Rixmod – The Riksbank's macroeconomic model for monetary policy analysis

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Rixmod is a large macroeconomic model that is in regular use at the Riksbank for policy analyses and forecasting. The aim is to obtain guidelines as to how a monetary policy that includes an inflation target should be conducted. The reason for introducing Rixmod was to offer within one and the same model a consistent analytical framework for forecasting and a tool for studying specific policy issues. The structure of the model makes it possible to throw light on what significance various economic mechanisms have for inflation.

This article describes the basic structure of Rixmod. The characteristics of the model are illustrated with some examples of policy simulations.

Rixmod – two models

Rixmod consists of a steady state model and a dynamic model. The steady state model describes the state the economy will reach when the effects of disturbances have faded away.

Rixmod consists of a steady state model and a dynamic model.[1] The steady state model describes the underlying state of long-term equilibrium, or the steady state, in the economy. By steady state is meant the conceptual state of balance reached by the economy when the effects of all disturbances have faded away. In this steady state, all relative prices and quantities are consistent with

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[1] Rixmod is based on the "Quarterly Projection Model (QPM)" designed by the Bank of Canada. However, it has been regularly adapted to Swedish conditions. For descriptions of the model see Black, Laxton, Rose & Tetlow (1994), Coletti, Hunt, Rose & Tetlow (1996) and Karlsson (1998). For analyses of different monetary policy issues carried out using Rixmod see Dillén, Karlsson & Nilsson (1998) and Dillén & Nilsson (1999). In a forthcoming paper Jonsson, Nilsson, Nilsson & Shahnazarian (2002) provide a more detailed technical description of Rixmod.

each other, economic agents' expectations regarding these variables are satisfied, and all agents achieve their targets. This steady state is determined by factors which, according to well-established macroeconomic theory, influence domestic consumers and enterprises and their transactions with the foreign sector. Even though such a steady state can seldom be observed in practice, it is important as a point of reference for assessing the character and consequences of the various disturbances that have occurred. The steady state is not constant but will change if structural changes, or permanent disturbances, occur.[2]

The dynamic model describes the mechanism for adjustments towards the steady state after disturbances of various types.

The dynamic model describes the mechanism by which the economy adjusts towards a steady state after it has been exposed to various types of disturbance. These disturbances could be either temporary or permanent. In event of a temporary disturbance the long-term steady state will remain unchanged.[3] In this case, the dynamic model will describe the adjustment back to the steady state. In the event of a permanent disturbance, the dynamic model describes the process of adjustment to the new steady state. The idea is that the dynamic model should capture aspects of economic behaviour that are not explained in the steady state model but exist in the data, such as rigidities of one kind or another in wage and price formation as well as imperfect information.

The steady state model in Rixmod shares fundamental similarities with dynamic general equilibrium models (DGEM).

The steady state model in Rixmod shares certain basic features with the dynamic general equilibrium model (DGEM) described in Jonsson (2002). Models of this type are based on the principle that macroeconomic models should be constructed using as the point of departure a microeconomic description of the decision-making processes of households and firms. This means that the individual agents' goal functions and budget restrictions are specified and that assumptions are made regarding market structures and about what information the agents have access to when they make their decisions.[4]

[2] By permanent disturbance is meant, by definition, a change in the long-term steady state. A permanent change in the tax structure, such as a reduction in direct taxes and a corresponding increase in indirect taxes, would cause a change in the steady state in Rixmod.

[3] A temporary disturbance does not affect the long-term steady state, but its effects can be longer or shorter in duration. Temporary disturbances could consist of a brief rise in commodity prices or a temporary rise in the rate of nominal wage increases (for reasons that are not explained in the model).

[4] DGEM has its origins in the "real business cycle" models of the eighties, which focused on productivity disturbances as the underlying explanatory factor behind economic cycles. DGEM uses the underlying methodology of "real business cycle" models but extends the analysis in various directions.

Rixmod contains mechanisms that are similar to those in DGEM, but there are key differences.

Even though Rixmod contains mechanisms that are similar to those in DGEM there are key differences. A DGEM can be used to explain long-term determining factors and short-term dynamic adjustments in the event of disturbances in one and the same model. In Rixmod the long-term steady state is described with the aid of the steady state model, while the short-term adjustments towards the long-term equilibrium are explained by the dynamic model. This dual way of looking at things is justified by the Riksbank's wish to be able to use Rixmod as a tool in its forecasting activities, coupled with the view that currently available DGEM are neither adequately developed nor detailed enough to be suitable for use in forecasting.

Like many other macroeconomic models, Rixmod is basically a single-product model.

For the same reasons the steady state model in Rixmod has been extended to include mechanisms for which no microeconomic foundations have been provided. In common with the DGEM discussed by Jonsson (2002) and many other macroeconomic models, Rixmod is basically a one good model, in which a particular product is produced according to an aggregated production function with the input of labour and physical capital. This good can be used for private consumption, capital formation, public consumption or exports. Nor is any formal distinction regarding its usability made between a product of domestic manufacture and an imported one. In the strict sense, in a one good model of this type there are no relative prices; regardless of where the product is produced or what it is used for the "price" is the same.[5] The one good model is thus not directly applicable for analysing a real economy that displays significant variations over time in relative prices, terms-of-trade and real exchange rates. Even if a formal multi-good model might be more satisfactory theoretically, the construction and use of such a solution would require a great deal of effort. In the solution preferred for Rixmod a relative price structure has been designed on top of the one good model. In this case the desired specification of the dynamic model has guided the design of the steady state model.

Calibration

Rixmod is a calibrated model.

Rixmod is a calibrated model. The calibration process involves selecting parameters to

[5] In such a model the real exchange rate is constant and no distinction is made between the real exchange rate and the terms-of-trade.

create system features that are believed to reflect the key mechanisms in the economy. The setting of parameter values is guided by several criteria: restrictions from economic theory, stylised facts in the form, for example, of the relative volatility of different time series, and dynamic adjustment rates (impulse-response functions).[6]

Satisfactory statistical measures of the explanatory power of individual equations do not necessarily mean that the model as a whole will have good characteristics.

One drawback with calibration is that there is no statistical measure of how well the model matches the data. The traditional method of determining model parameters is to use econometric estimating. However, it is difficult to use econometric estimating as the main method for parameter determination in the class of model to which Rixmod belongs. System estimates are needed to take into account the interdependence of the equations in the model; in the case of large models this is not possible as there are too few observations in relation to the number of parameters that need to be determined. In practice, therefore, econometric estimating of large models means that individual equations or possibly groups of equations have to be estimated independently of each other. However, satisfactory statistical measures of the explanatory capacity of individual equations do not necessarily mean that the model as a whole will have good characteristics. Furthermore, structural shifts can mean that estimates based on historical data do not reflect the current correlations.

The steady state model

The steady state stock-flow equilibrium involves three types of assets: government bonds, the stock of real capital and net foreign assets.

The steady state stock-flow equilibrium involves three types of assets: government bonds, the stock of real capital and net foreign assets. Whereas the level of the central government debt as a proportion of GDP is assumed to be an exogenously given policy decision, the capital stock and net foreign assets or liabilities are determined on the basis of rules of behaviour that have their foundations in economic theory.

When households/consumers decide on their consumption they balance the benefit of consuming today against the benefit of saving and thus being able to

[6] Karlsson (1998) discusses the calibration of Rixmod's steady state model. See also Dawkins, Srinivasan & Whalley (2001) for a review of calibration as a method for determination of parameters in economic models.

consume more in the future. The model is based on a common assumption in economic theory, namely that households/consumers plan their consumption over an infinite time horizon subject to a budget restriction. It is assumed that the household/consumer sector consists of identical individuals in overlapping generations and that population growth is determined by an exogenously given birth rate and an exogenously given mortality. The likelihood of dying reduces the value a consumer places on consumption planned for the future.[7]

In a steady state households consume a constant proportion of their total wealth.

In a steady state households consume a constant proportion of their total wealth. The total wealth of households consists of financial assets and human capital, which equals the present value of future earned incomes. What proportion is consumed in each period depends on the real interest rate, how willing consumers are to exchange consumption today for consumption tomorrow (the intertemporal elasticity of substitution), the subjective discounting by consumers of their future utility, and the likelihood of the consumer dying during the period.[8]

Firms choose the optimal level for their capital stock and the investments that will enable them to maintain this level.

Domestic firms produce using labour input and physical capital according to what is known as the Cobb-Douglas production function with constant returns to scale.[9] Firms choose the optimal level for their capital stock and the investments required to maintain this level. The capital stock required depends on such factors as the cost of capital, which, in turn, depends on such factors as depreciation, real required returns and taxation.

The supply of labour and the equilibrium unemployment rate are determined outside the model.

The supply of labour and the unemployment rate in steady state are determined outside the model. The quantity of labour that individuals provide, in combination with the

[7] These assumptions are made so that an analytical derivation will be manageable. The assumption that the likelihood of dying is the same for all individuals ("consumers") facilitates the aggregation of the decisions of the individual consumers. Blanchard-Fisher (1989) calls this assumption "a model of perpetual youth", that is to say the individuals in the model have eternal youth.

[8] See Jonsson (2002) for a more detailed description of the problems facing consumers when making decisions. One difference is that in Jonsson (2002) the consumer's choice between consumption and leisure is also modelled, whereas in Rixmod the supply of labour is exogenous (see below). Another difference is that Rixmod assumes overlapping generations with limited life expectations, while Jonsson (2002) assumes that the typical consumer has an infinite time horizon (can be explained on the basis of altruistic links between different generations). The demographic assumption of overlapping generations is the reason why the budget deficit has real effects in Rixmod (see section "Fiscal policy", p. 56).

[9] Constant returns to scale means that if the capital stock and labour input increase by the same factor, production will increase pro rata.

assumed equilibrium level of unemployment, determines how much labour firms employ in steady state. Real wages are determined by the normal marginal product conditions, which include total factor productivity and capital intensity.

Relative prices depend on domestic cost factors and import prices.

As Rixmod is essentially a one good model there is no microeconomic derivation for the relative price structure in the model. As the various demand components in the balance of supply will be satisfied by both domestically manufactured products and imports, relative prices will depend on both domestic cost factors and import prices. Differences in indirect taxation can also influence relative prices.

The real exchange rate is determined from a relation that includes the ratio of exports and the size of the domestic economy in relation to foreign economies.

A typical assumption for a small open economy is that the economy in question takes its export and import prices as given. On this assumption, the decisions of domestic agents will determine what export and import volumes are possible. In the steady state model Rixmod departs from this description by allowing the size of the domestic economy in relation to foreign economies to influence the real exchange rate and export prices. In Rixmod, the domestic economy can be said to be "an almost small open economy". The real exchange rate is determined from a relationship that includes the export ratio and the size of the domestic economy in relation to other economies. Higher exports in relation to GDP would require a depreciation of the real exchange rate. If the domestic economy grows faster than other economies the exchange rate will appreciate.[10]

Prices on the domestic credit market can be assumed to be determined internationally in the long run.

It is assumed that in the long term prices on the domestic credit market are determined internationally, which means, for example, that net foreign assets are determined as a residual factor. The government sector determines the level of the domestic national debt and optimisation decisions by firms determine the level of the capital stock. Consumers' decisions about their desired wealth simultaneously determine the net foreign assets, given the other two types of asset. In the steady state, the short (three months) yield is determined so as to be equal to the short foreign real yield plus an exogenously determined risk premium. The long (ten

[10] One possible explanation as to why the real equilibrium exchange rate varies with time is the differences in productivity trends in sectors that are either exposed to or shielded from competition. Alexius (1999) and Alexius & Nilsson (1997) discuss this Harrod-Balassa-Samuelson hypothesis and provide empirical support for the view that the real exchange rate will appreciate when the size of the domestic economy grows relative to other economies.

year) yield is given by the short yield plus an exogenously determined term premium. Risk premiums for various types of agents mean that the interest consumers and business enterprises have to pay on their loans is higher than the interest on the government debt.

The payments of interest on foreign debt must be financed out of a trade surplus. Other things being equal, a long-term increase in the net foreign debt will require a larger trade surplus. To achieve this increase in net exports it will be necessary for the real exchange rate to depreciate.

The public sector's targets for expenditure, transfer payments and net debt, as well as for most tax rates, are determined outside the model. The tax rate on labour income is adjusted so that the public sector's budget restrictions are satisfied.

It is assumed that the consolidated public sector purchases some of the private sector production and finances its purchases by levying taxes on or borrowing from consumers.[11] The public sector also makes transfer payments to households. The public sector's targets for its expenditure and transfer payments as a proportion of GDP, the target for the level of net debt in relation to GDP and most tax rates (capital tax and indirect taxes) are determined outside the model. The rate of tax on income from employment, on the other hand, is endogenous and adjusted so that the public sector's budget restriction is satisfied.

In the steady state model monetary policy is limited to an exogenously determined inflation target.

The steady state model does not take into account any real long-term effects of how monetary policy is conducted. In the steady state model, monetary policy is limited to an exogenously determined inflation target that will only influence the level and rate of change in nominal variables.

The dynamic model

Expectations formation and adjustment costs

The dynamics of Rixmod depend on the assumptions made regarding the occurrence of various types of adjustment cost and on how the expectations of agents in the economy are formed.[12]

Adjustment costs could, for example, consist of fixed costs in connection with

[11] Public consumption is assumed not to influence consumer benefit and therefore in the model it has no direct effect on households' consumption decisions.

[12] A third factor that affects the dynamics consists of monetary policy and fiscal policy response functions.

capital formation or of contract costs required for changing wages and prices. The existence of such costs means that consumers and business enterprises also adjust gradually after a disturbance in the hypothetical case with perfect foresight and when the effects of the disturbance are well known.

In Rixmod expectations are modelled as a combination of forward-looking and backward-looking components.

When analysing the effects of economic policy measures it is important to take into account how consumers' and business enterprises' expectations influence their decisions. These expectations could relate to income from employment, inflation, interest rates and exchange rates in the future. The main issue challenging macroeconomic research over the past few decades has been the importance of assuming that households and firms have model-consistent (rational) expectations or not.[13] Assuming that consumers and firms form their expectations rationally is appropriate in an analytical framework in which the agents in the economy are assumed to be rational and optimising. However, in order to describe their decision-making situation in a relevant way, such an approach should take account of the learning process and the cost of collecting information. Models that assume that expectations are strictly model consistent also have difficulties in explaining the dynamism contained in the data.[14] In Rixmod, therefore, expectations are modelled as a combination of forward-looking and backward-looking components, consisting of earlier values for the variable in question. The backward-looking components are relatively heavily weighted, in the interval of 0.65–0.8 depending on the variable. What the forward-looking component includes, apart from the model-consistent expectations, depends on whether the variable is real or nominal. Forward-looking expectations relating to real variables take account of the steady state value. As nominal price levels are not determined in the steady state model but by the mechanisms in the dynamic model and by the specific disturbances that are assumed to have occurred – there is no such anchor in the steady state for nominal variables.[15]

[13] If the expected value of the variable is model-consistent then it coincides with the solution provided by the model. A typical assumption that involves expectations that are not model-consistent (except in special cases) is that the agents in the economy have adaptive expectations.

[14] See, e.g. Lindé (2001).

[15] This is related to how the central bank's role as the "nominal anchor" is specified. In Rixmod it is assumed that the central bank has an inflation target, which means that some price drift will occur (see below, section "Monetary policy", pp. 57–58). It is possible in Rixmod to give some weighting to the inflation target in the price expectations that are formed. This gives an exogenous credibility to the inflation target. The Riksbank does not need to act equally forcefully in the event of disturbances in order to maintain confidence in the inflation target.

Potential production

In the dynamic model potential production is defined as the production that can be achieved with full employment using the capital stock in existence.

In the dynamic model potential production is defined as the production that can be achieved with full employment using the capital stock in existence.[16] Potential production will thus deviate from the production that is possible in the long term as long as the actual capital stock is not the same as the optimal long-term capital stock.[17] Equilibrium paths for such factors as real wages, consumption, exports and imports are also associated with the potential level of production. In the dynamic model, it is possible for actual consumption, for example, to deviate from the equilibrium path for consumption (on account of the rigidities noted above), but actual consumption will gradually approach the equilibrium path.[18]

Determination of demand variables

For each demand variable there is a backward-looking and a forward-looking component.

The equations in the dynamic model that determine consumption, capital formation, exports, imports, employment, etc. share a common structure. For each demand variable there is a backward-looking component, which consists of earlier realisations for the variable, and a forward-looking component. This basic structure has then been augmented to include specific determining factors for each of the variables.

When determining household consumption the forward-looking component consists of expectations regarding future disposable incomes, which means that the household's "permanent income" will play a part in its consumption decisions. Household consumption is also affected by current interest rates. If consumers' financial assets deviate from the desired long-term level, they will adjust their consumption with the object of closing the gap. A disequilibrium in consumers' financial assets is matched by a disequilibrium in the net assets/liabilities in relation to foreign countries. In Rixmod, therefore, consumption is influenced by whether or not the net position in relation to foreign countries deviates from its equilibrium value.

[16] Potential production is also determined by total factor productivity (TFP). The role of TFP is discussed below in an example.

[17] The fact that the actual capital stock is not the same as optimal long-term stock is due to the existence of adjustment costs and rigidities in the price and expectation formation process.

[18] These equilibrium paths are not equivalent to the dynamic adjustments that take place in the DGEM. When Rixmod is used for forecasting, the steady state model is used to generate a further type of time-varying steady-state path. This means that a distinction is made between long-term steady state and time-varying equilibrium paths that are derived from the steady-state model.

Disturbances that affect firms' capital costs will result in firms wishing to adjust their level of capital stock. However, firms will not change their investment plans so that they achieve the optimal, long-term capital stock immediately. Instead, they gradually adjust the actual capital stock towards the optimal long-term level. Investments will be determined by the planned adjustments in capital stock, taking into account the fact that it takes time for firms to put their investment plans into effect.

The forward-looking component in export and import demand consists of the trends along each equilibrium path. Over and above this, exports are positively affected and imports negatively affected by a temporary depreciation of the real exchange rate (with a time lag of up to one year). Export volumes are also positively affected by the foreign excess demand. Correspondingly, imports are affected positively by domestic demand and export volumes being higher than the level of aggregate demand that is compatible with equilibrium.

The forward-looking component in the determination of employment depends on expected production and productivity.[19]

Price and wage formation and inflation

The determination of prices and wages depends not only on lagged but also expected prices and wages, as well as on the excess demand situation.

In the steady state model it is assumed that prices are determined on perfectly competitive markets, which means among other things that a firm's marginal revenue is equal to its marginal costs. In the dynamic model, however, it is assumed that firms can influence prices. This means that in the short term they can set prices that exceed their marginal costs. This mark-up is assumed to depend on the demand situation. The cost of adjusting prices means that price setters will weigh the cost of deviating from the optimal price against the cost of changing the price. In this trade-off, the price setters' expectations of future prices and wages will play an important role. A similar structure for wage formation can be justified using a model for the labour market in which wages are determined after negotiations between employers and union organisations. The connection between prices and wages therefore depends on both lagged and expected prices and wages as well as measures of the excess demand.

[19] When firms make decisions on the level of employment they take account of future labour requirements. Expected future labour requirements are determined by expectations regarding demand, productivity and future use of capital.

Exchange rates and interest rates

The nominal exchange rate satisfies the conditions for open interest rate parity.[20] In Rixmod, changes in the real exchange rate are a fundamental force driving the nominal exchange rate. The expected nominal exchange rate is determined by the expected real exchange rate and expected trends in domestic prices in relation to expected changes in prices abroad.

Long nominal yields are determined partly by expectations regarding future short-term yields, according to the expectation hypothesis. Expectations regarding future short-term yields are model consistent. However, in Sweden's interest rates statistics, the long and short yields co-vary to a greater extent than can be explained by the expectation hypothesis. Over and above the expected changes in the short yield the long yield in Rixmod is therefore affected directly by changes in the short yield (parallel shift in the yield curve). Long international yields also have a direct effect on long domestic yields.

Fiscal policy

Tax on income from employment is adjusted to achieve the debt target; transfer payments function as "automatic stabilisers".

The public sector has long-term targets for the central government debt, public consumption and transfer payments. In the dynamic model the rate of tax on income from employment is adjusted in order to achieve the debt target. If, for example, the debt ratio is higher than the targeted ratio, the rate of tax on income from employment will be raised, which will increase tax revenue. The higher revenue is then used to reduce the debt ratio to its long-term steady state. Public expenditure (to a small extent) and transfer payments (to a greater extent) are counter-cyclical and will depart from their targeted levels as a result of developments in the state of the economy. Public transfer payments in particular therefore serve as automatic stabilisers. The fiscal policy response functions in the dynamic model are not forward-looking, as the government responds to deviations during the current period.

As consumers do not expect to live forever their consumption decisions are influenced by how the public sector finances its expenditure. Forward-looking consumers take account of expected tax rates in the future and of their effects on their incomes over their life cycle. A tax reduction or an unfinanced increase in expenditure today will mean higher taxes in the future, provided the public sec-

[20] Open interest rate parity means that the expected depreciation rate is equal to the yield differential in relation to other economies (taking account of an exogenous risk premium).

tor's long-term target for the net government debt remains unchanged. However, as individuals, consumers know that there is a certain probability that they themselves will not be affected by these compensatory tax increases as they are mortal (without actually knowing when their lives will end). Instead the tax increases will be paid by tomorrow's taxpayers. "Ricardian equivalence"[21] thus does not apply in Rixmod.

Monetary policy

The role of monetary policy is to maintain or bring about a state of stability in the general level of prices.

The role of monetary policy is to maintain or bring about a state of stability in the general level of prices. Monetary policy is forward-looking and focused on keeping inflation at 2 per cent. Inflation is kept on target by changing the short (three-month) nominal interest rate in relation to deviations in inflation from the target rate over six or seven quarterly periods.[22] The monetary policy rule also takes account of the latest interest rate in order to prevent interest rates from fluctuating excessively violently.

Monetary policy focuses on the trend in underlying inflation.

Monetary policy focuses on the trend in underlying inflation. Statistics Sweden's calculation of the UND1X is based on the CPI but excludes mortgage costs on private houses and changes in the net effect of indirect taxes and subsidies. In the approach selected for Rixmod UND1X inflation is a function of domestic unit labour costs and imported inflation.[23]

Monetary policy makes its effect through several different channels.

Monetary policy is transmitted through several different channels. As it is assumed that the Riksbank is able to control the short nominal interest rate, the bank can influence the costs incurred by business and consumers on investing and consuming today in relation to the future. As prices change only slowly in the short term, changes in nominal yields will lead to

[21] According to "Ricardian equivalence" it does not matter if an increase in public expenditure is financed by increased taxes or by lending (that is to say, a budget deficit).

[22] There is no repo rate in Rixmod; the assumption is that the Riksbank has full control over the three-month interest rate. The monetary policy rule in Rixmod does not correspond fully to the simple rule described by Heikensten (1999). According to the Riksbank's simple rule of thumb, monetary policy is adjusted with the object of restoring inflation to the target level over a one- to two-year horizon. Rixmod's monetary policy rule permits inflation to deviate from 2 per cent at the end of the horizon, but this deviation is determined by how much weight is given to achieving the target. However it is not possible with reasonable assumptions in the model to achieve exact target satisfaction within the target horizon.

[23] Unit labour costs are calculated from the nominal wage and a measure of steady state labour productivity. Import prices are determined largely by a weighted average of foreign prices of manufactured goods and commodity prices, and the nominal exchange rate.

changes in real interest rates. Investment demand is affected by changes in real interest rates. When the Riksbank raises the short-term rate by more than the long one, a yield gap will open which will have a restraining effect on private consumption. When the Riksbank changes the short nominal yield, the nominal exchange rate will also be affected. As prices only change slowly, changes in the nominal exchange rate will also have an effect on the real exchange rate. The real exchange rate affects, in turn, export and import volumes. Through these channels, the Riksbank is able to influence the pressure of demand in the economy and, thereby, inflation. The trend in the nominal exchange rate also has a direct affect on inflation through import prices.

Two examples of Rixmod simulations

To give a feeling for the characteristics of the model and for how it can be used in monetary policy analysis, this section presents two examples of Rixmod simulations. A common way of illustrating the properties of a macro model is to expose the model to simple and relatively well-defined disturbances, such as a permanent change in the government's net debt or a temporary rise in commodity prices. In the examples below, the disturbances are more complex, since the purpose is to show how Rixmod can be used to analyse a current policy issue.

Developments in the Swedish economy in 2001 can illustrate the difficulties monetary policy decision-makers can face.

A serious difficulty facing practical monetary policy is to measure changes in potential production and the accompanying production gap. Developments in the Swedish economy in 2001 can serve to illustrate the difficulties that monetary policy decision-makers can face. In 2001, GDP growth in Sweden was significantly lower than was generally expected at the end of 2000. Domestic private demand and exports were seriously weakened, and trends in labour productivity were also far weaker than expected. Instead, unit labour costs and inflation rose faster, and the exchange rate turned out to be weaker, than expected. A possible explanation for this could be that temporary effects had pushed up inflation by more than people had foreseen, and that this outweighed the deflationary effects of the lower demand, itself caused by slower international growth.

An alternative, or perhaps complementary explanation for this situation could, however, be that more fundamental supply side disturbances had occurred in the economy[24], disturbances that give rise to variations in potential GDP

[24] See, for example, the discussion in the box headed "The relationship between growth and inflation" in the 2001:4 Inflation Report.

growth. From this perspective, the "new economy's" combination of rapid growth and low inflation in the USA in the 1990s has been put down to the way positive supply side disturbances raised the potential GDP growth rate. Similarly, proponents of "real business cycle" models interpreted the slow-down in real growth that occurred in the USA in 2000 as the result of disturbances that had a negative effect on potential GDP growth.[25] In a situation where growth in actual GDP falls because a negative supply-side shock has reduced growth in potential GDP, there will be no unused resources. It would therefore not be possible for monetary policy to stimulate production by adopting an expansive stance. An expansionary monetary policy would only lead to higher inflation instead.

A common assumption in the examples is that the economy is initially in a steady state.

To throw light on these considerations, we will first look at the effects of an international recession on the Swedish economy, according to the Rixmod simulation. This will then be illustrated by a situation in which a disturbance has a negative effect on the supply side of the economy.

An assumption that is common to the examples is that the economy is initially in a steady state.[26] Even if the actual production in the Swedish economy, according to many analysts, was close to potential production in 2000 (i.e. the production gap had closed), this does not mean that the economy was also in a long-term steady state. An example of this is the rapid growth in exports and imports (relative to GDP) in the 1990s, which suggests that the economy was adapting to structural changes that involve an increase in the foreign trade ratio.[27] In the examples, the steady state corresponds to the assumption that the Swedish economy in 2000 was not too far from an equilibrium in terms of capacity utilisation, price trends and expectations.

The growth path that the economy was to follow in the original long-term steady state is referred to below as the "control solution". The figures reflect changes in the variables in two ways:

1) As a *percentage* deviation from the control solution. GDP, private consumption, exports, nominal hourly wages, nominal and real exchange rates, relative com-

[25] See, for example, the discussion in "Theory ahead of rhetoric: Economic policy for a 'new economy'" in the 1999 Annual Report and "Theory ahead of rhetoric: Measurement and the 'new economy'" in the 2000 Annual report, Federal Reserve Bank of Cleveland.

[26] As the economy is initially assumed to be in a steady state, the effects of the assumed disturbances are isolated. If the initial situation is not that of a steady state, it will be difficult to isolate the effects of the disturbances from the adjustment of the economy as a result of the initial disequilibrium.

[27] When Rixmod is used for the purposes of forecasting, filtering techniques are needed to take into account the impact of structural changes.

modity prices, total factor productivity (TFP) and potential production are presented in this way.

2) As a *percentage point* deviation from the control solution. Short-term interest rates, the rate of inflation (annual, measured in terms of UND1X or deflators), unit labour costs, the production gap and net exports (as a proportion of GDP) are presented in this way.

An international recession

In this example, the international recession opens up a negative production gap and lowers the inflation rate.

In this example, the international recession opens up a negative production gap and lowers the inflation rate (see figure 1).[28] The relative prices of commodities fall, which is to say that commodity prices are more sensitive to the fall in demand than prices of manufactured goods. It is assumed that central banks abroad take steps to overcome the recession by pursuing expansive monetary policies, with lower interest rates as a consequence. The economic cycle continues for a little more than five years. After the opening downturn, foreign demand recovers and a positive production gap opens after about two years. Capacity utilisation, the inflation rate, interest rates and relative commodity prices eventually return to their long-term steady-state levels. This upturn phase also has implications for developments in the domestic economy.

The domestic economy is affected by the rest of the world via a number of channels. Weaker demand abroad leads to lower exports. Changes in the terms-of-trade have an effect on incomes and wealth, which in turn affect domestic demand. Price trends abroad have a direct effect on domestic prices and an indirect one since foreign interest rates influence domestic interest rates and the exchange rate.

Figure 2 shows the effects of the international recession on the Swedish economy. One direct effect of the lower inflation rate abroad and falling commodity prices is that imported inflationary pressures weaken. The impact via the foreign trade means that falling demand and production abroad lower the demand for Swedish exports. This, in turn, leads to a lower level of activity in the Swedish economy, and subsequently to a lower rate of wage increases. Wage formation is influenced by several factors, including the expectations of lower inflation that is beginning to emerge. UND1X is affected initially mainly by the decline in

[28] The example is only intended to illustrate how Rixmod works and does not represent an assessment of what the international business cycle relevant to the Swedish economy looks like.

imported inflation, and eventually the lower rate of wage increases and the lower unit labour costs also help to contain inflation.[29]

In the example, the Riksbank immediately recognises the consequences of the global recession for the Swedish economy, particularly for inflation, and responds by cutting the short-term interest rate. However, domestic rates are reduced less than foreign rates, which initially strengthens the nominal exchange rate; a negative change in the krona index corresponds to an appreciation of the exchange rate. However, the rate of domestic inflation rises faster than inflation rates abroad, which gradually pushes price levels in relation to other countries above the level in the control solution. The nominal exchange rate will therefore have weakened by 1 per cent by the end of the economic cycle in relation to the control solution, while the real exchange rate will have remained unchanged.

Monetary policy stimulation boosts private consumption in the first two years, while there is only an insignificant impact on business investment plans. The increase in domestic demand will offset the shortfall in foreign demand, but will do so at the cost of a decline in household wealth, which is matched by a deterioration in the net position in relation to foreign economies. This decline in consumer wealth is not desirable in the long term and must eventually be reversed.[30]

The positive production gap abroad that is required to curb the fall in prices and to restore inflation to its target level means that demand for Swedish exports will once again increase two years after the initial disturbance to demand. To reverse the declining trend in their wealth, Swedish consumers will cut down on their consumption.[31]

A temporary decline in productivity

In this example, the lower growth rate is caused by a temporary decline in total factor productivity.

While lower demand leads to lower production and lower inflation, a negative disturbance on the production side can result in lower production but higher inflation. In this example, the lower growth is caused by a temporary decline in total factor pro-

[29] Figure 2 shows the nominal wage in relation to the control. When the process of adjustment to the disturbance ends, nominal wages have fallen by 1 per cent in relation to the control solution.

[30] During the first year, net exports as a proportion of GDP will decrease by 0.4 percentage points compared to control. The adverse volume effect on the current account is offset, however, by improved terms-of-trade brought about by the way import prices are affected by the lower relative price of commodities more quickly and to a greater extent than export prices. The current account still, however, is weaker than in the control solution, which undermines the net position in relation to other countries.

[31] Rising exports and falling imports will result in an increase in the trade surplus. A deterioration in the terms-of-trade, however, means that the current account will remain weak for another year or so.

Figure 1a. Downturn in international economic activity; production gap and relative prices of raw materials

Percentage points and per cent, respectively

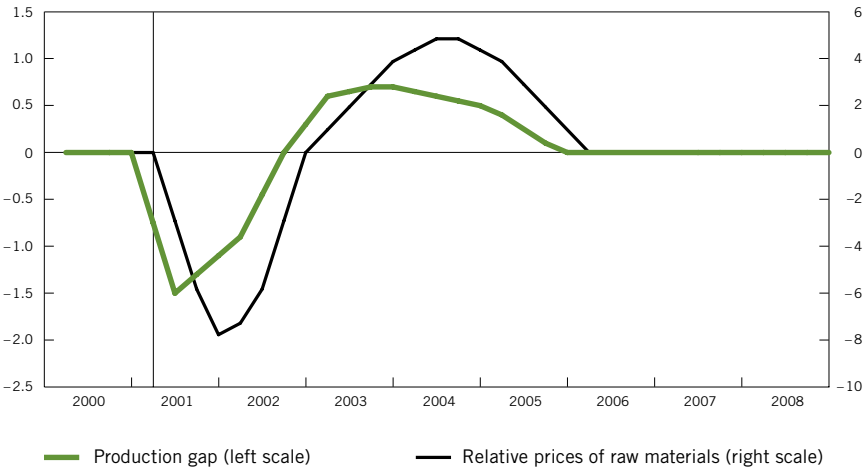
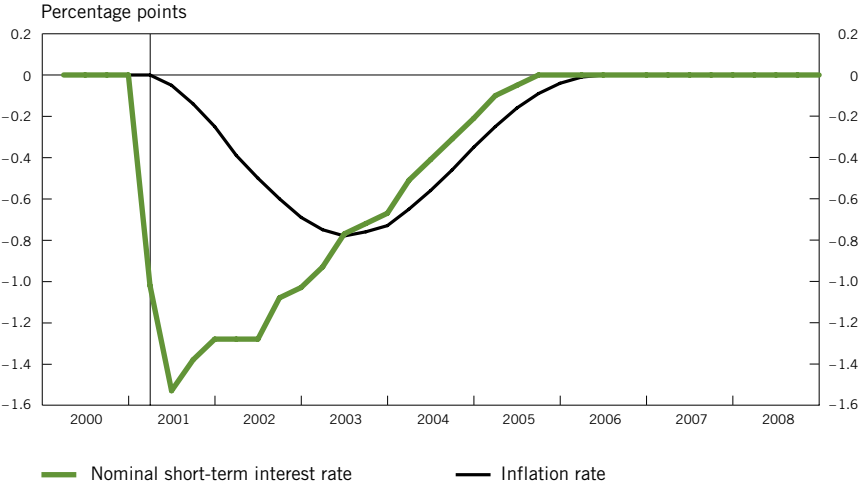


Figure 1b. Downturn in international economic activity; nominal short-term interest rate and inflation rate

Percentage points



ductivity (TFP).[32] Figure 3 shows the assumed disturbance, a temporary decline in TFP lasting about two years.

[32] In the empirical analysis of productivity trends, TFP is a residual item that is usually taken to reflect technological and organisational effects. See, for example, the box headed "Problems with the measurement of information technology's effects on growth in the United States, Sweden and Europe" in the Inflation Report 2000:4.

Figure 2a. Effect of downturn in international economic activity on UND1X, nominal short-term interest rate and GDP

Percentage points and per cent, respectively

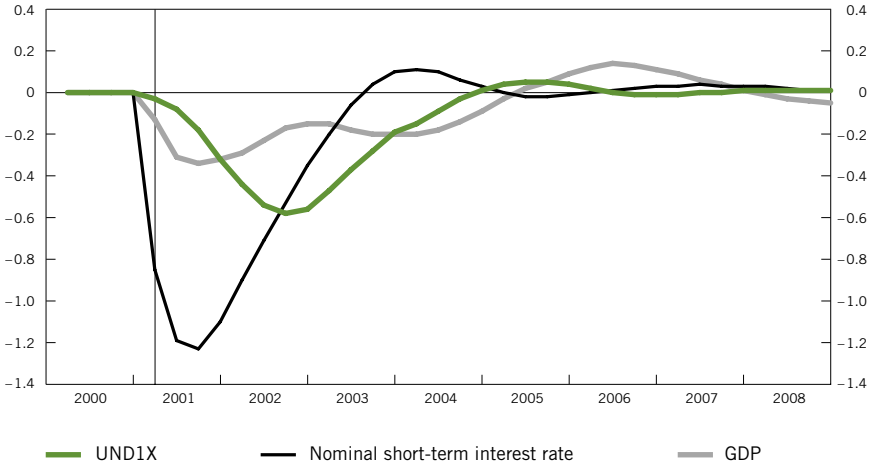
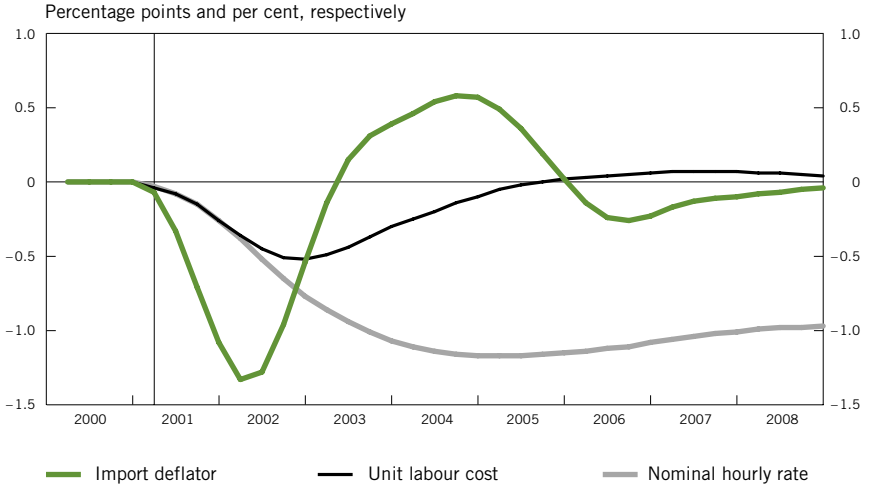


Figure 2b. Effect of downturn in international economic activity on import deflator, unit labour cost and nominal hourly rate

Percentage points and per cent, respectively



In the example, it is assumed that TFP gradually returns to the path it was following prior to the negative disturbance.[33] This means that after the effects of this disturbance have faded away, the economy will be back in its original steady

[33] A possible interpretation of the negative disturbance to TFP assumed in the example is that it turns out that certain investments made in previous years were based on incorrect assumptions.

Figure 2c. Effect of downturn in international economic activity on private consumption, exports and imports

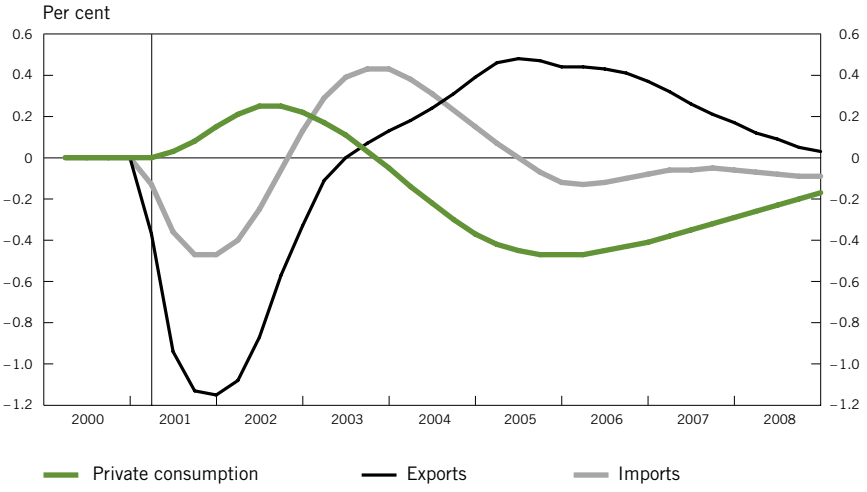
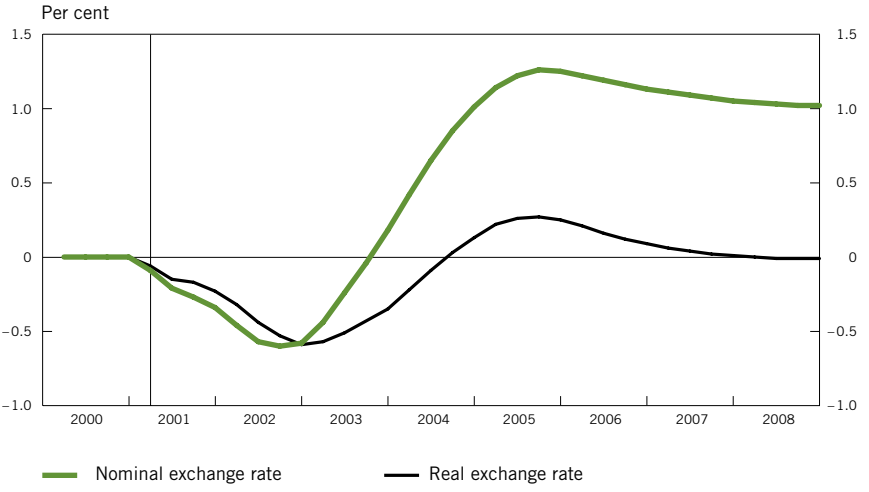


Figure 2d. Effect of downturn in international economic activity on nominal and real exchange rate

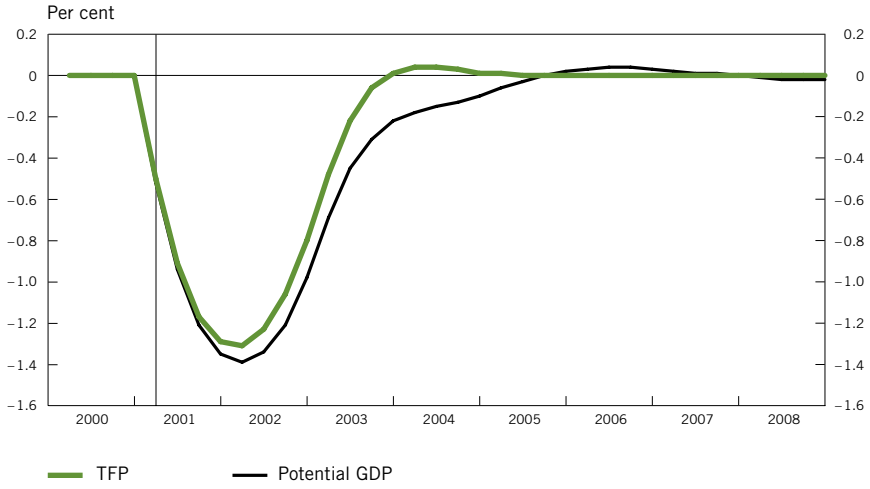


state.[34] Growth rates, relative quantities and prices (e.g. the real exchange rate) will, then, remain unchanged in relation to the control solution.

Households and firms in the economy did not foresee the initial reduction in TFP. Even if households and firms are forward-looking in their approach, and

[34] It is worth pointing out that the productivity shock only affects the domestic economy, not that of other countries.

Figure 3. A temporary decline in total factor productivity



even if they gradually realise that TFP will return to its original productivity path, they are by no means certain what effects the productivity changes will have on, say, wage trends and production costs.[35]

Whereas changes in TFP are exogenously determined in the example, potential production (see figure 3) is affected by the endogenous developments to the actual capital stock. Production capacity, as it is reflected in potential production, declines during the first year by almost 1.5 per cent in relation to the control solution.

Households see the shift in the economy's potential growth rate to a lower level and respond by reducing consumption growth relative to the control solution (see figure 4). Since the households initially regard the decline in productivity as lasting, the response in consumption is relatively vigorous, even though the households do not reduce their consumption by as much as their expected "permanent incomes" have fallen. They also offset the impact of the decline in production on consumption by reducing their net foreign assets.

Whilst consumers adjust the growth in their consumption more or less immediately to the lower potential growth, the business sector reduces its investments more gradually. With wages and salaries being slow to adjust and with falling labour productivity, unit labour costs in business start to climb, which causes prices to rise. In response to rising costs and lower than expected GDP growth,

[35] The example uses the steady-state model to work out the equilibrium paths consistent with the assumed trend in TFP. For example, the way consumers' permanent incomes behave in the underlying steady state affects consumer expectations regarding their total wealth and thus their spending power.

Figure 4a. Effects of a temporary decline in total factor productivity on UND1X, nominal short-term interest rate and GDP

Percentage points and per cent, respectively

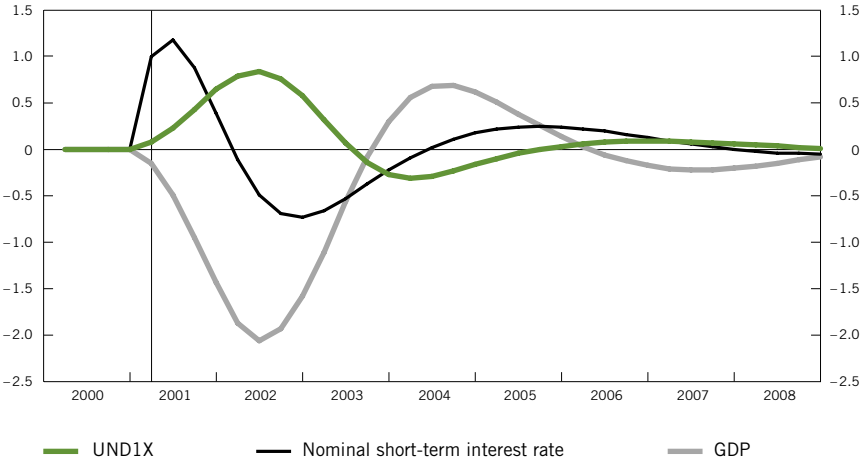
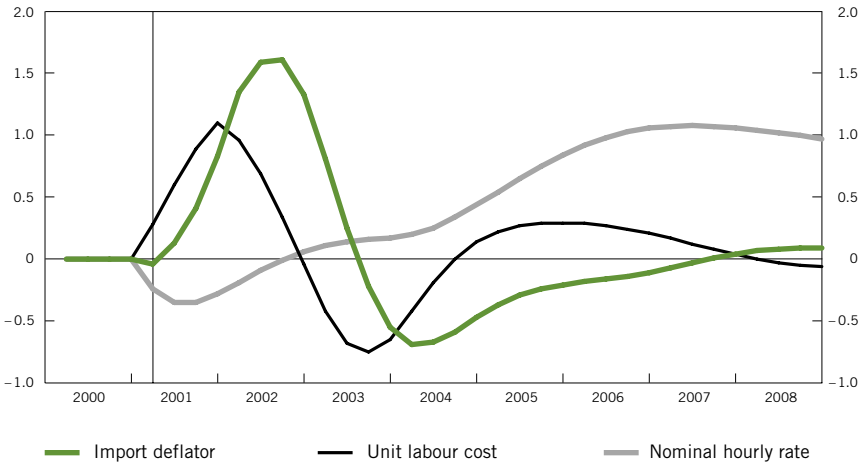


Figure 4b. Effects of a temporary decline in total factor productivity on import deflator, unit labour cost and nominal hourly rate

Percentage points and per cent, respectively



firms cut down on their capital expenditure. The fact that productivity first falls and then returns to its previous path generates a relatively powerful investment cycle. The production gap will initially be positive since lower productivity affects potential production faster than it affects actual production.

Monetary policy is initially focused on combating the inflationary pressures brought about by higher costs. This is essential as a means of preventing higher inflation influencing inflation expectations. Gradually, however, a negative pro-

duction gap will emerge as demand is moderated as a result of the lower potential growth. The weaker demand thus aids the Riksbank, in this case, in stabilising expectations at around the inflation target, which initially reduces the need for drastic increases in the short-term interest rate. After four quarters, the actual slow-down in production predominates over the decline in potential growth to such an extent that the interest rate will be lower than the long-term neutral rate.

The exchange rate is influenced by two opposing mechanisms. Because of the weaker productivity there is a tendency for the exchange rate to depreciate. The real exchange rate depreciates, but only temporarily as productivity is expected to return to its reference path. The nominal exchange rate will also depreciate. For the first year, the depreciating exchange rate will have a tendency to push up the inflation rate since imported inflation will increase. This tendency of the exchange rate to depreciate is offset by a tighter monetary policy, but since the inflationary pressures are higher than in other countries, the depreciation of the nominal exchange rate becomes permanent.

A comparison of the simulations

The results for a number of key variables in the two examples are compared in Table 1. One clear difference is that a global recession will reduce the inflation rate. This is an anticipated result of a negative demand-side disturbance. In the case of the global recession, an increase in domestic demand offsets the fall in exports. In the case with a temporary fall in TFP, both domestic demand and export volumes decline.[36]

In the case of an international recession, the short-term interest rate should be lowered in the first year by 1 percentage point; in the case of a lower productivity, the short-term interest rate should instead be raised by 1 percentage point.

The actual result will depend on what interest rate policy the Riksbank is pursuing, in accordance with Rixmod's monetary policy rule, in each case. In the case of the global recession, the short-term interest rate is reduced in the first year by 1 percentage point. If the underlying cause of the decline in production and demand is lower productivity, the short-term interest rate should instead be raised by 1 percentage point during the first year.

[36] However, in that imports decline more than exports, the trade surplus increases.

Figure 4c. Effects of a temporary decline in total factor productivity on private consumption, investment and net exports

Per cent and percentage points, respectively

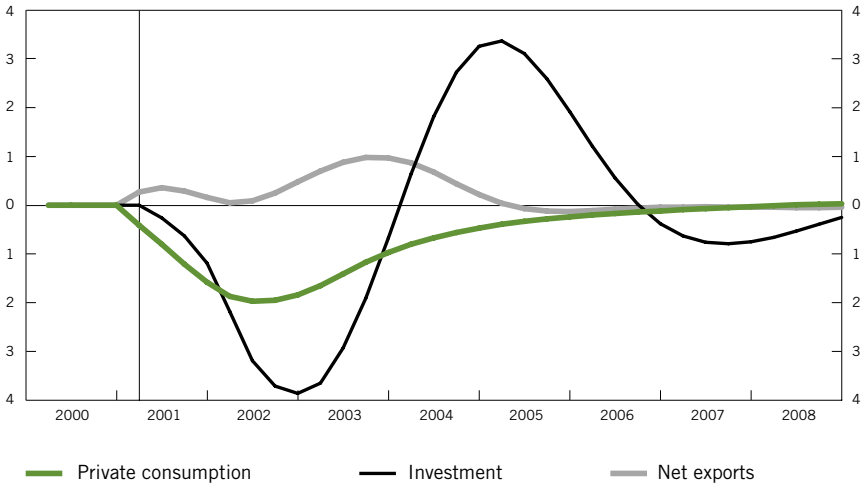


Figure 4d. Effects of a temporary decline in total factor productivity on nominal and real exchange rate

Per cent

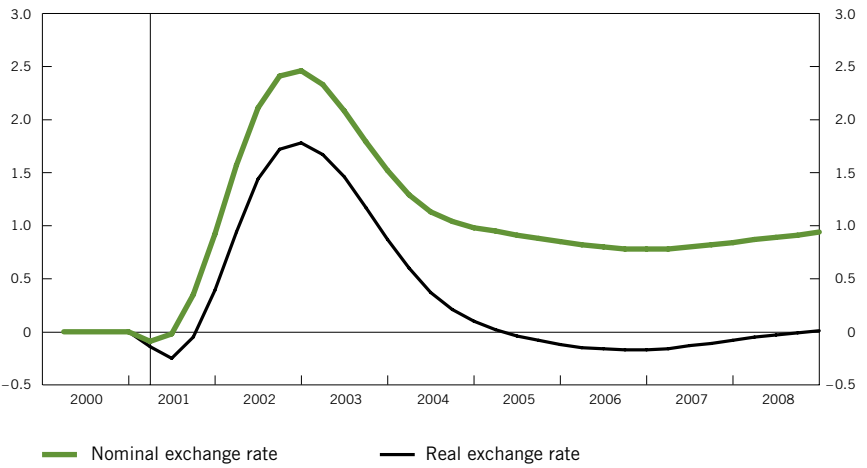


Table 1. Effects on the Swedish economy during the first year of an international economic downturn and a temporary decline in total factor productivity respectively
Deviation in per cent from the control solution

	Foreign demand	TFP
Households' consumption	0.1	–1.0
Public consumption	0.1	–1.5
Fixed gross investment	0.0	–0.5
Exports	–0.9	–1.2
Imports	–0.4	–1.6
GDP	–0.3	–0.8
Hours worked	–0.1	0.1
Labour productivity (GDP/hours worked)	–0.2	–0.9
UND1X (Dec/Dec)	–0.3	0.6
TCW nominal (level)	–0.2	0.3
Short-term interest rate	–1.1	0.9

Note: Deviations for UND1X and short-term interest rate are percentage points.

Concluding comments

Apart from the fact that the results in the examples naturally depend on the strength of the mechanisms built in to the Rixmod simulation model, the results are also sensitive to specific assumptions about the disturbances that are assumed to have affected the economy. In the examples it is also assumed that the Riksbank immediately understands the nature of the disturbances (and how they will evolve with time) and that it can assess the consequences for the Swedish economy, particularly for inflation. It is obvious that the assumptions in the model require a great deal of information and knowledge about the functioning of the economy, requirements that central banks in the real world would find very hard to satisfy. By varying the assumptions concerning, say, access to information, the formation of expectations, and the monetary policy response, the model can nonetheless help us to illustrate the consequences of decisions taken at times of uncertainty with regard to what has actually occurred and how the economy responds to disturbances.

Another area of application for Rixmod is in connection with the Riksbank's forecasting activities. Given a main scenario, Rixmod can be used to generate a variety of alternative scenarios. Examples of this are that the global economy is weaker than the forecast in the main scenario or that domestic utilisation of resources is initially higher than assumed in the main scenario.

When Rixmod is used in forecasting exercises, account needs to be taken of the fact that the actual data concerning economic developments reflect the effects of permanent disturbances, or structural changes, that have occurred. This is done by using a set of constructed – filtered – variables as the model's equilibrium paths. Over history these represent shifts in the long-term steady state in response

to various disturbances. During the forecasting period, they can be explained as a gradual adjustment towards the long-term steady state. The role these variables play in the dynamic model is that they are used to measure gaps in relation to observed variable values over history, or to the forecast values that make up the solution in the dynamic model. By applying this procedure, the assumptions concerning the long-term steady state are only gradually given any weight in the short-term forecast. The latter can be appropriate as it is preferable that the short-term forecast is not affected too much by what, when all is said and done, are fairly uncertain assumptions regarding the underlying, long-term development of the economy.

When making forecasts, it is also possible to "force upon" the model judgements that are based on other information than that taken into account in Rixmod. This type of procedure permits the use of a model while taking into account the fact that a model is by definition a simplified (and strictly speaking always incorrect) picture of reality.

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