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How to Evaluate the Forecasting Performance of a Macroeconomic Model

SUOMEN PANKIN KESKUSTELUALOITTEITA • FINLANDS BANKS DISKUSSIONUNDERLAG

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Abstract

This paper provides an answer to the question of how to improve the forecasting performance of a macro model to better account for economic developments and how to evaluate the forecasting uncertainty. The main tool in this assessment is stochastic simulation. Stochastic simulations in this paper involve both endogenous and exogenous variables. These simulations also allow us to assess the linearity of the model. Alternative dynamic simulations may, in turn, give some idea of the stability of the model. Finally, the forecasts may be improved by comparing the outcomes from the macro model and from a leading indicators' model. This kind of exercise is particularly useful in assessing the developments in the short run, in which case the macro models typically perform rather poorly.

Keywords: forecasting, macro models, simulation

JEL classification code: E37

Tiivistelmä

Tutkimus käsittelee kysymystä, miten makromallin ennustekykyä voidaan kohentaa vastaamaan paremmin talouden kehitystä ja miten ennusteisiin liittyvää epävarmuutta voidaan arvioida. Pääasiallinen apuväline analyyseissa on stokastinen simulointi. Tutkimusraportissa esitetyt stokastiset simuloinnit koskevat sekä endogeenisia että eksogeenisia muuttujia. Simuloinnit mahdollistavat myös mallin oletetun lineaarisuuden arvioinnin. Vaihtoehtoiset dynaamiset simuloinnit antavat puolestaan kuvan mallin stabiiliudesta. Ennusteita voidaan parantaa myös vertailemalla mallin simulointituloksia ennakoivien indikaattoreiden mallilla saatuihin arvoihin. Tällainen tarkastelu on erityisen hyödyllinen, kun arvioidaan talouden lyhyen aikavälin kehitystä, jonka suhteen makromallien ennustekyky on usein verraten huono.

Asiasanat: ennustaminen, makromallit, simulointi

Contents

1 Introduction

Although empirical macroeconomic models are still generally found useful (see e.g. Meyer (1997) the use of these models has in recent years met a lot of criticism. There have been several reasons for this criticism. The main reason, of course, is (the fact) that the forecasting performance has been rather poor.[1] Second, the theoretical foundations of the models have not adequately followed the overall developments of economic theory (for instance, in terms of rational expectations and the fiscal policy constraints). The econometrics has also been rather old-fashioned and inadequate. Thus, the implications of cointegration, simultaneity and so on have not been dealt with in a satisfactory way.[2]

There are many reasons for this state of affairs. One reason is surely the fact that the models have been too large (too detailed in terms of describing the economic environment) to allow for any sophisticated economic or econometric specifications. Another reason is (the fact) that the models have not undergone sufficient testing and evaluation of overall performance. Thus, it has been taken for granted that if the model is very accurate in describing the economy in the past also the forecasts are very accurate. In this paper, we concentrate just on this latter explanation and try demonstrate how to ensure that the forecasts are really reliable.

As the analytical tool, we use a small Finnish quarterly model (QMED) developed at the Bank of Finland's Economics Department initially developed for short-term forecasting purposes. We focus on the simulation properties of the model. First, we scrutinize the properties of the model by means of stochastic simulation, using the procedure suggested by Brown and Mariano (1981) with the actual residuals. For the sake of comparison, several simulations are also performed using Monte Carlo-generated data. The simulations concern both the overall sensitivity of the model and the sensitivity of the model in terms of exogenous variables. The purpose of these simulations is to assess the level of forecasting uncertainty: (can omit) stemming from both endogenous and exogenous variables. This analysis boils down to the computing of certain confidence intervals for a recent model forecast. The simulations also make it possible to examine the linearity of the model. This issue is crucial, for instance, in evaluating the values of various dynamic multipliers of the model.

In addition to stochastic simulation, we analyze the stability properties of the model. Thus, we estimate the model recursively from 1976 to 1995, so that four quarters of the data are always dropped from the sample starting from the first

[1] Obviously, one cannot blame the models for poor forecasts. But because the models are actively used in the forecast process one cannot exclude them from all responsibility. To illustrate the magnitude of forecast errors one may compute the country-average of mean absolute forecast errors (MAE) for GDP in the case of OECD forecasts (according to Economic Outlook in June). For the period 1981–1996, the current years' average MAE for the 21 OECD countries turned out to be 1.1 %, the next year's MAE 1.6 % and the combined current and next year's value 2.5 % (for details, see Andersen (1997) and Mäki and Virén (1997)). Compared with the actual change rates of GDP these are really alarmingly large values.

[2] One has to be cautious in making very far-reaching and general conclusions because there are considerable differences between models. In some respects, there has also been a lot progress in developing the models (see e.g. Brayton et al. (1997)).

quarter of 1976 and continuing until the last quarter of 1985. Dynamic simulation paths are computed for each estimated model version and these time paths are then compared to discern how much (estimation) sample selection affects the model's forecasts.

2 Simulation results

2.1 Some computational properties of the model

The QMED model is a small aggregate macro model with 14 stochastic equations and 10 identities. The total number of variables is 50. Currently, the model is estimated from quarterly data covering the period 1976–1996. The model incorporates rational expectations in terms of expected inflation and real income which affect via real interest rates, as well as via private consumption and wage formation.

The model tries to take into account the main features of a small open economy. Thus, growth is very much affected by export market developments. As for the domestic determinants of growth, (union) wage behaviour plays the key role. Wage shocks show up both in real income changes and in deterioration of international competitiveness. Finally, fiscal policy effects show up not only in aggregate demand but also in interest rate developments.

The model is basically Keynesian although some supply-side effects are also incorporated in the model. Thus, we have both capacity utilization and unemployment rate equations which allow for certain supply shocks (in particular, scrapping of the capital stock due to oil price shocks and changes in the natural rate of unemployment). Wages or, more precisely, wage drift is determined by a Phillips curve and prices are determined according to a mark-up model. The Phillips curve in specified according to the natural rate hypothesis although the capacity variable is allowed to affect the rate of wage changes. Thus, supply shocks would mainly affect via wage (or cost) developments.

To illustrate the main behavioural dependencies of the model we may present some key parameter values for the interest rate(s), the exchange rate, and the contract wages. Thus, the following values are obtained:[3]

[3] The values are percentage differences between the simulated values and the base 4 and 40 quarters respectively after a sustained once-and-for-all increase in the respective variables. Obviously, the long-run (10 years) values are not very meaningful because of the simple structure of the model.

	Interest rates +1 %		Exchange rate depreciation +1 %		Contract wages +1 %	
	1 year	10 years	1 year	10 years	1 year	10 years
GDP	-0.1	-2.4	+0.2	+0.0	+0.1	+0.2
Consumer prices	-0.0	-0.5	+0.2	+0.6	+0.4	+0.7
The current account/GDP	+0.0	+1.1	+0.1	+0.2	-0.1	-0.2
The unemployment rate	+0.2	+1.1	-0.1	+0.1	-0.0	+0.2

Output appears to be quite sensitive to interest rates, also prices react according to the conventional Phillips-curve mechanism. As for the exchange rate, the effects are quite conventional: in the short run there are some real effects but they die out in the long run. The same is largely due to contract wages which have a positive demand effect and a negative supply (cost) effect. We do not discuss the details of the model. A short presentation of the equations and variables is provided in Appendix 1. Otherwise, we refer to Hukkinen and Virén (1995), which contains a more complete description of the model.

The rational expectations version of the model is solved using the Fair-Taylor (1983) algorithm. Because the model is relatively small and the maximum number of leads is only four, the computational problems are generally minimal. However, this does not mean that the model simulations are similar to those obtained with standard backward-looking expectations models. The simulated values for the sample period depend on post-sample period values. Thus, if a forecast is computed for, say, the period 1996-2000, the values of the exogenous variables both for this period and for certain subsequent periods are needed (depending on the forecast horizon and on the number of periods over which the solution path is extended in type III iterations (cf. Fair and Taylor (1983)). Thus, when rational expectations models are used in forecasting, one cannot simply leave the post-forecasting period values of the exogenous variables unspecified or extrapolate them mechanically. In particular, if the forecasting (dynamic simulation) period is short and these future values are merely assumed to be constant, the simulation results are markedly different from the case where the future values are based on all available information (cf. Sulamaa and Virén (1989)).

2.2 Results of the stochastic simulations

Procedure

The stochastic simulations were carried out as follows. First, we ran a standard (deterministic) dynamic simulation for the forecasting period 1996Q1-2000Q4. The solution, called the **baseline**, is used as a point of reference for subsequent simulations. Secondly, we obtained 500 shuffled residuals for the period 1996Q1-2000Q4 (the current forecasting period) from the original (OLS) residuals by means of random drawings. Thirdly, we obtained 250 pseudo values for each exogenous variable using the AR(8) model (augmented with a linear time trend) residuals of the exogenous variables (estimated for the period 1976Q1-1995Q4) as a set of values from which 20 values were drawn randomly. Thus, the pseudo values for the exogenous variables were obtained as $X_{it} + \epsilon_{ijt}$, i = 1,2,..,20, j = 1,2,...,250, where ϵ_{ijt} is the shuffled value of the residual.

In the case of exogenous variables, there is no self-evident way of carrying out the stochastic simulations. Our method is similar to the analysis of Fair (1989). The AR(4) and AR(8) residuals are used simply to get some idea of the uncertainty attached to the exogenous variables. If the time path of the variable is very smooth (volatile), it is obviously much easier (more difficult) to make correct assumptions about the future values of the variable. However, one should keep in mind that this is a very crude way of estimating the uncertainty. It turns out that the time paths of the AR model forecasts for 1996Q1–2000Q4 do not always make sense. Thus, if the exogenous variables are replaced by univariate AR models and the whole model is solved, the new baseline differs substantially from the original baseline. Hence, we prefer to approach the experiment by treating the exogenous variables in the "old-fashoned" way: stochastic shocks are added to these variables to get the new pseudo variables.

Presentation of results

The results are presented as follows: The stochastic simulation results using the OLS residuals from the estimated behavioural equations are presented in Table 1. In Table 1, the results correspond to the case in which all residuals (in all stochastic equations) are taken into account. The table shows how this appears in the model forecast for these endogenous variables. The results of this exercise are also illustrated in Figure 1. The figure includes the actual time paths of the shocked values of GDP. In the same way, Figure 3 illustrates the behaviour of GDP prices. For expositional reasons, only 250 simulations are reported here. The bold line represent the average values of these simulated time paths. With these data, we construct the confidence intervals (at the 95 per cent level of significance) computed as the average value ± 2*(standard deviation). Figures 2 and 4 report the corresponding time-series.

The stochastic simulation results for the exogenous variables are briefly reported in Table 1, which contains the annual average errors and standard deviations with respect to the GDP forecast in the case where all exogenous variables are shocked at the same time.

Interpretation

In commenting on the results we start with the case in which all endogenous variables are shocked at the same time. The first thing which ought to be mentioned here concerns the spread of the simulated time paths. It is no surprise that there is a lot of volatility, but the time paths cannot be characterized as explosive. The variance increases over time, which is natural, but even after 20 quarters the forecast values of GDP concentrate very much around the baseline solution.

Quarterly values are clearly more volatile than annual values. In most cases the latter values are of greater interest (by contrast, no one is interested in the value of GDP in, say, 1999Q3). Scrutinizing the annual values reveals that the average simulation error of GDP is −0.20 per cent for the last year of the five-year forecasting period. The corresponding standard deviation is two per cent. Thus, the 95 per cent confidence interval is about nine per cent. In the case of GDP prices (implicit GDP deflator), the average error is one (strictly speaking, −1.3 per cent) and the standard deviation two per cent, implying a confidence interval of eight per cent.

The fact that the average error of GDP and GDP prices is not exactly zero may be the result of nonnormal error terms or nonlinearities. The first explanation seems more likely, i.e. the distribution of estimated residuals is not in all cases normal. Thus, the residuals are clearly (negatively) skewed, and they are marked by excess kurtosis. It is no surprise that using these residuals in stochastic simulation introduces some error in the levels of the endogenous variables.

Regarding the nonlinearity issue, we also carried out a stochastic simulation with genuinely normally distributed random numbers (with variance equal to the variance of the OLS residuals). It turned out that the average simulation errors in the case of the random normal variates were almost equal to zero, suggesting that the model is indeed linear. This is an important bit of information for interpreting the different policy simulations (and dynamic multipliers). In the linear case, the size of the effect depends linearly on the size of the change in the respective exogenous variable(s) and hence the effects of different policy actions do not depend on the level of the policy variable but rather on the change.

We have discussed mainly the behaviour of GDP. Some comments on other variables are also called for. If we first consider the nature of the forecast uncertainty, we notice that the variable with the largest average simulation error and the largest variance is business investment. Thus, the level of investment for the year 2000 can be forecast only very imprecisely. One cannot exclude the possibility that investment expenditure in 2000 will be at the same level as at the beginning of 1996, nor can one exclude the possibility that it will be twice as high as in 1996. Clearly, business investment is the weak link in the model. The reason is obvious: the investment equation involves a high degree of simultaneity. Investment both depends on and directly affects GDP. Also the capacity channel increases the simultaneous nature of the model.

In addition to investment, wages and income are variables that are difficult to forecast. This is also intuitively obvious, as it is very difficult to say anything about future incomes policy (union behaviour), i.e. whether future wage settlements will be moderate or excessively high.

Finally, we turn to the results of the analysis of exogenous variables. The results in Table 1 suggest that if uncertainty with respect to the future values of exogenous variables is somehow proportional to the variance of the AR(8) residuals of the respective variable, the resulting GDP effects are quite small. This is true both in terms of bias and variability of simulated forecasts. None of the variables is strikingly bad in this respect. Not surprisingly for a small open economy, export prices, volume of eastern trade, inventory investment and the foreign interest rates are the variables making the largest contribution to GDP forecasts.

2.3 Analysis of stability

Evaluating the tracking performance

Next, we analyse the model's performance in mimicking Finnish business cycles fluctuations. Thus, we examine the dynamic simulation paths for the period 1985–1995. The period was an exceptionally volatile one in Finnish economic history. First the country experienced a very strong boom (which was fuelled by a very favourable terms of trade development and liberalization of financial markets). Then the collapse of Eastern trade came down hard on an over-heated, excessively indebted and poorly competitive economy, causing an exceptionally severe depression in 1990. Thus, gross domestic product decreased by about 13 per cent over the three year period 1991–1993 while unemployment increased from less than 100 000 to over 500 000 (i.e. to about 20 per cent in terms of the unemployment rate).[4]

In 1985–1995 the sum of absolute changes in the GDP growth rate was more than 40 percentage points, which illustrates the difficult task of forecasting the future cyclical developments. Here, we examine whether the QMED model can track the actual time path of GDP and GDP prices for the period 1980–1995. The tracking exercise itself is quite conventional, but here we go beyond the usual practice of computing a single dynamic simulation path for the period of interest in that we also compute a backward dynamic simulation path (reversing the order of the time periods). More importantly, we pay considerable attention to the stability properties of the model. Thus, we compute eleven alternative dynamic simulation paths by re-estimating the model for eleven consecutive time periods. The first period is 1976Q1–1995Q4, the second 1977Q1–1995Q4 and so forth. Thus, we have eleven different parameter vector estimates which we use to produce the alternative dynamic simulation paths.

The results of this exercise are reported in Figures 5–8. In Figure 5 we have three conventional dynamic simulation paths for the standard version of the model (estimated from the data of 1976Q1–1995Q4). In Figure 6 static simulation paths are presented for GDP using both forward and backward simulation (the time horizon in these simulations is of course one quarter). In the latter case the order of the time periods is reversed so that time goes from 1995Q4 to 1980Q1. In Figures 7 and 8, the time horizon of both (now dynamic) simulations is set at four quarters. Finally, in Figure 9 we report the differences between actual and simulation values of GDP and the GDP deflator. The differences are computed for the endpoint values of the 1985–1995 simulations (in terms of the actual 1995 value of GDP).

Clearly, the tracking performance of the model is very good; both the upturn and downturn in GDP are correctly forecast. Also the slowdown of inflation is well explained by the model. Although it is often pointed out that dynamic simulation is not a means of proving the validity of restrictions imposed on the model (cf. Pagan (1989)), the performance is so strikingly good that we consider it

[4] See Bordes, Currie and Söderström (1993) or Dornbush, Goldfain and Valder (1995) for a more detailed description of the Finnish crisis.

to provide same justification for using the model for forecasting purposes.[5] More importantly, the simulation results seem to be highly robust in terms of the estimation period. Thus, for instance, dropping the first ten years of the original sample period only slightly shows up in the endpoint values of GDP (the same result also holds in terms of the whole simulation path). If the model estimated for the period 1976-1995 is used in simulation, the actual 1995 value of GDP is exceeded by 3.5 per cent. If the estimation period is limited to 1985-1995, the corresponding number is 1.5 per cent. Given the large changes in GDP over the period 1985-1995 (the sum of absolute changes in growth rates equalling 40 percentage points), these differences appear to be quite unimportant. In the case of the GDP deflator, the difference is larger (from +2.5 per cent to -1.5 per cent) suggesting that the high inflation period, 1976-1985, shows up in the estimated parameters of the model and the model is not completely immune to the regime change which took place in the mid-1980s. One should not, however, exaggerate the difference, which averages only 0.4 % per annum. One may compare this with the difference between the inflation rates for the first and second halves of the estimation period. For 1976-1985 the average inflation rate was 9.1 per cent, while for 1986-1995 the corresponding figure was only 3.5 per cent. Thus, one might admit that the model does not fully take into account the change in the inflation regime in the 1980s, but the model's performance is still relatively good. Although we end up with a relatively comforting conclusion as to the QMED model's performance, it is clear that in general one should investigate carefully whether models used for macroeconomic forecasting are crucially dependent on the specific data values for the estimation period.

Comparison with a monthly leading indicator model

As a final exercise, we compare the model forecast with a forecast derived from a leading indicator model. The latter model makes use of monthly data for GDP (starting from 1980). Three indicators are used as explanatory variables: the rate of change of stock prices, the interest rate spread and the terms of trade variable. These variables have been surprisingly powerful in predicting future changes in GDP and, moreover, the relationship has been very robust.

To illustrate the performance of this indicator model, we have computed ex ante forecasts for 12 months with these models starting from 1985M1 (see Figure 10, which also contains the four-quarter forecasts from the structural (QMED) model. The parameters of the leading indicator model have always been estimated with the data that precedes the forecast period. Thus, the model does not "know" the data before the forecast is made. The leading indicator model appears to be a bit more erratic than the structural model, especially for the third and fourth quarter. For the first and second quarters, the leading indicators could help forecasting GDP. In fact, they would be even better than the structural model if they were used alone (recall also that in terms of data requirements and computational burden the leading indicator model would be clearly superior). If

[5] See e.g. Fisher and Wallis (1990) for an analysis of the tracking performance of UK models. See also Brinner (1988) and Brunner and Kamin (1994) for dynamic similation exercises for the US and Japanese economies.

the time horizon becomes longer (see Figures 11 and 12) the leading indicator model forecasts become excessive volatile but they are still strikingly good in terms of the business cycle turning points.

Clearly, the example shows that it would be useful to compare forecasts from different type of models and possibly combine the forecasts (for this alternative, see e.g. Miller and Chin (1996)). One could use a system where the monthly leading indicator forecasts have a full weight in the short run but no weight in the long run. The forecasts from the structural model would be weighted in an opposite manner. Our experience suggests that advancing this way would clearly pay off in the accuracy of forecasts.[6]

3 Concluding remarks

Assessing the forecast performance of a macroeconomic model is not an easy task. Ex-post performance of individual estimated equations does not necessarily tell much of the whole model´s properties. It is obvious that one has to use several alternative approaches to ensure that the forecasts are sufficiently accurate and reliable. In this paper, we have suggested that one should make use of at least the following procedures:

- stochastic simulations in terms of both endogenous and exogenous variables.
- dynamic (and static) simulations with different orderings of the data points.
- comparisons between structural model forecasts and leading indicators.

These exercises would at least provide rough estimates of the confidence intervals and give some idea of the stability and cyclical tracking ability of the model. In particular, if the models which are estimated recursively from different data samples could pass muster in dynamic simulations that would, according to our experience, be very useful information in assessing the quality of the model(s).

[6] Thus, the mean absolute percentage error for QMED four quarter forecasts (for the data shown in Figure 8) is 1.4 %, the corresponding leading indicator forecasts 1.5 % and the weighted QMED/leading indicator forecasts 1.2 %.

Table 1. **Results from stochastic simulations**

	96	97	98	99	2000
Effects of OLS residuals of all endogenous variables on					
Gross domestic product	-0.07	-0.03	0.01	-0.04	-0.20
	1.04	1.50	1.82	2.10	2.26
GDP deflator	0.02	-0.16	-0.47	-0.84	-1.31
	0.07	1.43	1.65	1.89	2.12
Effects of AR(4) residuals of all exogenous variables					
Gross domestic product	-0.11	0.45	0.53	0.58	0.70
	0.41	0.60	0.64	0.56	0.58
GDP deflator	-0.04	-0.03	0.06	0.22	0.23
	0.29	0.35	0.44	0.43	0.41

Average error (first line) refers to the percentage difference between the baseline and the 250 simulations computed over 20 quarters. The displayed figures are annual sums. Standard deviation (second line) is the corresponding statistic for the sums of quarterly standard deviations with respect to the baseline. More complete results are presented in Hukkinen and Virén (1995).

Figure 1. **Stochastic simulation results for the growth rate of the Gross Domestic Product**

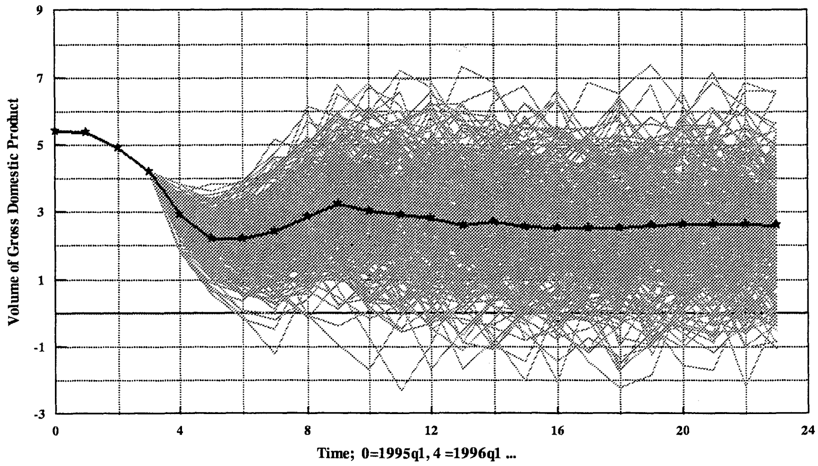
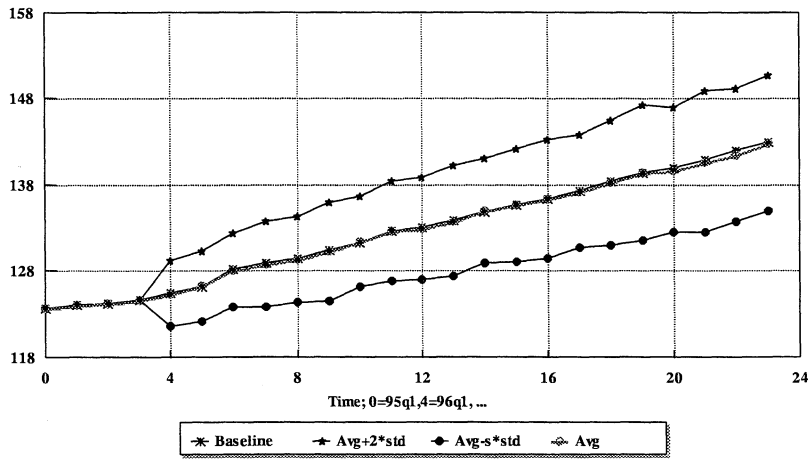


Figure 2. **Forecast for the Gross Domestic Product**



Displayed figures are billions of GDP at constant 1990 Finnish markka prices. The "baseline" is the deterministic dynamic simulation path, "avg" is the average of 250 stochastic simulations and "avg ±2*std" is the 95 per cent confidence interval. In this and the following figures 5-10, the vertical scale represents GDP volume.

Figure 3. **Stochastic simulation results for the growth rate of inflation**

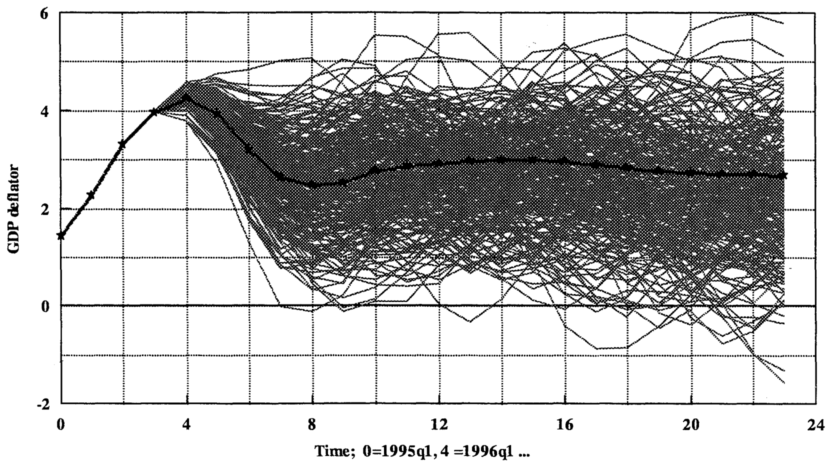


Figure 4. **Forecast for the rate of inflation**

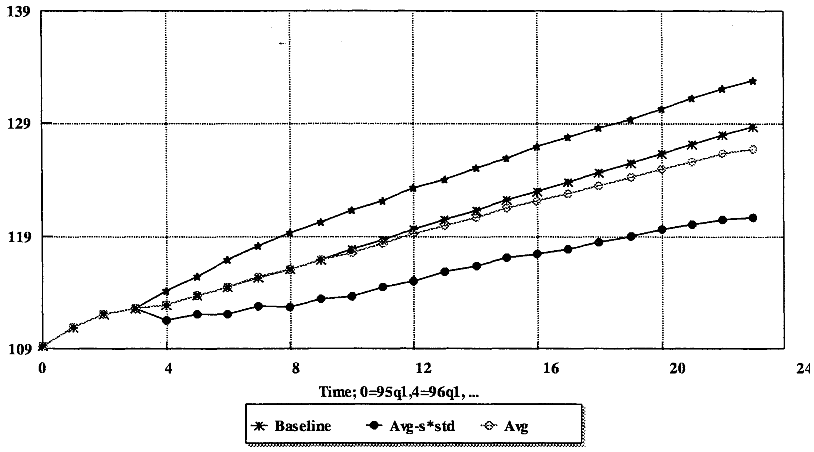


Figure 5. **Dynamic simulation results for 1980–1995**

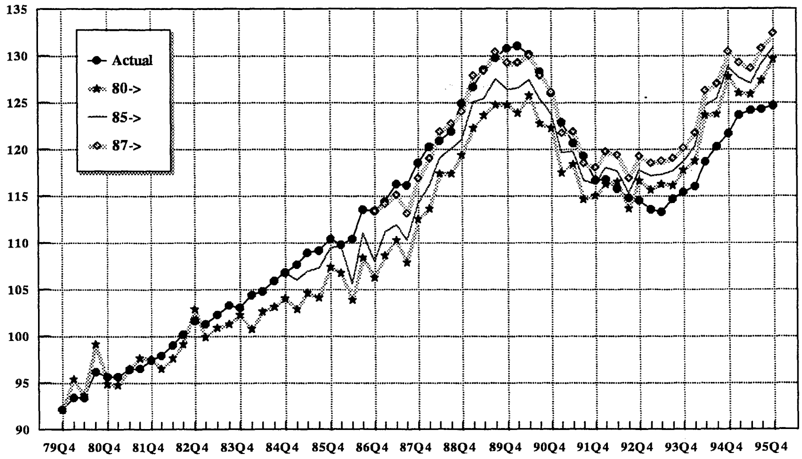


Figure 6. **Quarterly static simulation results for 1976–1995**

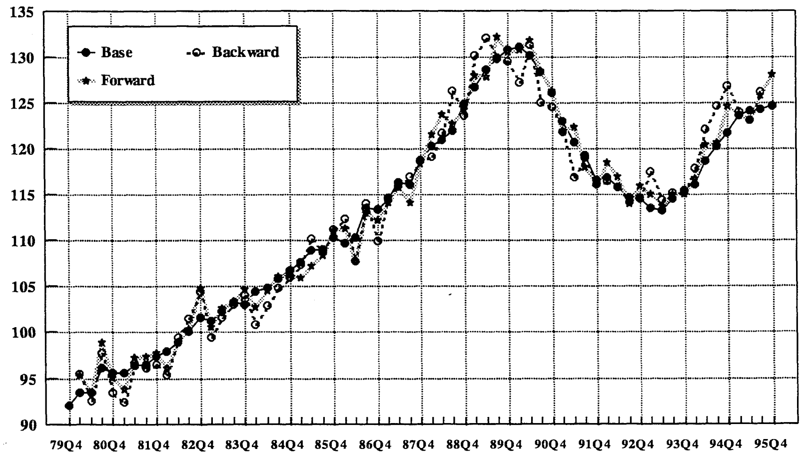


Figure 7. **Annual dynamic simulation results for 1976–1995**

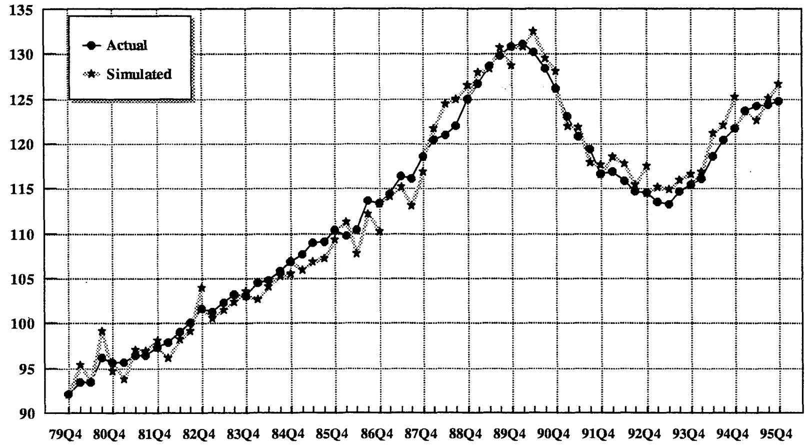


Figure 8. **Simulation errors for the endpoint values of 1985–1995 simulation**

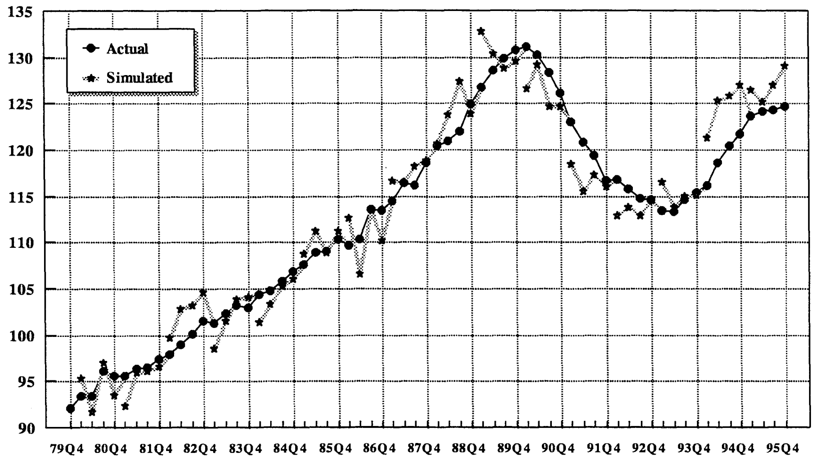


Figure 9. **Simulation errors for the endpoint values of 1985–1995 simulation, %**

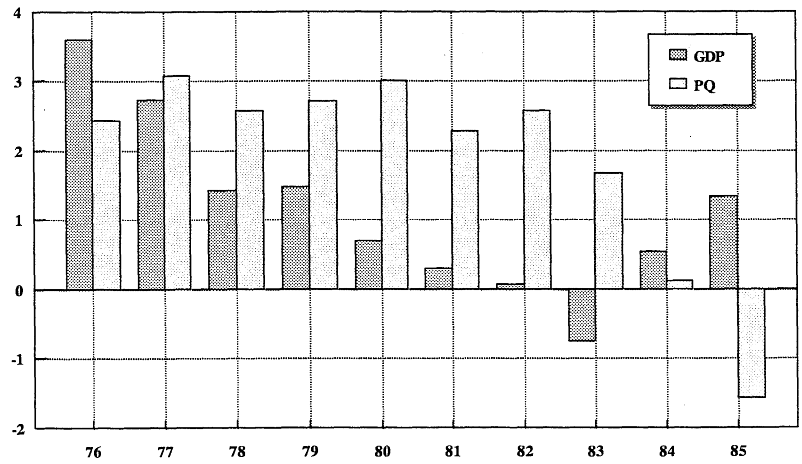


Figure 10. **Comparison of QMED and leading indicator forecasts for four quarters**

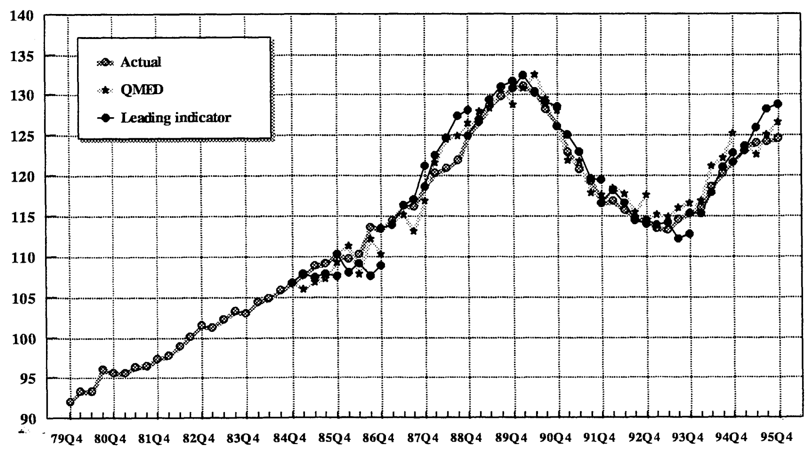


Figure 11. **Comparison of QMED and leading indicator forecasts for alternative time horizons**

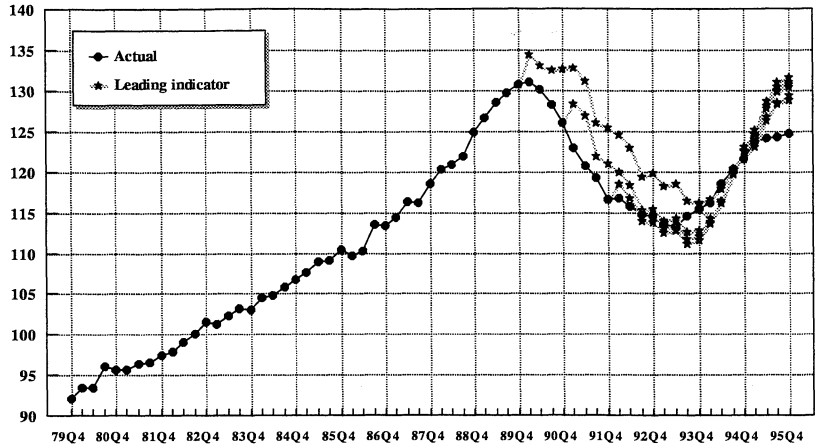
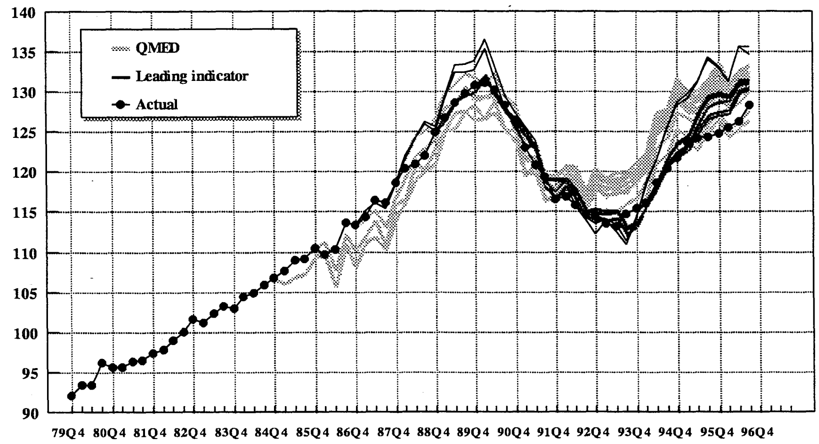


Figure 12. **Recent leading indicator forecasts**



References

Andersen, P. (1997) **Forecast Errors and Financial Developments**. BIS Working Paper 51.

Bordes, C. – Currie, D. – Söderström, H.T. (1993) **Three Assessments of Finland's Economic Crisis and Economic Policy**, Bank of Finland, Series C, No. 9.

Brayton, F. – Levin, A. – Tryon, R. – Williams, J. (1997) **The Evolution of Macro Models at the Federal Reserve Board**. Paper presented at the Carnegie-Rochester Conference on Public Policy, November 22–23.

Brinner, R. (1985) **The Power of Economic Theory and Macroeconomic Models during the Past Decade**, DRI Memo. Presented in the Fifth World Congress of the Econometric Society, Boston.

Brown, B. – Mariano, R. (1981) **Residual Based Procedures for Predicting and Estimation in a Nonlinear Simultaneous System**. Econometrica 52, 321–343.

Brunner, A. – Kamin, S. (1994) **Determinants of the 1991–1993 Japanese Recession: Evidence from a Structural Model of the Japanese Economy**, International Finance Discussion Papers, Board of Governors of the Federal Reserve System, No. 479.

Dornbusch, R. – Goldfajn, I. – Valder, R. (1995) **Currency Crises and Collapses**, Brookings Papers on Economic Activity 2:95, 219–293.

Fair, R.C. (1989) **Does Monetary Policy Matter? Narrative vs. Structural Approaches**. National Bureau of Economic Research Working Paper No. 3045, Cambridge MA.

Fair, C.R. – Taylor, J.B. (1983) **Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectations Models**. Econometrica 51, 1169–1185.

Fisher, P. – Wallis, K. (1990) **The Historial Tracking Performance of the UK Macroeconomic Models 1975–1985**. Economic Modelling 7, 179–197.

Hukkinen, J. – Virén, M. (1995) **Assessing the Performance of a Macroeconomic Model**. Bank of Finland Discussion Papers No. 5/95.

Lahti, A. (1989) **Rational Expectations in a Macromodel: An Empirical Study**. Bank of Finland, Series D:72, Helsinki.

Lahti, A. – Virén, M. (1989) **The Finnish Rational Expectations QMED Model: Estimation, Dynamic Properties and Policy Results**. In J. Gruber (editor) Economic Decision Models, Lecture Notes in Economic and Mathematical Systems No. 366, Springer-Verlag, Heidelberg, 283–304.

Meyer, L. (1997) **The Role of Structural Macroeconomic Models**. Paper presented at the AEA Panel on Monetary and Fiscal Policy, in New Orleans, January 5.

Miller, P. – Chin, D. (1996) **Using Monthly Data to Improve Quarterly Model Forecasts**. Federal Reserve Bank of Minneapolis Quarterly Review 20. No. 2, 16–33.

Mäki, T. – Virén, M. (1997) **Fiscal Policy Coordination in OECD Countries**. Paper presented at the AEA Conference on Public Deficits and the Monetary Union, in Rome, November 27–28.

Pagan, A. (1989) **On the Role of Simulation in the Statistical Evaluation of Econometric Models**. Journal of Econometrics 40, 125–139.

Sulamaa, P. – Virén, M. (1989) **Examining the Effects of Anticipated Policy Actions: Results with the Finnish Micro-QMED Model**. Bank of Finland Discussion Papers 35/89, Helsinki.

Appendix 1 The contents of the model

Endogenous variables

1. Exports

$xq_t = 2.48 + .46xq_{t-2} + .39fq_{t-1} - .72(px/pf)_{t-1} + .13fe_t$

$R^2 = 0.97$, $DW = 1.77$

2. Imports

$mq_t = .52 + .12mq_{t-1} + .18mq_{t-2} + .10cq_t + .41xq_t - .46(pm - pd)_t + .37hs_{t-1}$

$R^2 = 0.96$, $DW = 1.76$

3. Private consumption

$cq_t = .74 + .86cq_{t-1} + .12(yh - pc)_{t+1} - .04(rb - \Delta pc_{t+1})_{t-3} - .68\Delta pc_t - .23\Delta un_t + .09\Delta ph_t + .07\Delta ph_{t-4}$

$R^2 = .99$, $DW = 2.32$

4. Business investment

$$\Delta_2 i1q = .27\Delta_2 i1q_{t-1} - .18\Delta_2 i1q_{t-2} + 1.63\Delta yd_t + .01\Delta bbf_t - .33(rb - \Delta pi_{t+1})_{t-4} - .19rdif + .12\Delta sx_{t-5} + .09\Delta sx_{t-10}$$

$R^2 = 0.69$, $DW = 2.00$

5. Residental investment

$ih_t = 5.18 + .34ih_{t-1} + .25bbh_{t-1} + .08bbh_{t-2} - .29(rb - \Delta ph_{t+1})_{t-3} + .03\Delta(yh_{t-4} - pa_{t-4} - .12D76$

$R^2 = 0.96$, $DW = 1.88$

6. Households' disposable income

$\Delta yh_t = .07 + \Delta pc + .52\Delta(yh - pc)_t + .33\Delta y - .03(pg \cdot gq + pi \cdot ig)/yv)_{t-1} - .07(yh - yv)_{t-4}$

$R^2 = 0.50$, $DW = 1.61$

7. Wage rate

$\Delta w_t = 1.03\Delta wc_t + .02\Delta pc_{t+4} - .04(un - nun)_t + .56hs_t$

$R^2 = .96$, $DW = 1.65$

8. Negotiated wage rate

$\Delta wc = .32\Delta pc_{t-1} - .31\Delta lm_t - .01(yh - yv)_{t-1} - .02(wc - pm)_{t-1}$

$R^2 = 0.40$, $DW = 1.93$

9. Consumption prices

$\Delta pc_t = .11\Delta w(1 + ltax)_t + .19\Delta w(1 + ltax)_{t-1} + .20\Delta w(1 + ltax)_{t-2} + .08\Delta pm_t + .07\Delta pm_{t-1} - .03(pc - px)_{t-1}$

$R^2 = 0.63$, $DW = 1.72$

10. Investment prices

$\Delta_2 pi_t = .30\Delta_2 pi_{t-1} + .44\Delta_2 w(1 + ltax)_t + .06\Delta_4 pm_t$

$R^2 = 0.47$, $DW = 1.65$

11. Public consumption prices

$\Delta pq_t = .83\Delta w_t(1 + ltax_t) + .08\Delta pm_{t-3} - .01(pg - pc)_{t-1}$

$R^2 = 0.70$, $DW = 2.82$

12. Government bond yield

$rb_t = -.12 + .60rb_{t-1} + .08\Delta_4 pc_{t+4} + .29rd_t + .05rdif_{t-1} + .20rf$

$R^2 = 0.94$, $DW = 1.12$

13. Capacity utilization rate

$hs_t = .17 + .92hs_{t-1} + .41\Delta y_t - 1.53\Delta ln_t - .01i1q_t - .01(pv - pq)_t$

$R^2 = .90$, $DW = 2.12$

14. Unemployment rate

$un_t = 7.98 + .95un_{t-1} + .16run_t - .10hs_{t-1} - .16\Delta y_t$

$R^2 = 0.99$, $DW = 1.43$

15. Gross domestic product (volume)

$Y = CQ + GQ + XQ + IQ + IW - MQ$

16. Gross domestic product (value)

$YV = CQ \cdot PC + GQ \cdot PG + IQ \cdot PI + PX \cdot XQ - PM \cdot MQ + V_1$

17. Private demand

$YD = I1Q + IH + CQ + XQ$

18. Total fixed investment

$IQ = IG + I1Q + IH$

19. Current account

$CA = PX \cdot XQ - PM \cdot MQ + TR + V_3$

20. Transfers and other expenditure

$TR = .005YV + IE + V_4$

21. Interest expenses

$IE = -1.15 + .003RF \cdot DEBT$

22. Foreign debt

$DEBT_t = DEBT_{t-1} + CA_t + V_{3t}$

23. GDP deflator

$PQ = YV/Y$

24. Private demand prices

$PD = (\Pi \cdot IQ + PC \cdot CQ + PX \cdot XQ)/(IQ + CQ + XQ)$

Lower case letters denote logarithms, capital letters untransformed values. For space reasons, the t-values and other test statistics are not displayed.

Exogenous variables

bbf	Building permits for firms
bbh	Building permits for households
D76	Dummy for 1976Q1
fe	Exports to non-market economies
fq	Foreign import demand
gq	Public consumption
ig	Public investment
iw	Inventory investment plus statistical error
ltax	Employees' social security expenses
lm	Total employment
ln	Working-age population
nun	Natural rate unemployment
pf	Foreign producer prices
ph	Implicit price deflator for residential investment
ph	House prices
pm	Import prices
po	Import prices of oil products
px	Export prices
rd	Bank of Finland base rate
rdif	Interest rate differential between Finland and Germany
rf	Long-term interest rate for FRG, UK and USA
sx	Stock prices
v1	Statistical error in national accounts
v2	Statistical error in national accounts
v3	Statistical error in national accounts
v4	Statistical error in capital account

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