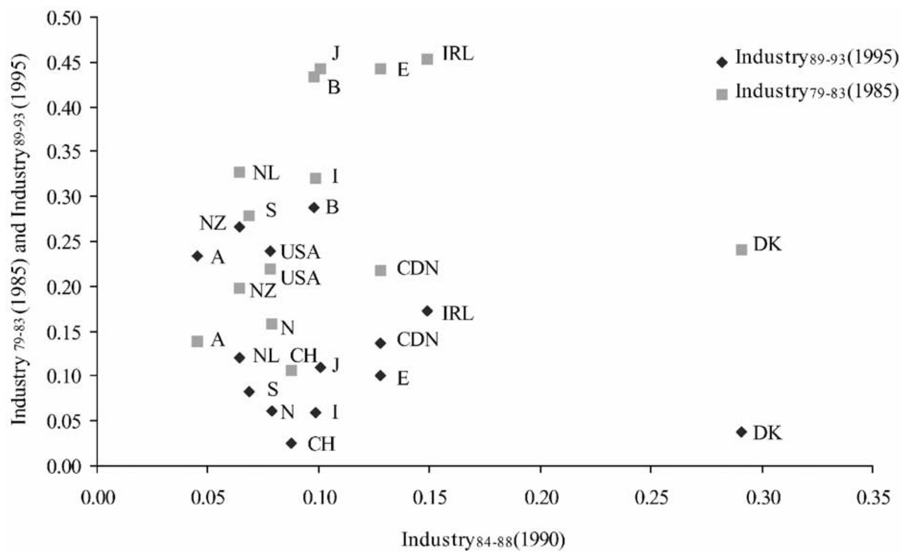

Fig. 12. RMS, Industry$_t(n)$. Note: Correlation coefficients: Industry$_{79–83}$(1985)/Industry$_{84–88}$(1990):0.19, Industry$_{79–83}$(1985)/Industry$_{89–93}$(1995): 0.12, Industry$_{84–88}$(1990)/Industry$_{89–93}$(1995): −0.37.

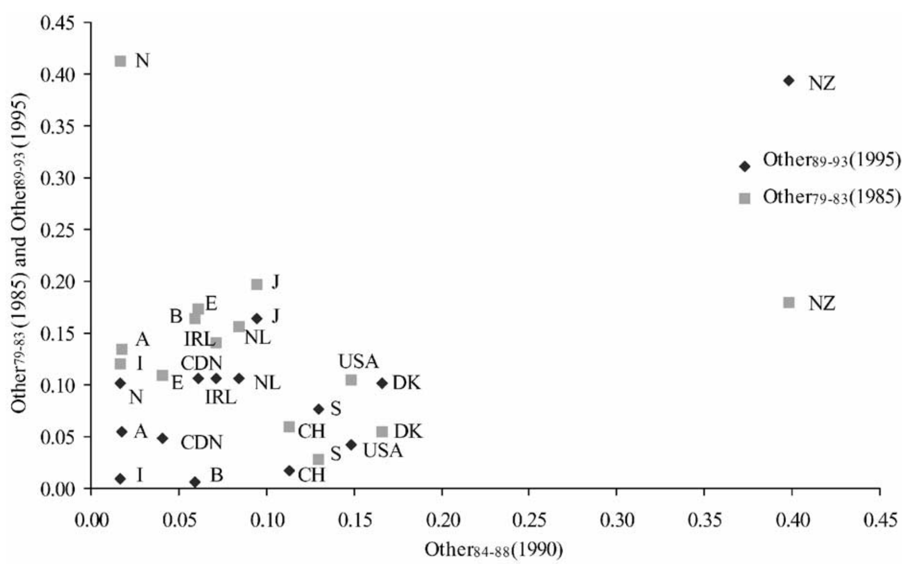

Fig. 13. RMS, Other$_t(n)$. Note: Correlation coefficients: Other$_{79–83}$(1985)/Other$_{84–88}$(1990): −0.18, Other$_{79–83}$(1985)/Other$_{89–93}$(1995): 0.25, Other$_{84–88}$(1990)/Other$_{89–93}$(1995): 0.81*.

Even though the correlation coefficient between Other$_{84–88}$(1990) and Other$_{89–93}$(1995) is positive and significantly different from zero, one concludes, because of the strange figures for NZ, that there is no correlation between forecast errors in 1985, 1990 and 1995.

5.6. Correlation between forecast errors in sectors

TPES is the sum of consumption in sectors plus losses due to transformation and distribution. A small/big forecast error can consequently be caused by small/big forecast errors in all three sectors.

This is not the case. No significant correlation coefficients can be found between sectors in any of the three forecast years, cf. Table 1. Then of course, the hypothesis that a relatively small/big TPES$_t(n)$ is connected with relatively small/big forecast errors in all three sectors is rejected. Norway has small forecast errors in industry and big errors in the other 2 sectors while the UK has big forecast errors in industry and a small forecast error in the other 2 sectors.

Table 1
Correlation coefficients between sectors[a]

Sectors\forecast year	1985[b]	1990[c]	1995[d]
Industry/Other	−0.08	0.01	0.23
Transport/Other	−0.48	−0.03	0.11
Industry/Transport	0.30	0.04	0.01

[a] Note: West Germany included in 1985 and 1990 and the UK in 1985 and 1995.
[b] Review years 1979–83.
[c] Review years 1984–88.
[d] Review years 1989–93.

6. Conclusions

As expected, the second oil crisis caused considerable forecast errors. The sudden oil price decrease in 1986 did not have the same opposite effect due to irreversibility in energy demand etc. To a great extent, forecast errors are caused by wrong growth rate expectations. The wrong expectations have materially caused big forecast errors especially in industry.

Forecast errors in oil consumption are only bigger than forecast errors in TPES in the first review years and since 1983 we have negative oil forecast errors due to negative forecast errors in the transport sector. There has been a general tendency to underestimate demand for transportation. An unexpected high growth rate in energy demand in the transport sector can of course be a severe problem in the future regarding the commitments of reducing greenhouse gas emissions.

A small forecast error for TPES in 1995 is the result of considerable, negative forecast errors in the transport sector and corresponding positive forecast errors in industry.

Studies of income- and price elasticities reveal big differences between OECD countries. Differences in elasticities imply differences in forecast errors as unexpected events occur. Therefore, a considerable scattering of forecast errors is a fact and small forecast errors measured on country averages are often the sum of considerable positive and negative forecast errors.

Even when forecast year is close to review year considerable forecast errors can occur, perhaps because of misprints. Late revision of forecasts can also explain relatively big forecast errors.

Focusing on review years 2–6 years before forecast year we only find a positive correlation coefficient between $TPES_{84-88}(1990)$ and $TPES_{89-93}(1995)$. Elsewhere, a relatively small forecast error in one forecast year is not connected with relatively small forecast errors in another forecast year.

Furthermore, no significant correlation coefficient between forecast errors in sectors has been found. Countries having relatively small forecast errors in one sector do not have relatively small forecast errors in other sectors.

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