An estimated general equilibrium model for forecasting

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The purpose of economic forecasts is to support economic agents' decision-making by providing a coherent picture of the present state of the economy and the outlook for the future. Since 2004, a key tool for preparing the Bank of Finland's forecast has been the Aino model.[1] It is employed as a tool for integrating forecast information. The new version of the Aino model was introduced in the preparation of the March 2010 forecast. This article describes the features of the model and its use in the preparation of forecasts.

Describing business cycle fluctuations with general equilibrium models

In developed economies, business cycle fluctuations, ie fluctuations around trend economic growth, occur at fairly regular intervals. These fluctuations are the result of shocks, often described as impulse-like, that are reflected in the economy either rapidly or after a lag. An individual shock typically has a short-term effect on the economy. If the economy is not hit by new disturbances, the impact of the shock eases over time and the economy returns to the original equilibrium. General equilibrium models such as the Aino model have been developed mainly for analysing cyclical fluctuations.

The various schools of economic thought emphasise different factors as causes of shocks and cyclical fluctuations. According to the real business cycle (RBC) theory, business cycles are driven primarily by fluctuations in the pace of technological development. Economic history is full of examples of how major innovations, eg the microcomputer, have boosted productivity and thus given a positive and long-term impetus to economic growth.

In addition to innovations affecting the production capacity of the economy, fluctuations on the demand side may also cause cyclical movements. For example, exchange rate movements or changes in consumer preferences affect the structure of demand in the economy and trigger adjustment processes that may induce business fluctuations. Some of the shocks, eg unexpected changes in interest rates or tax rates, are measurable and observable, whereas the majority of shocks, eg preference shocks, are unobservable and not directly measurable in occurrence or impact. Modern general equilibrium models can also be used to examine unobservable shocks and their transmission between sectors of the economy. The development of statistical methods and software has enabled the quantitative analysis and numerical observation of these shocks. An example of this type of exercise is presented in the last paragraph of this section.

In general equilibrium models, shocks typically have both direct and indirect effects on real variables or relative prices. For example, an unexpected rise in domestic wages will result in an increase in production costs. The direct effect of pay increases is a rise in costs and subsequent upward pressure on prices. If at the same time, wages remain unchanged in the rest of the world, Finnish companies' competi-

[1] The Aino model is described in the article 'Aino: the Bank of Finland's new dynamic general equilibrium model of the Finnish economy' by Juha Kilponen, Antti Ripatti and Jouko Vilmunen. Bank of Finland Bulletin 3/2004.

tiveness will decline. A large relative increase in domestic wages may induce Finnish companies to relocate production abroad. The total indirect effect of a wage increase may be more significant for the economy than the direct impact on costs.

The original Aino model still useful in analysing fiscal policy

The Aino model that was introduced in 2004 was developed for analysing fiscal policy issues related to demographic change, the increasing proportion of pensioners and the resulting fiscal policy challenges. The model has also been used for integrating forecast information and in preparing alternative projections.

In the model, the lifespan of an economic agent consists of time spent in the labour force during which savings are accrued for pension years, and time in retirement during which consumption is financed with income transfers in the form of pensions, savings and, to an extent, by working. The public sector is modelled so that key taxes and income transfers are allocated between the working-age population and pensioners. Employment pension funds and the related pension scheme are modelled in line with that in Finland, ie as a partly-funded scheme.

Aino has been used to analyse ways of funding pension and public expenditure caused by population ageing. The model takes into account many of the indirect effects of the various funding methods on economic developments, eg the effect of an increase in pension contributions on labour supply. The indirect effects are clearly stronger than expected and thus provide a clearer picture of the challenges to public finances due to population ageing.[2]

A key indirect effect is due to the fact that pension contributions are comparable to taxes. Pension contributions have the same behavioural effects as income taxes, and pensions work like income transfers. Increases in pension contributions will reduce labour supply and thus slow the accrual of pension contributions. Calculations made using the Aino model show that the labour supply effect causes an extra burden of several percentage points on employment pension contributions if the distribution principles of the pension scheme are unchanged.

Another interesting outcome of economic policy analysis is that the pension contribution burden of the retirement of baby-boomers should be smoothened over time using accrued employee pension contributions as a buffer. As a result of this smoothing, the distortions are reduced.[3]

Apart from fiscal policy analysis, Aino has been used in other studies and surveys on the structure of the economy. The importance of competition in the labour and product

[2] Kilponen, J. – Kinnunen, H. – Ripatti, A. (2006) Population ageing in a small open economy – some policy experiments with a tractable general equilibrium model. Bank of Finland Discussion Papers 28/2006.

[3] Kinnunen, H. (2008) Government funds and demographic transitions – alleviating ageing costs in a small open economy. Bank of Finland Discussion Papers 21/2008.

markets was one of the first areas of research where the Aino model was used.[4] The model enables the examination of developments in a company's pricing margins and the effects of margin changes on the economy. Competition in the labour market can be linked to wage formation and developments in the world economy in an examination of the importance of Finland's price competitiveness for exports and economic growth.[5]

Structure of the Aino model

The structure of the new estimated Aino model corresponds fairly closely to the original Aino model as regards the structure of output. The structure of the model has been embellished, with a view to inflation forecasting.

The description of households' lifespan has been simplified to make the use of the model in forecasting more straightforward. The retirement period has been excluded from households' lifespan. Instead, households' consumption behaviour has been enriched with habit formation. Habit formation means that consumers try to maintain habitual consumption behaviour. For example, an unexpected decline in income does not immediately cause households to adjust their level of consumption to the changing income outlook. This gives aggregate consumption a sluggishness that is more consistent with the observations than does a modelling technique that allows for sudden changes in the level of consumption.

In the model, wages are assumed to be fairly rigid because, although they are adjusted regularly and mechanically for inflation, the average length of wage agreements is two years.[6] This together with the monopolistic elements in labour supply leads to inefficient restrictions on the use of labour that vary over time.

An important change to the original Aino model is the more precise modelling of Finland as a small part of the euro area. Moreover, a distinction is made between the euro area financial market or in the financial markets of the rest of the world. Economic agents can invest in the euro area financial market and the financial markets of the rest of the world. A key difference is of course that investments in the euro area are not affected by exchange rate movements. Investors want to be compensated also for the riskiness of investments. In the model, this compensation is the risk premium. The risk premium for an investment in Finland is assumed to depend on Finland's net external debt[7] and the risk premium does not depend on the currency area from which the investment is made. In

[4] Kilponen, J.– Ripatti, A.(2006) Labour and product market competition in a small open economy – Simulation results using a DGE model of the Finnish economy. Bank of Finland Discussion Papers 5/2006.

[5] Railavo. J. – Rantala, A. – Ripatti, A. (2008) Suomen viennin odottamattomat vaihtelut, palkat ja kokonaistaloudellinen kehitys: Laskelmia Aino-mallilla. BoF Online 6/2008. (Unexpected fluctuations in Finnish exports, wages and macroeconomic developments: calculations with the Aino model. BoF Online 6/2008, in Finnish only).

[6] The average length of wage agreements is a parameter that is estimated from statistical data, based on the structure of the model.

[7] This is consistent with the observation on the recent euro area crisis that the current account deficit correlates with the risk premium of a country's public debt.

addition, Finland is assumed to be such a small part of the euro area that economic developments in Finland do not affect economic developments in the euro area and thus do not affect euro area monetary policy.

In the Aino model, the corporate and production sector is constructed so that the model is more consistent with statistical data – particularly inflation data. The model is still based on a single representative product produced in Finland. The product is priced assuming monopolistic competition and stickiness as in the labour market. This domestic intermediate good is used, together with imported goods, to manufacture consumer, investment and export goods. Export companies are large and have gained pricing power in the international markets through specialisation.

In the model, the production of consumer goods comprises three product groups: domestic intermediate goods, imported consumer goods and imported oil-based energy products. Domestic intermediate goods and imported goods have strong substitutionability. In addition, the price formation of imported goods is rigid, as a result of which changes in world market prices are transmitted slowly into domestic inflation. As a result of strong substitutionability, changes in domestic and foreign relative prices are reflected in sizeable shifts in demand between domestic and foreign consumer goods. In the model, this channel is restricted by costs related to changes in the import ratio of consumer goods. The situation is very different for oil-based products. Firstly, oil-based products, eg motor fuels, are difficult to replace in the short-term. Secondly, changes in the world market price for oil are very quickly transmitted to domestic prices of oil products. The relative change is however slightly dampened by the fact that the fuel tax is measured in cents. Due to this structure, the model should be able to forecast more precisely how changes in oil prices are transmitted to the Finnish economy via consumer price inflation.

The public sector is smaller than in the previous version of the Aino model because of the simple fact that the taxes and income transfers from households are no longer divided between working-age population and retirees. However, the key taxes, eg income tax, corporate tax and indirect taxes, are part of the general government budget constraint. Income transfers are tax-exempt and hence free lump sums, and in the model they do not affect household behaviour. Public sector consumption is also divided into two parts. The first part consists of public sector purchases, ie the part of public expenditure where the producer is the private sector. The second part is public sector output. Public sector output is created by public sector employment. Fluctuations in public sector employment have a significant impact on the labour market and thus on the whole economy.

The model as a forecasting tool

In addition to policy analysis, the Aino model is used as a forecasting tool and for calculating alternative projections.

The Bank of Finland was the first central bank, after the Bank of England, to use a dynamic stochastic general equilibrium (DSGE) model in the preparation of forecasts.

In preparing forecasts, the outcomes are controlled based partly on discretion as to factors external to the model. The actual published outcome of the forecast is thus never a mechanical model forecast; instead it is based on both the model and these exogenous factors. The model helps to assess the macroeconomic importance of these exogenous factors as they are systematically taken into account.

Due to the nonlinearity of the original Aino model, the initial values of the unobservable variables had a significant impact on the outcome of the forecast. Forecasting techniques have been greatly improved and so enable richer and more efficient forecasting and use of the model than in 2004 when the Aino model was introduced.

The vast quantitative uncertainty inherent in the forecast is described via alternative scenarios. Without the macroeconomic model, it would be impossible to prepare alternative scenarios as consistent calculations. On the one hand, the model leads one to systematically consider the sources of economic uncertainty, and also provides a fairly extensive picture of the macroeconomic effects of the uncertainty. The model also helps us to understand the various impact channels of the variables and their interrelated strengths for assessing macroeconomic effects.

The new Aino model facilitates preparation of forecasts and analysis of forecast errors

The strengths of the new Aino model are in forecasting. Firstly, the model has a linear structure.[8] Secondly, linearity enables the use of methods that facilitate the preparation of forecasts. For example, the calculation of unobservable variables becomes a simple mechanical procedure. Thirdly, linearity means that the parameters of the model can be estimated using Bayesian estimation methods.[9]

In dynamic macroeconomic models, economic agents react optimally to economic disturbances. The model is a description of such optimisation by economic agents. When the structure of the model is fixed and the parameter values are known, disturbances in the linear model can be calculated from historical data, using the Kalman filter. Disturbance processes can be linked to economic phenomena, eg technological advancement, price margins, or consumers' preference for foreign products. Disturbance processes can be forecast because they work slowly.

Discretion is introduced into the forecast with the help of these disturbance processes with close observance of the behavioural norms of economic agents included in the model. For example, if the forecaster believes that economic growth will pick up as a

[8] The model is log-linearised around the deterministic stable growth path. The linearity of the model is hence the result of approximation.

[9] The estimation method was developed by Smets and Wouters in the article 'An estimated stochastic dynamic general equilibrium model of the euro area'. Journal of the European Economic Association 1/2003.

result of faster-than-normal productivity growth, the projection for technological advancement can be adjusted accordingly. As the pace of technology growth has an impact on most economic variables, we need a model for calculating the macroeconomic response.

In the preparation of forecasts, indicator data usually give a very clear picture of economic developments in the current or next quarter. The model however rarely captures the same situation; instead, it must be guided to produce it. A model can be given a resultant situation; then based on its internal structure, the model selects the outcome of the disturbance processes that will produce that situation. This selection can of course still be influenced. The linearity of the model enables this and thus enhances the effectiveness of the model for preparing forecasts.

Shock processes in the Aino model

The number and types of shocks chosen for a general equilibrium model depend on the purpose of the model. Of the shocks applied to the Aino model, only five are linked to measurable observed variables – eg the oil price shock and the interest rate shock – and they all are foreign variables. The other shocks, eg to capital-saving technology and to the price margin on exports, are unobservable.

As the Aino model includes so many types of shocks, it is reasonable to separate them into groups. The shocks were divided into five categories. The category 'technology shocks' includes shocks affecting technological advancement. These either improve or weaken productivity by affecting the efficiency in the use of production factors such as labour, capital or oil. Price shocks include price and wage margins: the price margins on domestic and imported capital and consumer goods, price margins on exported goods, and wage margins. The third category includes exogenous, foreign shocks that spread to Finland as a result of international economic developments, eg oil price shock, commodity price shock and price shock in export markets. Policy shocks include interest and exchange rate changes, and fiscal policy shocks to public consumption and taxation. Preference shocks include consumer preference shocks and preference shocks affecting the utilization of production factors by companies. The latter can best be described with the following example. In Aino, it is assumed that companies producing eg export goods use in their production process intermediate goods manufactured in Finland and imported raw materials. A positive preference shock to raw materials increases export companies' use of raw materials relative to domestic intermediate goods. This will lead to an increase in raw material imports into Finland and reduce the demand for domestic intermediate goods. Preference shocks also affect the relative prices of final products.

Example: an analysis of the recession, using the shock processes in the Aino model

The features of the new, estimated Aino model include the possibility of decomposing the observed time series

into shock processes, as described by the model. The calculation can also be solved the other way round, in which case the model gives the impacts of the various shocks on each observed variable. The shocks are weighted based on the impact channels described by the model and as a result the weighted shocks add up to the original time series. Quarterly changes in the three observed variables – output, volume of consumption, and average wages – and the shocks caused by these changes between 2005 and 2010 are shown below in Charts 1 to 3. The solid curves describe the quarterly changes in the variables.[10] The bars show the groups of shocks that affect the observed variable. If the shock caused an increase the variable, the bar is on the positive side of the axis; if a decrease, the bar is on the negative side of the axis. The net sum of these negative and positive areas gives the final growth rate of the variable. The size of the bar shows the magnitude of the shock category and its total impulse effect.

The effects of the shocks on various variables differ from each other. Both of the real variables examined are mainly affected by the preference shock, technology shock and the foreign shock. The price shock has a strong effect on average wages. Policy shocks have smaller effects. The decomposition of shocks illustrates well a feature of general equilibrium theory: for example, the effect of a technology shock on production factors is not restricted to production but spreads to consumption and other areas of the economy.

The financial market turbulence that started in the US mortgage market in 2008 quickly expanded into a global economic crisis. The crisis spread to Finland via international trade. Exports collapsed by 20% in 2009, and output aimed at the domestic and foreign markets shrank by10%. Gross domestic product declined by 8% in 2009.

Total output collapsed with exports (Chart 1). Output declined in the fourth quarter of 2008, as a result of a negative technology shock and a foreign shock. The effects of these shocks continued in the first quarter of 2009, but weak demand, appearing as a preference shock, slowed output growth in 2009. Without public demand – stimulus measures – domestic output would have declined even more.

Private consumption started to decline already in the second quarter of 2008 as consumers were frightened by gloomy economic news (Chart 2), and the contribution of the preference shock diminished. Private demand started to expand already in mid-2009. The monetary and fiscal policy stance changed to became supportive of private consumption at the end of 2008, which was appeared as a positive policy shock up until 2010. The sharp fall in oil prices slowed the decline in private consumption in 2009, which appeared as a positive foreign shock (Chart 2).

Chart 3 shows how slowly average wages per hour reacted to the collapse of output. In 2008, average wages rose by nearly 5% and the growth in wages

[10] In the charts, the solid curves show the variables' algorithmic changes.

did not slow down until the second quarter of 2009. In early 2009, the wage margin shock – in the price shock category – still gave a strong boost to wage growth, which is shown in Chart 3 as a positive price shock. In contrast, the technology shock dampened wage growth. The policy shock – in the period under review it is affected mainly by the easing of income taxation – is systematically below the horizontal axis, thus indicating a dampening of wage growth.

Shock categories can affect the real variables in a number of ways (Charts 1–3). For example in 2008–2010, the preference shock category has opposite effects on private consumption and output, whereas a negative technology shock reduces output, consumption and wages.

The story told by the shock processes reaches the same conclusion as the Bank of Finland's macroeconomic forecasts, although the shock processes are not discussed in the forecast publication at the same level of detail. In the analysis of the outcome of the forecast and the writing of the forecast, in particular, the economists' view is emphasized, rather than a model-driven forecast. Contribution decompositions however provide the user and developer of the model with an abundant amount of additional information on the workings of the model. A good example of a similar analysis is that of Christiano, Motto and Rostagno, who use a shock contribution distribution to compare the monetary policy of the ECB and the US Federal Reserve and the effects of

Chart 1.

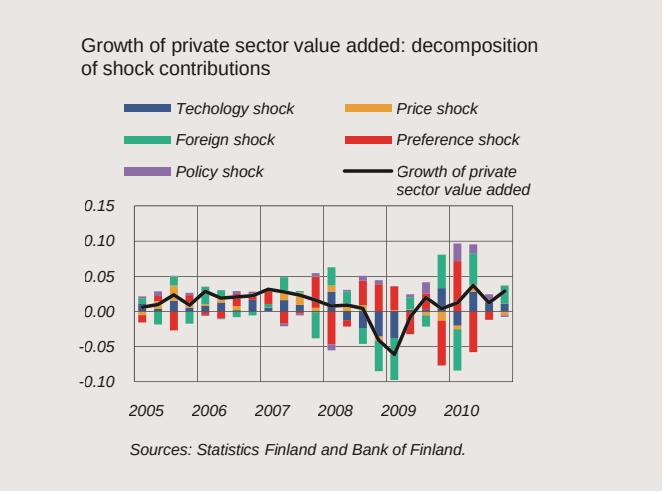


Chart 2.

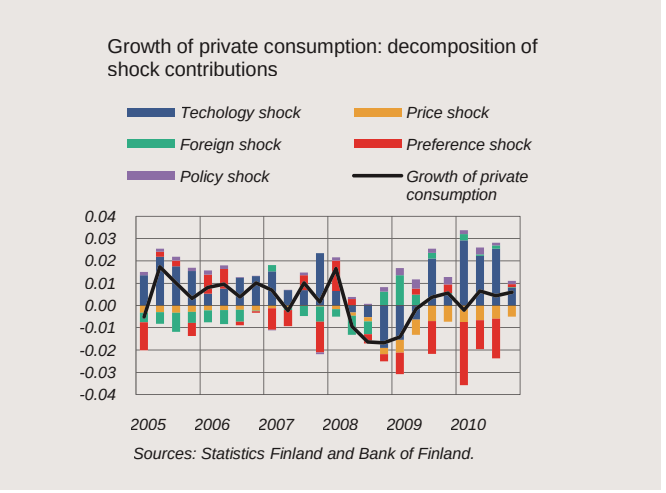
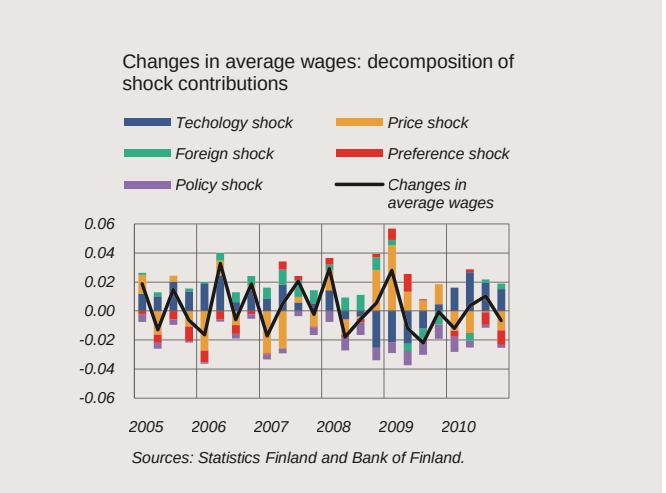


Chart 3.



various shocks on euro area and US economic growth in 1999–2005.[11]

The old and new models serve different needs

The new estimated version of the Aino model was introduced in the preparation of the March 2010 forecast, and the Bank of Finland will continue to use the model in forecasting and analysis. A linear model enables the production of shock exercises like the ones presented in this article also for the forecast period, and the exercises will facilitate more comprehensive rationale for the forecast. The new model and the unobservable variables that are more easily identifiable enable a more systematic analysis of staff projections and a more embellished economic interpretation.

The old version of the Aino model has already been replaced by the new one in the preparation of forecasts, but the old model is still used extensively in policy exercises. The detailed description of fiscal policy in the model will be further developed, and the model will be used mainly in fiscal policy analysis.

Key words: prices, wages, costs, economic growth, monetary theory, inflation, business cycle theory, econometrics

[11] Christiano – Motto – Rostagno (2008) Shocks, structures or monetary policies? The Euro Area and US after 2001, Journal of Economic Dynamics and Control. Elsevier, vol. 32(8).