USING EDGE – A DYNAMIC GENERAL EQUILIBRIUM MODEL OF THE EURO AREA

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Abstract

This paper presents a new dynamic general equilibrium model with some nominal rigidities that has been calibrated on Euro area data. The model includes consumption/saving decisions using a Blanchard stochastic lifetimes approach; valuation of private financial wealth according to the present value of capital income; overlapping Calvo wage contracts in the labour market and a neoclassical supply side with Cobb-Douglas technology. The structure of the model is explained as is its calibration, using data from new Euro area statistics and experience from the US. The model has been developed for both forecasting and policy simulation purposes. However, the paper concentrates on its simulation properties especially in the field of Euro monetary policy. In particular it explores the macroeconomic benefits that stem from credibility. The model, which has been set up in TROLL, is deliberately designed to have a simple and transparent structure and properties. It has been developed from the framework of the Bank of Finland's BOF5 model but typically shows rather more rapid adjustment processes.

As a member of the Eurosystem the Bank of Finland has to be able to make its own judgements about the prospects for price stability in the euro area and about the implications this has for setting policy in the Eurosystem. In order to provide consistent and coherent advice from a clear point of view it is sensible to base this process on a relatively simple and analytically understandable macroeconomic model. As the Bank of Finland has been developing its view of the Finnish economy over a long period of time and incorporating that in a series of econometric models, the latest of which is BOF5 (Willman *et al*, 1998), this would seem a sensible starting point for a euro area model. At least there is some experience in how models of this sort work and some confidence in their use. A key issue for the Bank is transparency. Transparency is normally thought of as making the Bank's thinking transparent with respect to the outside world but in the current context it also needs to be transparent within the Eurosystem. The other National Central Banks and the ECB need to be able understand readily how the Bank of Finland views the workings of the euro economy and therefore be able to understand the ex ante advice as well as the ex post analysis of the effects of different shocks, assumptions and policy reactions.

Although the euro area is sixty times as large as Finland in economic terms and rather more closed and complex, there is no reason why the same sort of macroeconomic framework should not apply but with different parameters. However, BOF5 is quite a large model, with nearly 400 equations 60 of which are estimated. Even if it were possible, replicating this at the euro level would be a major and long-term exercise. Policy has had to be made with the tools available from the outset of the Eurosystem (effectively late 1998 although the euro did not come into being until 4th January 1999). It therefore seemed sensible to start with a smaller model which incorporated the main theoretical features. EDGE has therefore been designed to have the minimum structure consistent with incorporating the main relationships in the economy relating to the operation of monetary policy. It has 40 equations 13 of which are behavioural. The remainder are definitions, identities and policy rules. The model is deliberately designed to have a similar structure of variables to the ECB's Area-Wide Model (AWM) for comparability and use in the policy process (Fagan et al, 2001).

However, modelling the euro area presents two further fundamental problems. The euro area is a new construct. Although its constituent member states existed before, they were not operating together in the same way even in the period immediately beforehand. Estimating a model using data related to the past is therefore not necessarily a very good guide to what behaviour will be in the future. After all the whole point of Economic and Monetary Union is to change the behaviour of the euro economy, making it more flexible, more dynamic and hence able to grow faster in real terms on the one hand and more stable both in nominal (price) terms and in terms of real fluctuations round the faster growth path on the other. The model therefore has to be able to cope with structural change and have a structure that allows us to explore the implications of changes in behaviour. Secondly, even if we could set up such a model for estimation the data did not exist. We have therefore created our own database from published sources (described in Table 4) but many of the series are very short.[1] Therefore, despite the advantages of estimation there is no alternative initially to calibrating the model on the basis of international evidence of parameter values, consistent with the characteristics of the new information held in the euro database. As time passes no doubt it will become possible to move nearer an estimated model.

In Section 1, which follows, we outline the structure and thinking behind EDGE and list its equations. A fuller version is published in Kortelainen (2001). The key requirements for the model are that it be forward-looking and incorporate model consistent expectations, that there be a private sector that can respond to foreign and domestic demand and supply shocks, that there be a foreign sector and fiscal and monetary authorities that can set policy in a describable manner. The model needs to converge towards a coherent steady state with plausible adjustment paths. Section 2 therefore describes how we derived the parameter values and the adjustment paths in the light of existing evidence and indications about how the euro area may work.

The main part of the paper is, however, Sections 3 and 4, where we examine how the model works in practice. In Section 3 we show how the model responds to a range of common shocks including changes in fiscal and monetary policy, domestic and foreign demand and supply shocks. Given recent and widely discussed prospects we include exchange rate and stock market shocks. Section 4 on the other hand explores how the monetary authority – the Eurosystem – interacts with the rest of the economy. We explore three straight-forward cases.

In the first case we explore the importance of 'credibility' and show the difference in impact on the economy of a policy change if the bank is credible and the difference in impact if the Eurosystem acts as if it were credible when it is not. In the second two cases we consider problems of a structural change in the economy, firstly in the NAIRU and secondly in real rate of interest. Both of these are treated as aspects of either a 'new economy' or simply the impact of closer integration stemming from EMU. We show the differences in impact if the central bank and the private sector perceive the change from when they do not and explore how different learning mechanisms affect the outcome. In particular we explore the consequences if the private sector misperceives the central bank's reaction function. Thus we solve the model with the central banks basing its decisions on one reaction function and the private sector basing its decisions on a different central bank reaction function.

1 An Outline of the EDGE Model

The economy modelled in EDGE is divided into five sectors: households, firms, the government, the monetary authority and the rest of the world. The model itself, shown in Appendix 1 has some 40 equations, 13 of which are behavioural, 5 define public policy, with the remaining 22 being identities. While the model is

[1] An earlier version of this model used a database developed by Fagan et al (2001). The new database and the calibration is described in detail in Kortelainen (2001).

set out in dynamic form, it converges to a steady state in which stock equilibrium is defined and the real rate of growth is set (see Appendix 2).

We follow the representative agent approach for both households and firms. Households are assumed to maximise the discounted value of lifetime consumption, using the Blanchard (1985) stochastic lifetime approach in a similar manner to that implemented in Sefton and in't Veld (1999). Behaviour is thus forward-looking with households basing their current actions on their expected wealth, derived from both financial assets and income (human wealth). Firms face a Cobb-Douglas technology (although Ripatti and Vilmunen (2000) show how this can be extended to a CES framework). The representative firm maximises the discounted value of expected real dividends (profits). This generates an adjustment process for capital and labour demand derived from inverting the production function and a demand for inventories. Wages are negotiated along the lines of overlapping Calvo (1983) contracts. Thus in determining capital, labour and wages the behaviour is forward-looking. Adjustment process are deliberately simple but unlike many similar models there is no attempt to add in subsequent adjustment processes to put more grit in the wheels of change. In the case of real wages the bargain depends on marginal product of labour and the departure of unemployment from the 'NAIRU'. Prices tend to short-run marginal labour cost in the long run, adjusting according to a quadratic loss function.

The modelling of the foreign sector is based on trade equations rather than on the net acquisition of foreign assets. This approach is not yet satisfactory as the available statistics include trade within the euro area as well as outside it. Prices of both exports and exports depend upon foreign and domestic prices and the CPI (and investment deflator) depend on domestic and import prices. Completing the model, we assume that government adjusts the direct tax rate to achieve the steady-state debt to nominal GDP ratio, given decisions over public investment, consumption and indirect taxes. The path is controlled by the net lending to GDP condition as in the Maastricht Treaty. Similarly, given an inflation target the monetary authority sets interest rates following a Taylor rule (using the 'unemployment gap' described in the case of wage setting rather than an output gap in addition to the deviation of inflation from the target). The exchange rate is then determined by uncovered interest rate parity, given the exogenously determined foreign rate of interest.

2 Calibration

It is not possible to use simple estimation to derive the parameters of a euro area model as there is no past history of the area. It is therefore necessary to approach the problem in a more complex and indirect manner. We can try to infer the likely behaviour of the euro area by (a) considering how its components functioned in the past (b) observing how behaviour has been changing in recent years as the member states have sought to converge (c) projecting such changes into the future (d) comparing the projected behaviour with that in similar areas – principally the United States (e) comparing the process of structural change with that observed in other instances. In conducting these steps we can use a combination of our own new estimates and the cumulation of modelling experience of others.

This strategy represents a process of calibration, using the evidence available to derive plausible values for the model parameters. However, this is only a starting point as such a process works best for individual parameters and characteristics of the steady state. It does not work so well for deriving the properties of the model as a whole. Two things are required for the complete model. One is that it fits quite well to the characteristics of the data we can create for the euro area, particularly in the most recent periods. The second is that the simulation properties of the model seem plausible – again in the light of previous experience with the member states and experience with models of other large 'countries'.

The bulk of this paper is concerned with the model's simulation properties, which we turn to in the next section. Here we deal with the earlier steps in the calibration process, using the database described in the previous section.

The key parameters to be established for the *steady state* (shown in Table 1) are

g the real rate of growth
δ the rate of depreciation

to set the equilibrium path
χ the equity premium
β the share of capital in the economy

and a series of other parameters to set the steady-state ratios for inventories, government transfers, debt, real consumption, real investment and other income to GDP. Weights need to be determined for the components of the price indexes and the trade equations need to be calibrated as a whole in a manner consistent with stable exchange rate determination. Values have to be assigned to the NAIRU and to the two key parameters in the consumption function – the subjective diecount factor and the probability of death. Lastly the adjustment speeds of labour demand, wages and the GDP deflator need to be set.

The results of these choices are set out in Appendix 2. Where series were stable we used estimated or average values from the data period available for the euro area. Where they were unstable we used values prevailing at the end of the period, particularly for the projection of the model into the future. Thus, for example, g was calibrated as 0.5% per quarter to omit the slower growth associated with convergence to the Maastricht criteria but without a return to the higher rates occurring before the 1990s or any strong new economy effect. Such prospects are best left to simulations. In the same way the NAIRU was estimated as an HP filter through the data period with its most recent value projected forward. Again it may very well be appropriate to argue that structural reforms will enable this value to fall in the future and hence this can be entered into the simulations as we explore in the next section.

The calibration of the equity premium is largely based on the US experience (Siegel, 1992). Calibrating the consumption equation proved a little difficult as the parameter values that fit the data well imply a sensible marginal propensity to consume but rather implausibly high values for the subjective discount factor and probability of death. Rather than solve this by the traditional method of adding somewhat arbitrary lags to the consumption equation we decided to remain data consistent as an initial step.

While we can fix the government sector according to practice prevailing in the data period as described, the monetary authority's reaction function is probably the most important choice from our point of view. Again what is necessary is a simple starting point from which simulations of different functions can be run as well demonstrate in the next section. We therefore posit a Taylor rule based on the foreign real rate of interest and equal weights on the inflation and unemployment gaps. No smoothing is assumed, although the specification of the equation allows this. Taking all these calibrations together and filling the model across the data period generates a reasonable fit, as indicated by Table 2.

The second step is to calibrate the dynamic model. This involves the conputation of leads and lags for principal equations (shown in Table 3). Kortelainen (2001) shows the results from some stochastic simulations to determine how well the calibrated model seems to track the properties of the data.

3 Simulations to Set the Characteristics of the Model

EDGE is coded and solved in TROLL, using the Laffarque-Boucekkine-Juillard algorithm to solve the model forward. In setting up the simulations we first need to run the steady state model far enough forward to generate suitable terminal conditions for the dynamic model. We have used 800 periods (200 years). Then in solving the dynamic model over the same time horizon we insert a correcting factor for all the nominal and price variables in the terminal period to equate the differences between the dynamic and steady state models. Thus while the real variables converge to their steady state values there is no such requirement for the nominal variables.

We did not experience problems of convergence and EDGE appears to be dynamically stable over the long run. This therefore should give a suitable base from which to compute policy simulations.

In order to set the properties of the model we ran a series of standard shocks to the policy variables: taxes, government spending and the inflation target; to drivers of the model: rate of growth of the labour force, world demand, equity premium etc. However, some shocks can only be temporary such as those to the exchange rate and interest rates if the steady state is to be regained. To illustrate this we show examples of the following shocks in this section:

1 A shock from government policy in the form of a permanent increase in public consumption equivalent to 1% of GDP

2 A domestic shock in the form of a permanent increase in the equity premium by 1%.

3 A foreign shock in the form of a permanent increase in world demand by 1%.

It is important to have some yardstick against which to judge the resultant paths. Hunt (2000) was particularly helpful in providing a comparison with the responses of the IMF's MULTIMOD. (There is always a danger of circularity here in that if models are calibrated[2] against each other they may embody modellers' prejudices rather than observed behaviour.)

3.1 A shock from government policy

The key feature of the model that this simulation increasing public consumption permanently by the equivalent of 1% of GDP illustrates is that a shift of resources towards the government reduces overall GDP, as productivity in the public sector tends to be below that in the private sector (the picture is shown in Fig.1). This of course is mainly because of the higher levels and growth rates of productivity that are possible in manufacturing industry compared with more service based activities. In the short run there is an increase in activity as it takes time for the increase in taxation required to finance the increased public expenditure to reduce private sector spending. The counterweight to this is that unemployment falls as a result of the sectoral shift towards more labour intensive activities. Because spending runs ahead of tax revenue in the short run public debt increases, inflation also rises and along with that nominal interest rates rise as the central bank tries to maintain price stability. The interest rate increase is sufficiently large for it to be a real as well as a nominal increase. This in turn leads the real and nominal exchange rates to increase as well. Because of the size of the initial shock to government debt it takes a long time for nominal magnitudes to return to equilibrium and a noticeable proportion of the adjustment process is still to come after the 15 years shown in the Figure.

3.2 A permanent increase in the equity premium

An increase in the equity premium is in effect a downward shock to wealth as a result of an increase in risk in the corporate sector. The immediate effect is a cutback in consumption as the private sector tries to adjust (Fig. 2). This slows the economy, inflation falls, the real exchange rate falls and unemployment rises. The jump in these variables is largely the result of the impact of expectations of the future problems being discounted back into current asset prices. Monetary policy can ease under these circumstances and real wages fall. What is

[2] The simulations shown stem from an earlier version of the model but the changes do not affect the qualitative results and in most cases have little visible impact on the graphs shown.

interesting in this example is that monetary policy cannot solve the adjustment problem. Because the shock is to wealth, a stock variable, the adjustment is not nearly complete even within the 15 year period shown. If nominal interest rates were to be cut even further in the hope of having a rather smaller cut in inflation then the real adjustment process for wealth would merely be dragged out rather longer, making the loss on the unemployment side of the Taylor rule greater. The result would therefore look rather different if the central bank were purely targeting inflation.

3.3 A permanent increase in world demand

What is interesting from the simulation of a foreign demand shock is that it has very little impact on the economy (Fig. 3), with the exception of the trade variables themselves. Because the shock is seen to be permanent it has an immediate effect on behaviour through expectations, even though the realisation, period by period will come through much more steadily. The immediate effect of this increase in demand comes through partly on trade volumes and partly through an appreciation in the real and nominal exchange rate. As a result imports increase more than exports as in effect the terms of trade move in favour of the euro area.

4 Monetary Policy Simulations

Thus far the shocks we have imposed show the central bank responding following a simple Taylor rule. Clearly the areas of greatest interest to us are to explore what happens when the central bank is itself the initiator of shocks and how the way the bank operates can affect the operation of the economy. One of the obvious changes, which we do not explore here is that rule itself could be changed. We could alter the weights in the rule or indeed replace the Taylor rule by an inflation forecast targeting rule (Amano *et al,* 1999). An inflation targeting rule is more difficult to implement as we have to be able solve the model for the inflation forecast before then implementing the rule. Since the rule itself is part of the forecast this is a tedious process. However, in this paper we focus on three aspects of the operation of the Taylor rule itself. The first is simply to assess what happens when monetary policy settings change in the form of

4 A temporary shock in the form of a two year increase in interest rates by 1%.[3]

In this case the shock is not anticipated but it is not a 'surprise' in the sense that central bank is deviating from its anticipated rule for a short-run advantage. It is merely responding to information that it has, in the expected

[3] This simulation is labelled 4 as it follows on from the three in the previous section.

manner. There is thus an asymmetry in the first period when the change is implemented.

However this 'straightforward' form of shock has only limited interest for the policy maker. We, therefore go on to show what happens if the central bank tries to implement a change in policy in the form of a change in the inflation target. We are concerned in this instance to show the importance of 'credibility'. If a central bank is 'credible' in this sense then the private sector will expect the policy change to succeed and inflation expectations will shift by the full extent of the change in target. Our simulation in this case is thus:

5 An exploration of the importance of *credibility* in the form of a monetary policy shock of a 1% increase in the inflation target

a when the central bank is credible

b when the central bank is not believed and the central bank and private sectors act simultaneously

c when the central bank is not believed and the central bank acts first.

The importance of simulation 5c is that in this case the private sector has the opportunity of observing the central bank's action. We can perhaps relate this simulation to the discussion of transparency. If the private sector can be better informed about what the central bank is doing then the costs of policy will be lower.

Even so the case explored here is rather extreme. It seems unlikely on the one hand that a large policy change would be fully credible immediately. At least some of the private sector would doubt that it would be sustained. Hence to some extent credibility would be earned by experience (see Vilmunen (1998) and Mattila (1998) for a discussion of these 'peso' problems). On the other hand it also seems unlikely that the central bank would not eventually gain a substantial measure of credibility if it persevered with its policy. In some respects this is akin to the process of learning (Tetlow *et al,* 1999). If events do not turn out as anticipated then one would expect that both the central bank and the private sector we realise that their view of the world may be incorrect and slowly adjust their behaviour towards the new circumstances.

Our next step therefore is to take the case of an external shock and show the difference in impact when central bank recognises the shock from when it does not. The particular shock is as follows:

6 An examination of the impact of the central bank's failure to recognise a structural shift in the economy in the form of a 1% fall in the NAIRU.

Two simulations have to be run in this instance, the first showing what happens when the central bank does recognise the structural shift and the second when it does not. This issue is one of the most important in monetary policy as structural shifts are always difficult to detect (unless due to regulatory change, in which case the debate is over the size of the response) and confusion by the central bank of shift in a relationship with a shock to the relationship[4] can have major consequences, particularly since it may mislead the private sector.

We take one such example of learning but rather than just exploring how the private sector might learn whether the monetary authority has actually changed its behaviour we take the case of a change in the supply-side of the economy and consider the effect on the behaviour of the model of different learning processes:

7 An exploration of learning in the form of a 1% reduction in the real rate of interest

a when both central bank and private sector perceive it immediately

b when the central bank fails to realise it

c when the central bank and the private sector learn of the change linearly over 5 years

4.1 A temporary interest rate shock

The three shocks we have shown thus far (in the previous Section) can be permanent, although in the case of the government spending shock it is because of a matching increase in financing. It is rational for the private sector to act as if these shocks were permanent in the light of no other evidence as future shocks could be of either sign, unless of course public expenditure is reaching the bounds of plausibility as a share of GDP. A change in interest rates on the other hand is inherently a short run temporary phenomenon unless there has been a change to expected growth rates, productivity or the inflation target. As is clear from Fig. 4, a 2 year (nominal) interest rate rise has no long-term impact on the economy. In almost all cases variables have returned to the steady state after 3 years, i.e. within one year of the ending of the shock. However, as there is a one-off fall in inflation, this will result in a permanent appreciation in the nominal exchange rate (temporary appreciation in the real exchange rate). Net foreign assets will also make a one-off permanent adjustment. The rise in unemployment (fall in GDP) is substantial – over 2% of GDP – in the short run but rapidly disappears. As before the impacts of the shock are spread among quantities and prices, with the real wage falling temporarily as well as unemployment rising. Thus stickiness in the system is clearly limited.

Even in the case of a temporary interest rate shock it is necessary to find the cause somewhere in order to conduct a logically coherent simulation. Otherwise it will merely appear as a monetary policy surprise that will generate expectations over changes in the target of monetary policy. In this case we assume it is a shock to foreign interest rates that requires a response of domestic monetary policy through the Taylor rule.

[4] i.e.confusing a shift in a curve with a shift along it.

4.2 The importance of *credibility* in monetary policy

Thus far the only policy shock we have considered is a fiscal policy shock. The change in interest rates in the previous simulation was not a monetary policy shock but an external shock to which monetary policy responded in a predictable manner. In this set of simulations we explore how much the credibility of the central bank affects the impact on the economy.

In Fig. 5a we consider the case where the central bank is credible. The shock takes the form of an announced increase in the inflation target by 1%. Nominal interest rates have to increase by 1% as well permanently. The nominal exchange rate will now depreciate steadily by 1% a year compared to the base level. The interest burden on government is also increased permanently, although the response of taxes ensures that this cost is fully financed in the long run. Perhaps the most interesting result is that there is a one-off gain in real terms from this move. There is a jump in GDP, mainly through exports and consumption in the short run before returning towards the steady state in the second year. This is the real counterpart of the increase in inflation.

In the next two Figures (5b and 5c) we consider the consequences if the central bank is not believed. Since increases in inflation targets are only too believable we have considered the case of a reduction in the inflation target (by 1%). Here although the inflation rate falls the central bank is unable to get it to fall by 1%, it only falls by 0.15%. Whereas in the case of a credible policy change the real interest rate falls back to the steady-state value very quickly, when the central bank is not credible, it deviates permanently by almost half a percentage point. Thus instead of there being an upward blip in the real interest rate and single step down in activity, the effect is permanently adverse to the tune of 0.1% of GDP. The permanently higher real interest rate draws in foreign funds, accumulating foreign assets with a small trade surplus (imports fall more than exports) and the real exchange rate depreciates.

In the simulation shown in Fig. 5b the model is solved simultaneously so the central bank sets policy in the light of its lack of credibility. An alternative way of looking at this, shown in Fig. 5c is to assume that the central bank sets policy on the assumption that it will be believed and then the private sector responds. In this case the costs are lower in the case of the domestic economy and inflation returns to the steady-state value steadily over the period. Although real and nominal interest rates are still somewhat higher than in the credible case the margin is now considerably smaller. The effect on the foreign sector is however greater as the exchange rate depreciated by more and the trade gap is wider, also increasing net foreign assets.

4.3 Learning

It is rather unrealistic to assume that the central bank could carry on period after period in the assumption that it was credible, when the evidence revealed it was not. In the same way the private sector could be expected to adjust its behaviour as the central bank repeated its response. It would be more realistic to assume that the parties learn form each other.

The central bank's reaction function is of the form

$$R = r^* + \pi + 0.5(\pi - \pi^*) - 0.5(1 - \beta)(U - U^*)$$

where $r^*$is the equilibrium real rate of interest and $U^*$the NAIRU. Currently the NAIRU is exogenous in the model. We can therefore readily explore the idea that an element of the 'new economy' emerges in the euro area and as a result the NAIRU falls. One of the key problems for monetary policy (see Wieland, 1998) for example, is that the monetary authority may not observe this change. If we take the case of the fall in the rate of productivity growth in the 1970s (Orphanides, 2000) this failure of perception can be quite long standing. If the central bank were to spot the change immediately this would have a favourable effect on the real economy right from the outset (Fig. 6a). All the components of GDP would rise and unemployment would fall rapidly by the amount of the change in the NAIRU. Monetary policy would initially ease because of the downward shock on inflationary pressures, although it would have to rise slightly as the economy approaches new capacity constraints. As the benefit is purely domestic imports will rise more than exports, the exchange rate depreciate and the net foreign assets will be lower compared to GDP. If the central bank does not notice the change in the NAIRU then the gains are slightly more muted. (Fig. 6b) shows the differences if the gain is not recognised. The GDP gain is smaller, the unemployment gain smaller – indeed unemployment never falls by the extent of the fall in the NAIRU and monetary policy is run permanently tighter to the extent of nearly 30 basis points. If we compare Figures 6a and 6b we can see that this is a striking difference in stance. Instead of a brief initial cut in interest rates and then only a 5 basis point rise, policy is tighter because the central bank interprets the increase in economic activity as a threat to future inflation. The inflation does actual materialise although not to the anticipated extent.

To implement learning we return to the case where the shock is a permanent fall in r^*as this represents the simplest change to the Taylor rule. In the first case (Fig. 7a) we therefore explore what would happen if the central bank failed to adjust immediately and learnt steadily over a period of 5 years, by imposing a linear adjustment on r^*in the Taylor rule. (We experimented with a number of other exogenous learning processes but the results were qualitatively similar.) As the bank learns, so real (and nominal) interest rates fall and the real economy falls back to the baseline path. The short-run oscillations are quite complex; financial, product and labour markets adjust at different rates, leading to an uneven path for inflation. Unemployment, government debt and net lending, net foreign assets and the current account all show reversals in their time paths.

If we assume that the same exogenous process of linear learning also applies to the private sector then the results are both more substantial and different in character (Fig. 7b). The initial effect is now positive as the private sector expands activity, assuming that the policy reaction implies a change in the inflation target (upward). The impact on inflation is much more substantial. Unemployment falls by 0.24 percentage points instead of rising by 0.35 points.

Real wages converge to the steady-state from above and not below. Thus there are actually real gains to the economy from the slower learning, although inflation performance is worse. This is, however, a result of the particular simulation and other forms of slower learning would generate different results. The key feature is that if the central bank is slower at learning than the private sector then there are real costs, in part because the private sector confuses the slow learning with a policy change. If the central bank were very transparent then its thinking could be clear to the private sector and this error would not be made. An exploration of transparency in that sort of detail is however beyond the current analysis.

5 Implications

The EDGE model that we have developed illustrates five important lessons for euro area monetary policy.

– The first is the importance of credibility. If the private sector does not believe that the central bank will succeed in its actions then this forecast tends to be self-fulfilling as expectations of inflation do not change. In so far as the bank can achieve its policy aims this will be at much greater cost in terms of output and unemployment. The other side of this relationship is also worth recalling, as it implies that a credible central bank that responds as expected will have to do relatively little to achieve its policy objectives, as inflation expectations are not jolted by shocks.

– Secondly, it shows the importance of transparency. If the private sector cannot readily detect when the central bank has reacted to new information it will tend to assume that it is the goals of policy that have changed. This also will add to the costs of monetary policy.

– Thirdly the model suggests that the faster the private sector can learn the smaller the loss.

– Fourthly, if the central bank fails to recognise a structural shift it can negate the benefits of that shift by applying an unchanged policy rule. The problem is worsened if the private sector notices the shift but the central bank does not.

– Taking these together, if the central bank thinks that a structural shift may be taking place and wants to adjust policy in the light of that probability, it needs to make its actions explicit rather than trying to hedge its assessment in secrecy. This last circumstance is probably the most important for the euro area as a new system. Neither the Eurosystem nor any of the other participants in the economy have really good evidence on how it works. They form judgements based on past behaviour and their knowledge of the requirements of the future and update them in the light of experience. Mistakes in that process are inevitable but the way the process of learning is undertaken affects its cost.

The simulations illustrate the importance of three key features of the model itself. In the first place it illustrates the importance of forward-looking behaviour with respect to wealth and the valuation of assets. Shocks affecting those values have substantial effects in the short run but adjustment processes can be very long lived, exceeding the 15 years illustrated in the Figures. Secondly behaviour differs markedly if a shock is perceived to be transitory rather than permanent and the impact is much more limited. This also has a clear implication for monetary policy. Monetary policy actions that are not expected to endure will be relatively ineffective. Thirdly it illustrates the key importance of building the reaction of both fiscal and monetary policy into the model. Private sector actions depend crucially on what they think the monetary and fiscal authorities will do in the future. The effectiveness of current policy depends on private sector expectations of future policy. Non-convergent rules will not be credible.

The policy rules illustrated in the paper are just that, illustrations. They do not imply that authorities have to follow rigid rules but they illustrate the interaction between the behaviour patterns that the authorities have and the behaviour patterns the private sector thinks they have. In the circumstances we illustrate it is not normally beneficial for the authorities to disguise their intentions because the private sector is well aware of the incentives and the longer term consequences of nonsustainable actions. Particularly in the case of monetary policy, there are substantial payoffs to designing some sort of 'precommitment technology' that allows the private sector to believe that the monetary authority will actually carry out the actions necessary to maintain its objective of price stability in the future.

This is a young model, which will develop as we gain experience in using it. The calibration process is a continuing one as new evidence about parameter values and plausible properties appears. With the euro area only being in place for only two years the learning curve is likely to be steep for some time to come.

6 References

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A Appendix 1 List of Equations

Labour demand:

$$L_t = 0.483 \cdot E_t L_{t+1} + 0.492 \cdot L_{t-1} + 0.025 \cdot \left(\frac{Y_t}{TK_t^{0.41}} \right)^{1.69}$$

Capital stock:

$$\begin{aligned} \Delta \log K_t &= -0.324 \cdot E_t \Delta \log K_{t+2} + 0.986 \cdot E_t \Delta \log K_{t+1} + 0.3378 \cdot \Delta \log K_{t-1} \\ &\quad +0.0005 \cdot \left(\frac{PF_t}{PC_t} \left(\frac{0.41 \cdot Y_t}{K_t} \right) - \frac{(r_t + \chi + 0.01)}{1 + r_t + \chi} \frac{PI_t}{PC_t} \right) \end{aligned}$$

Nominal wages:

$$WN_t = 0.49 \cdot E_t WN_{t+1} + 0.5 \cdot WN_{t-1} + 0.01 \cdot \left[0.59 \cdot Y_t / N_t \cdot PF_t \cdot \left(1 - 3 \cdot \left(U_t - \overline{U_t} \right) \right) \right]$$

GDP deflator:

$$P_t = 0.495 \cdot P_{t-1} + 0.485 \cdot E_t P_{t+1} + 0.02 \cdot \left(\frac{WN_t}{(1 - \tau_t^{indirect})} \cdot \frac{L_t}{0.59 \cdot Y_t} \right)$$

Consumption:

$$C_t = 0.6 \cdot \frac{1}{1 + r_t + \chi} \cdot E_t C_{t+1} + 0.015 \cdot ((1 + \zeta_t) \cdot \frac{A_{t-1}}{PC_t} + \frac{YDN_t}{PC_t})$$

Windfall gain:

$$\zeta_t = \frac{A_t}{A_{t-1}} - 1 - \frac{YDN_t - C_t \cdot PC_t}{A_{t-1}} - \pi_{t-1}$$

Wealth:

$$\begin{aligned} A_t &= \frac{1}{1 + R_t/400 + \chi} E_t \left(A_{t+1} + GDN_{t+1} + NFA_{t+1} \right) \\ &\quad + \left(PF_t \cdot Y_t - WN_t \cdot L_t - 0.01 \cdot PI_t \cdot K_{t-1} - 0.33 \cdot GOY_t \right) + GDN_t \\ &\quad + NFA_t \end{aligned}$$

Inventories:

$$KI_t = 0.88 \cdot T \cdot L_t^{0.59} K_t^{0.41} - 0.5 \cdot (Y_t - T \cdot L_t^{0.59} K_t^{0.41}) + 0.494 \cdot E_t (Y_{t+1} - T \cdot L_{t+1}^{0.59} K_{t+1}^{0.41})$$

Exports:

$$\log X_t = 0.48 \cdot \log Y_t^* + 0.72 \cdot \log DD_t - 0.41 \cdot \log\left(\frac{PX_t}{P_t^* \cdot e_t}\right) + 0.63$$

Imports:

$$\log M_t = 1.2 \cdot \log DD_t - 0.9 \cdot \log(\frac{PM_t}{P_t}) - 3.9$$

Export prices:

$$\log PX_t = 0.32 \cdot \log P_t + 0.68 \cdot \log(P_t^* \cdot e_t) - 0.05$$

Import prices:

$$\log PM_t = 0.48 \cdot \log PX_t + 0.38 \cdot \log(P_t^* \cdot e_t) + 0.14 \cdot \log(PC_t^* \cdot e_t) - 0.65$$

Consumer price deflator:

$$\log PC_t = 0.90 \cdot \log P_t + 0.10 \cdot \log PM_t + 0.01$$

Investment deflator:

$$\log PI_t = 0.85 \cdot \log P_t + 0.15 \cdot \log PM_t + 0.10$$

IDENTITIES:

Private nominal disposable income:

$$YDN_t = YFN_t - TAX_t + INN_t + TRF_t - GOY_t + NFN_t - 0.01 \cdot PI_t \cdot K_{t-1}$$

Real GDP:

$$Y_t = C_t + CG_t + I_t + X_t - M_t + \Delta KI_t$$

Capital accumulation equation:

$$I_t = K_t - 0.99 \cdot K_{t-1}$$

Indirect taxes:

$$TIN_t = \tau_t^{indirect} \cdot YEN_t$$

Direct taxes.

$$TAX_t = \tau_t^{direct} \cdot YEN_t$$

Public disposable income:

$$GYN_t = TAX_t + TIN_t + GOY_t - TRF_t - INN_t$$

Interest outlays of Government:

$$INN_t = R_t/400 \cdot GDN_{t-1}$$

Net foreign assets:

$$NFA_t = NFA_{t-1} \cdot (e_t/e_{t-1}) + CA_t$$

Net factor income from abroad:

$$NFN_t = R_t^*/400 \cdot NFA_{t-1}$$

Current Account:

$$CA_t = X_t \cdot PX_t - M_t \cdot PM_t + NFN_t$$

Public debt:

$$GDN_t = GDN_{t-1} - GLN_t$$

Public net lending:

$$GLN_t = -GCN_t - GIN_t + GYN_t$$

Domestic demand:

$$DD_t = C_t + CG_t + I_t + \Delta KI_t$$

Nominal GDP at factor cost:

$$YFN_t = Y_t \cdot PF_t$$

Nominal GDP:

$$YEN_t = Y_t \cdot P_t$$

GDP deflator at factor price:

$$PF_t = P_t \cdot (1 - \tau_t^{indirect})$$

Expected inflation rate, quarterly:

$$\pi_t = \log PC_{t+1} - \log PC_t$$

Expected real interest rate:

$$r_t = R_t/400 - \pi_t$$

Effective exchange rate (UIRP):

$$\log e_t = \log e_{t+1} + (R_t^* - R_t)/400$$

Unemployment rate:

$$U_t = (N_t - L_t)/N_t$$

Public nominal consumption:

$$GCN_t = CG_t \cdot P_t$$

Public nominal investment:

$$GIN_t = IG_t \cdot PI_t$$

Public other income

$$GOY_t = 0.20 \cdot YEN_t$$

Public real consumption

$$CG_t = \gamma \cdot YEN_t$$

Policy parameters

Transfers:

$$TRF_t/YEN_t = 0.25 \cdot U_t + 0.20$$

Direct tax rate:

$$\Delta\tau_t^{direct} = 0.05 \cdot (GDN_t/YEN_t - \psi) - 0.1 \cdot (GLN_t/YEN_t + \psi \cdot (\pi_{t-1} + g))$$

Inflation rate target:

$$\bar{\pi}_t = 0.0027$$

Taylor rule:

$$\begin{aligned} R_t &= (1-\Omega) \cdot R_{t-1} \\ &\quad \Omega \cdot \left[\begin{array}{c} 400 \cdot r^* + 100 \cdot \log\left(PC_t/PC_{t-4}\right) \\ +50 \cdot \left[\log\left(PC_t/PC_{t-4}\right) - 4 \cdot \bar{\pi}_t\right] \\ -50 \cdot 0.59 \cdot \left(U_t - \overline{U_t}\right) \end{array} \right] \end{aligned}$$

B Appendix 2 The Steady State Model

Output:

$$Y = TK^{0.41}L^{0.59}$$

Capital stock:

$$K = (PF/PI) \cdot 0.41 \cdot Y/(r + \chi + 0.01)$$

Wages:

$$WN = 0.59 \cdot PF \cdot Y/L$$

Consumption:

$$C = \left(\frac{1 + r + \chi - 0.6 \cdot (1 + g)}{1 + r + \chi}\right)^{-1} \cdot 0.015 \cdot (A + YDN)/PC$$

Private wealth:

$$A = (r + \chi - g)^{-1} \cdot (PF \cdot 0.41 \cdot Y - 0.01 \cdot PI \cdot K - 0.33 \cdot GOY) + GDN + NFA$$

Change in inventories:

$$\Delta KI = 0.88 \cdot g \cdot Y$$

Exports:

$$\log X = 0.48 \cdot \log Y^* + 0.72 \cdot \log(C + CG + I + X + \Delta KI) - 0.41 \cdot \log(PX/(P^* \cdot e)) + 0.63$$

Imports:

$$\log M = 1.2 \cdot \log (C + CG + I + X + \Delta KI) - 0.64 \cdot \log (PM/P) - 3.9$$

Export prices:

$$\log PX = 0.32 \cdot \log P + 0.68 \cdot \log(P^* \cdot e) - 0.05$$

Import prices:

$$\log PM = 0.48 \cdot \log PX + 0.38 \cdot \log(P^* \cdot e) + 0.14 \cdot \log(PC^* \cdot e) - 0.65$$

Consumer price deflator:

$$\log PC = 0.90 \cdot \log P + 0.10 \cdot \log PM + 0.01$$

Investment deflator:

$$\log PI = 0.85 \cdot \log P + 0.15 \cdot \log PM + 0.10$$

IDENTITIES:

Employment:

$$L = N \cdot (1 - U)$$

Technical progress:

$$\log T = \log T_{-1} + g \cdot 0.59$$

Public interest outlays:

$$INN = R/400 \cdot GDN$$

Net factor income from abroad:

$$NFN = R^{*}/400 \cdot NFA$$

Government other income:

$$GOY = 0.20 \cdot YEN$$

Government budget constraint:

$$TAX = GLN - TIN - GOY + GCN + GIN + TRF + INN$$

Private nominal disposable income:

$$YDN = YFN - TAX + TRF + INN - GOY + NFN - 0.01 \cdot PI \cdot K$$

GDP identity:

$$Y = C + CG + I + X - M + \Delta KI$$

Current Account:

$$CA = X \cdot PX - M \cdot PM + NFN$$

Nominal GDP at factor cost:

$$YFN = Y \cdot PF$$

Nominal GDP:

$$YEN = Y \cdot P$$

Government nominal consumption:

$$GCN = CG \cdot P$$

Government nominal investment:

$$GIN = IG \cdot PI$$

GDP deflator at factor price:

$$PF = P \cdot (1 - \tau^{indirect})$$

Domestic real interest rate:

$$r = R/400 - \pi$$

Inflation rate:

$$\log PC = \log PC_{-1} + \pi$$

POLICY VARIABLES:

Indirect taxes:

$$TIN = \tau^{indirect} \cdot YEN$$

Transfers:

$$TRF/YEN = \omega_1 \cdot U + \omega_2$$

Government real consumption:

$$CG = \gamma \cdot Y$$

Government real investments:

$$IG = \xi \cdot Y$$

STEADY-STATE CONDITIONS:

Unemployment rate:

$$U = \overline{U}$$

Investment:

$$I = (0.01 + g) \cdot K$$

Government net lending:

$$GLN = -GDN \cdot (g + \pi)$$

Government debt :

$$GDN = \psi \cdot YEN$$

Net foreign assets:

$$NFA = CA/(g + \pi)$$

Domestic nominal interest rate:

$$R = 100 \cdot \log\left(PC/PC_{-4}\right) + 400 \cdot r^*$$

Inflation rate:

$$\pi = \bar{\pi}$$

C Appendix 3 List of Variable Names

Symbol	Explanation	Symbol	Explanation
A	Asset wealth	P^*	Foreign prices
C	Consumption	PM	Import prices
CA	Current account	PI	Gross investment deflator
CG	Public consumption, real	PX	Export prices
DD	Domestic demand	π	Inflation rate
e	Effective exchange rate	$\bar{\pi}$	Inflation target
g	Real growth rate in steady-state	r	Real interest rate, domestic
GCN	Public consumption, nominal	r^*	Real interest rate, foreign
GDN	Public debt, nominal	R	Nominal interest rate, domestic
GIN	Public investment, nominal	R^*	Nominal interest rate, foreign
GLN	Public net lending	T	Technical progress
GOY	Public other income, nominal	TAX	Direct taxes by households
GYN	Public disposable income, nominal	τ^{direct}	Direct tax rate
I	Investment, real	$\tau^{indirect}$	Indirect tax rate
IG	Public investment, rea	TIN	Indirect taxes
INN	Public interest outlays, nominal	TRF	Public transfers
K	Capital stock	U	Unemployment rate
ΔKI	Change in inventories	$\overline{U}$	NAIRU
KI	Inventories	W	Real wages
N	Labour force	WN	Nominal wages per employee
L	Labour demand	χ	Equity premium
M	Imports	X	Exports
NFA	Net foreign assets	Y	Real GDP
NFN	Net factor income from abroad	Y^*	World GDP, real
P	GDP deflator	YDN	Private disposable income, nominal
PC	Consumer price deflator	YEN	Nominal GDP
PC^*	World commodity prices	YFN	Nominal GDP at factor cost
PF	GDP deflator at factor price	ζ	Windfall gain

List of parameters

Symbol	*Explanation*
β	The factor share of capital in production
ψ	Steady-state government debt to nominal GDP ratio
ω_1 and ω_2	Steady-state transfers equation parameters
ξ	Steady-state government real investments to GDP ratio
γ	Steady-state government real consumption to GDP ratio

Figure 1: A shock from government policy in the form of a permanent increase in public consumption equivalent to 1% of GDP
Difference from baseline

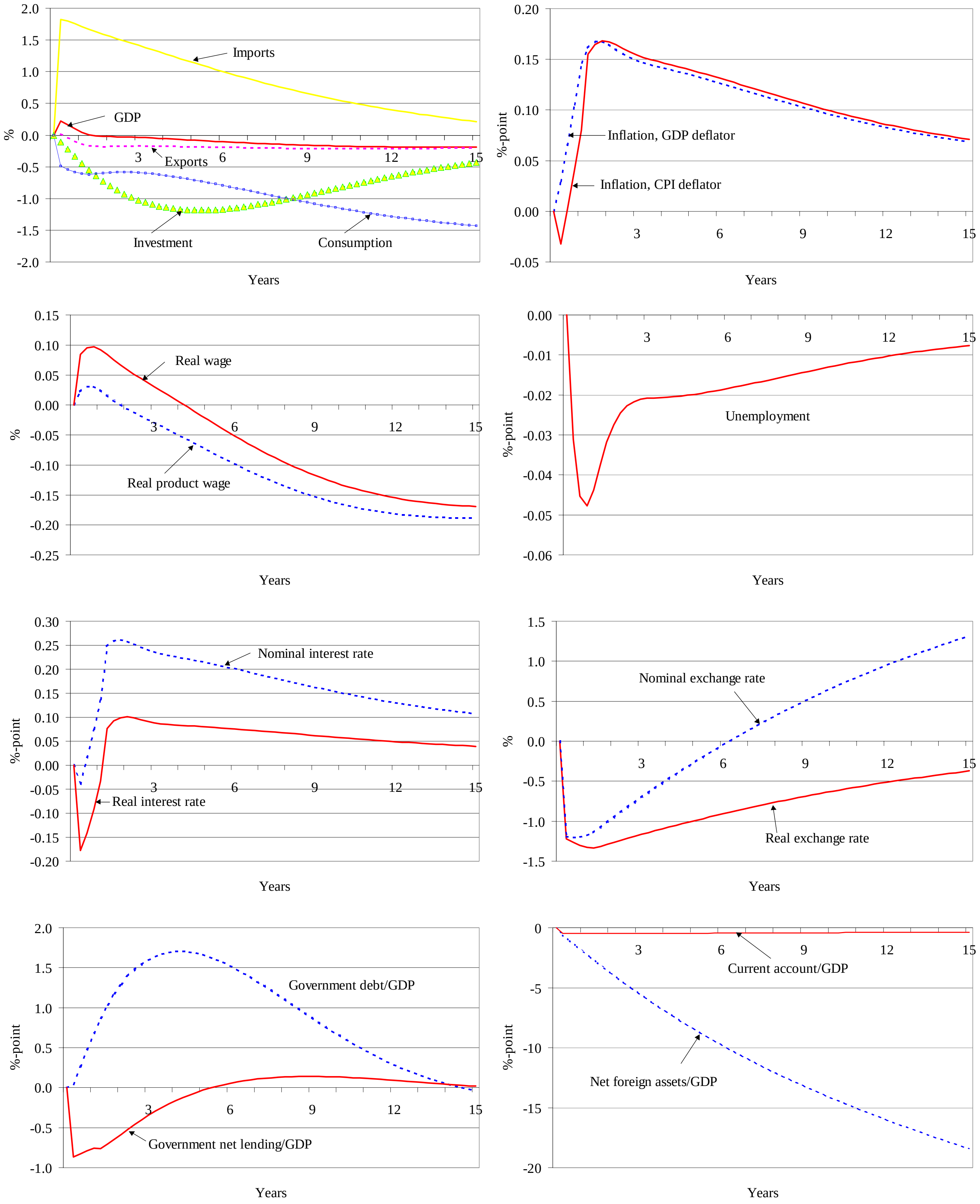

Figure 2: A domestic shock in the form of permanent increase in equity premium by 1%-point
Difference from baseline

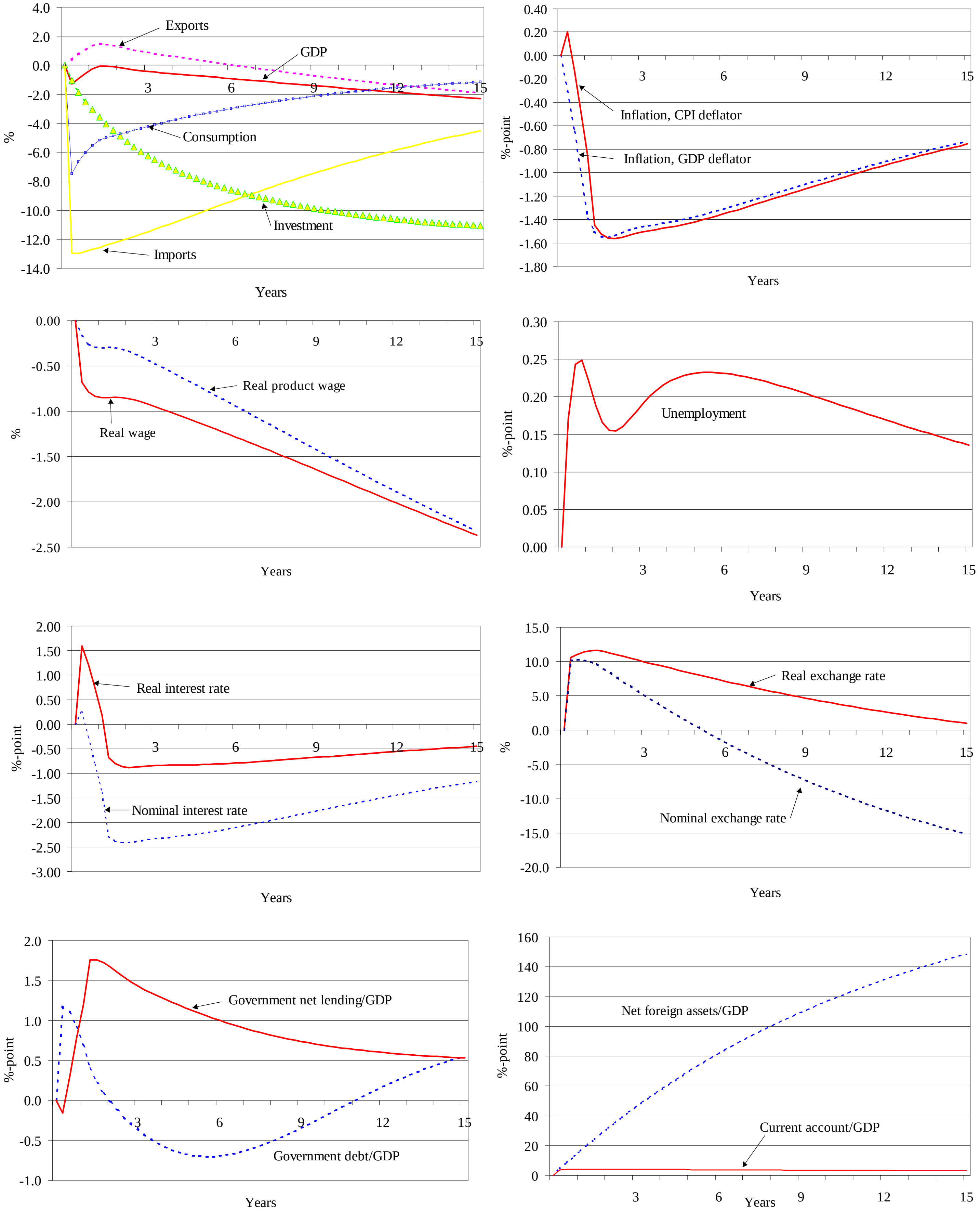

Figure 3: A foreign shock in the form of a permanent increase in World demand by 1%
Difference from baseline

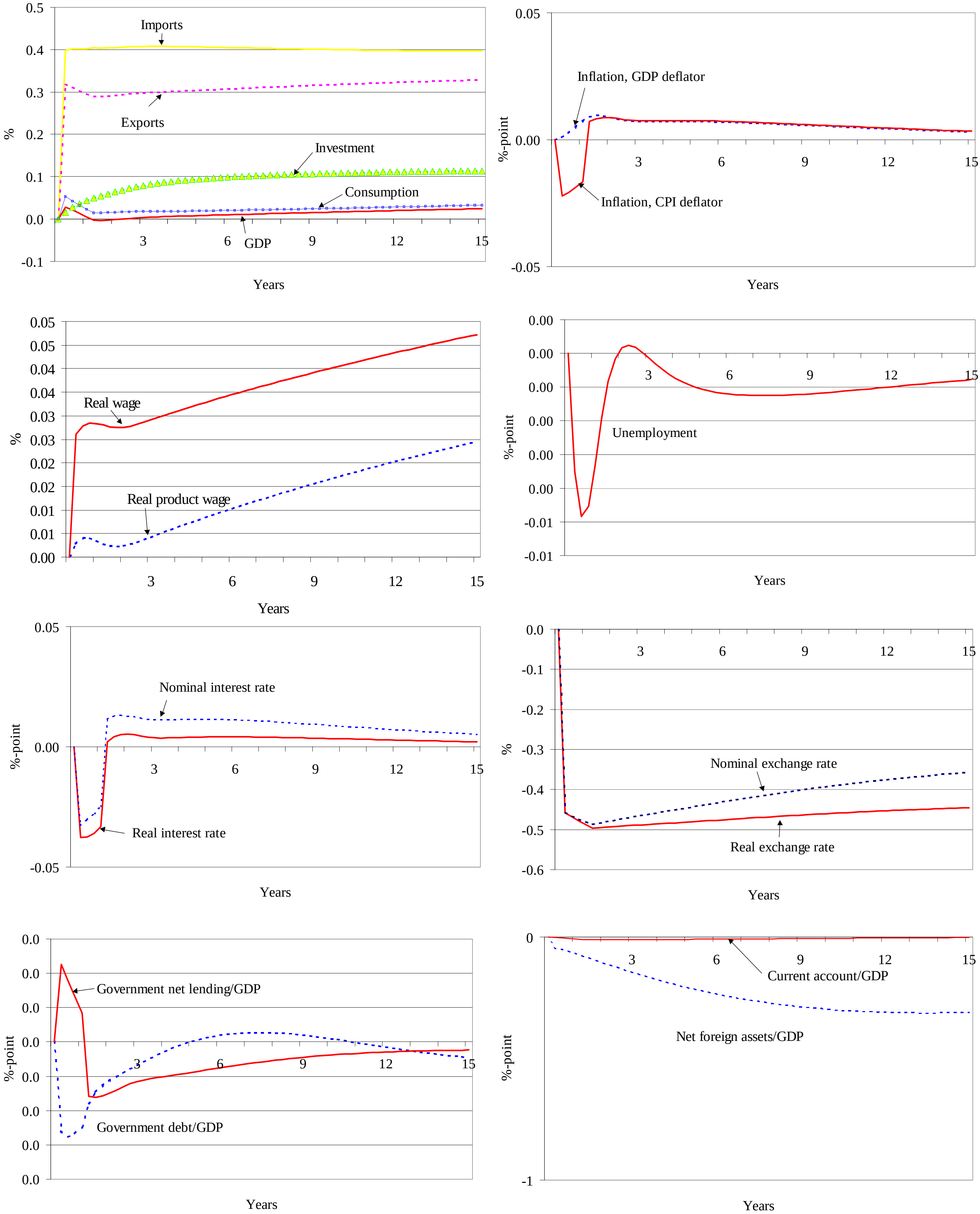

Figure 4: A temporary shock in the form of a two years increase in interest rates by 1%-point
Difference from baseline

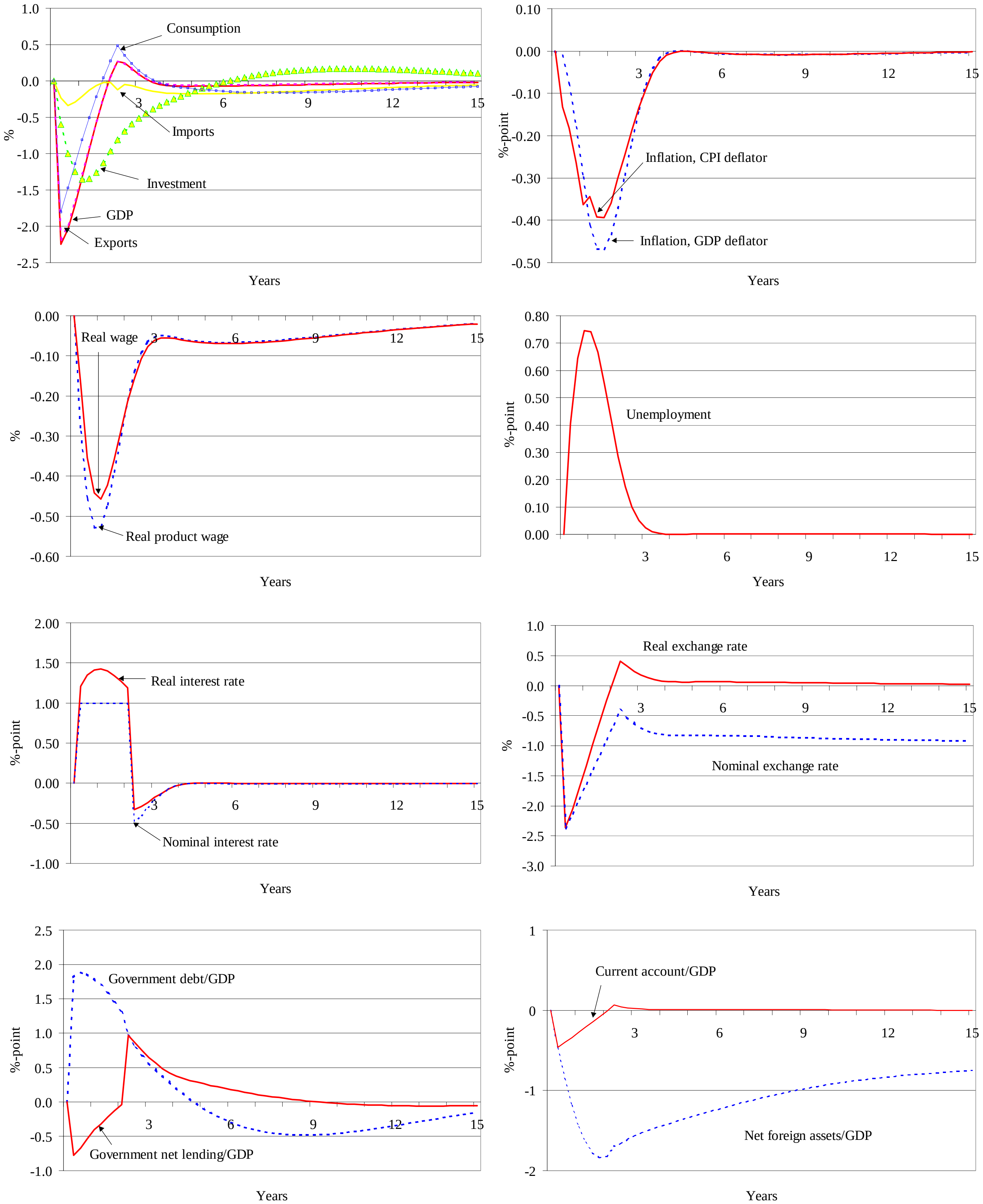

Figure 5a: An exploration of the importance of credibility in the form of a monetary policy shock of a 1%-point increase in inflation target when the central bank is credible
Difference from baseline

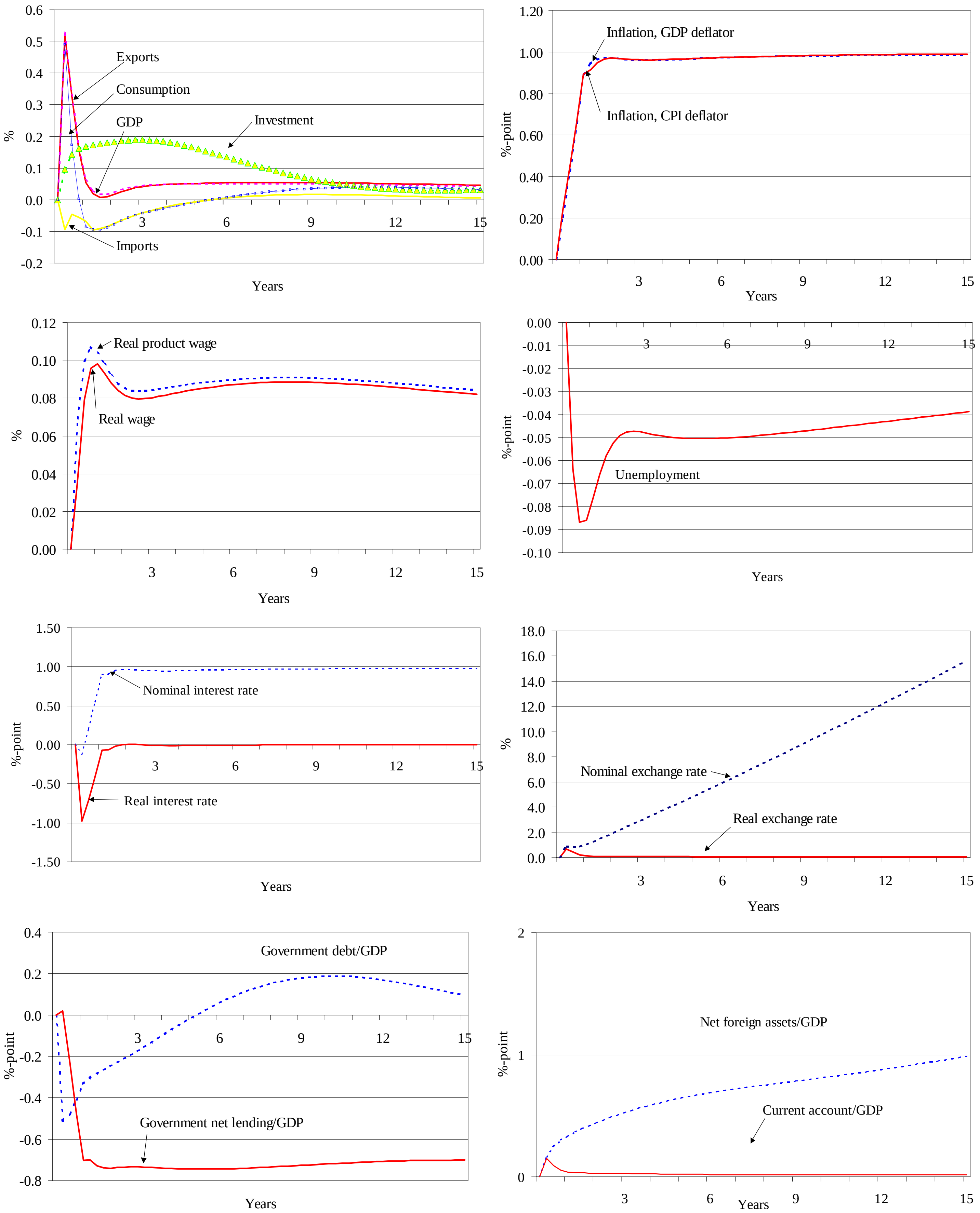

Figure 5b: An exploration of the importance of credibility in the form of a monetary policy shock of a 1%-point increase in inflation target when central bank is not believed and the Central bank and private sector act simultaneously, Difference from baseline

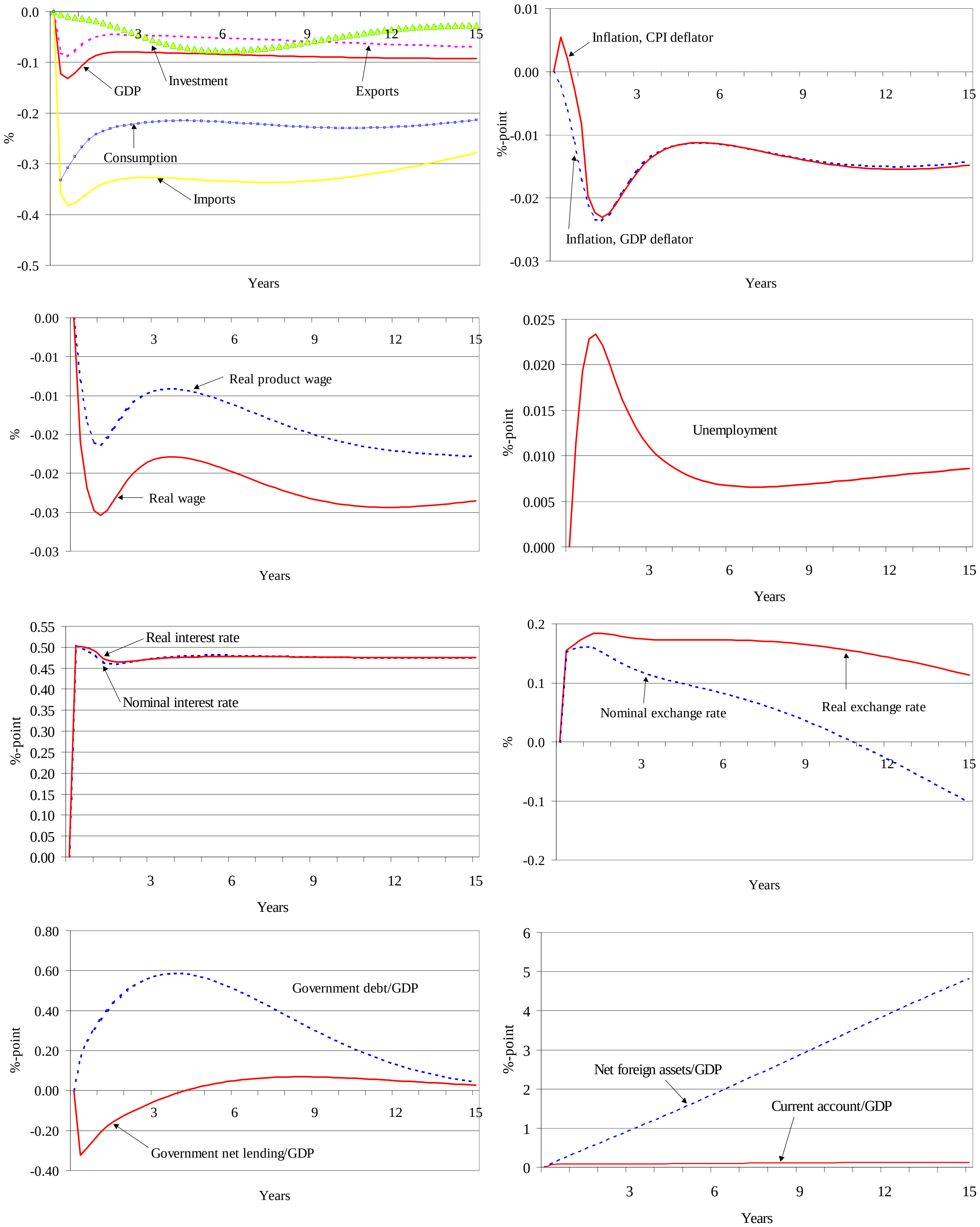

Figure 5c: An exploration of the importance of credibility in the form of a monetary policy shock of a 1%-point increase in inflation target when central bank is not believed and the central bank act first, Difference from baseline

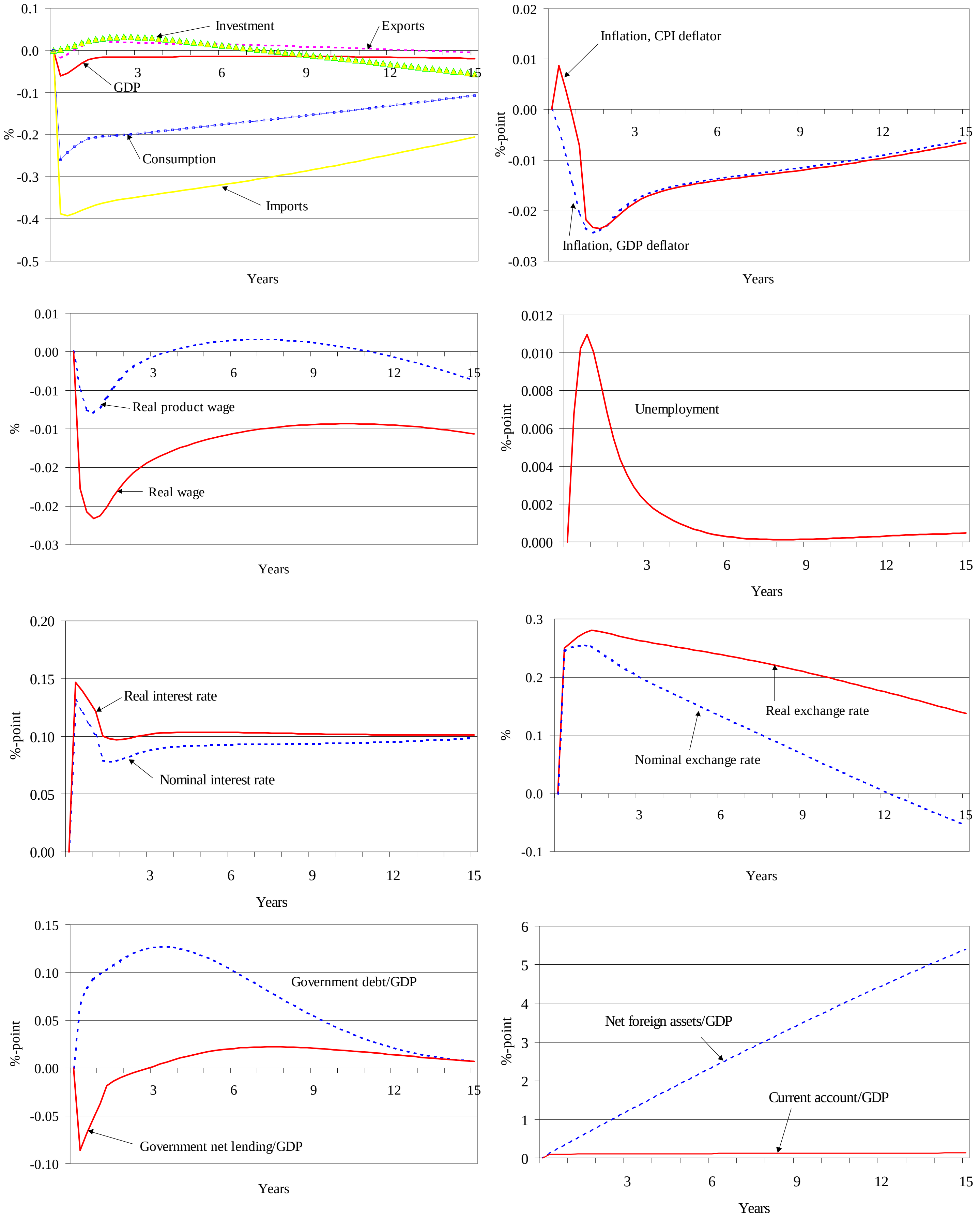

Figure 6a: A Permanent fall in NAIRU by 1.0%-point
Central Bank does see the fall in NAIRU
Difference from baseline

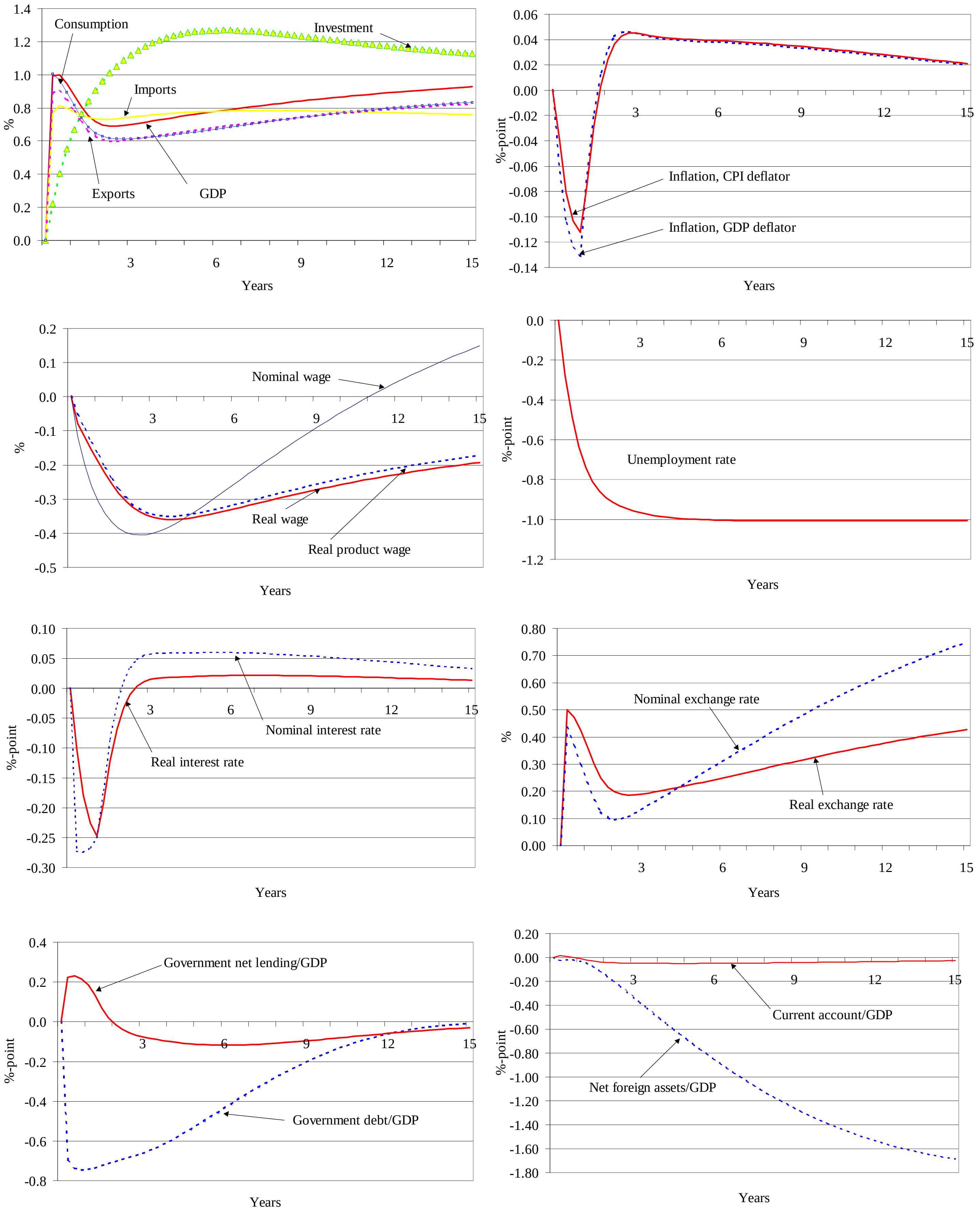

Figure 6b: A Permanent fall in NAIRU by 1.0%-point
Myopic vs. Sharp-eyed Central Bank
Difference from baseline

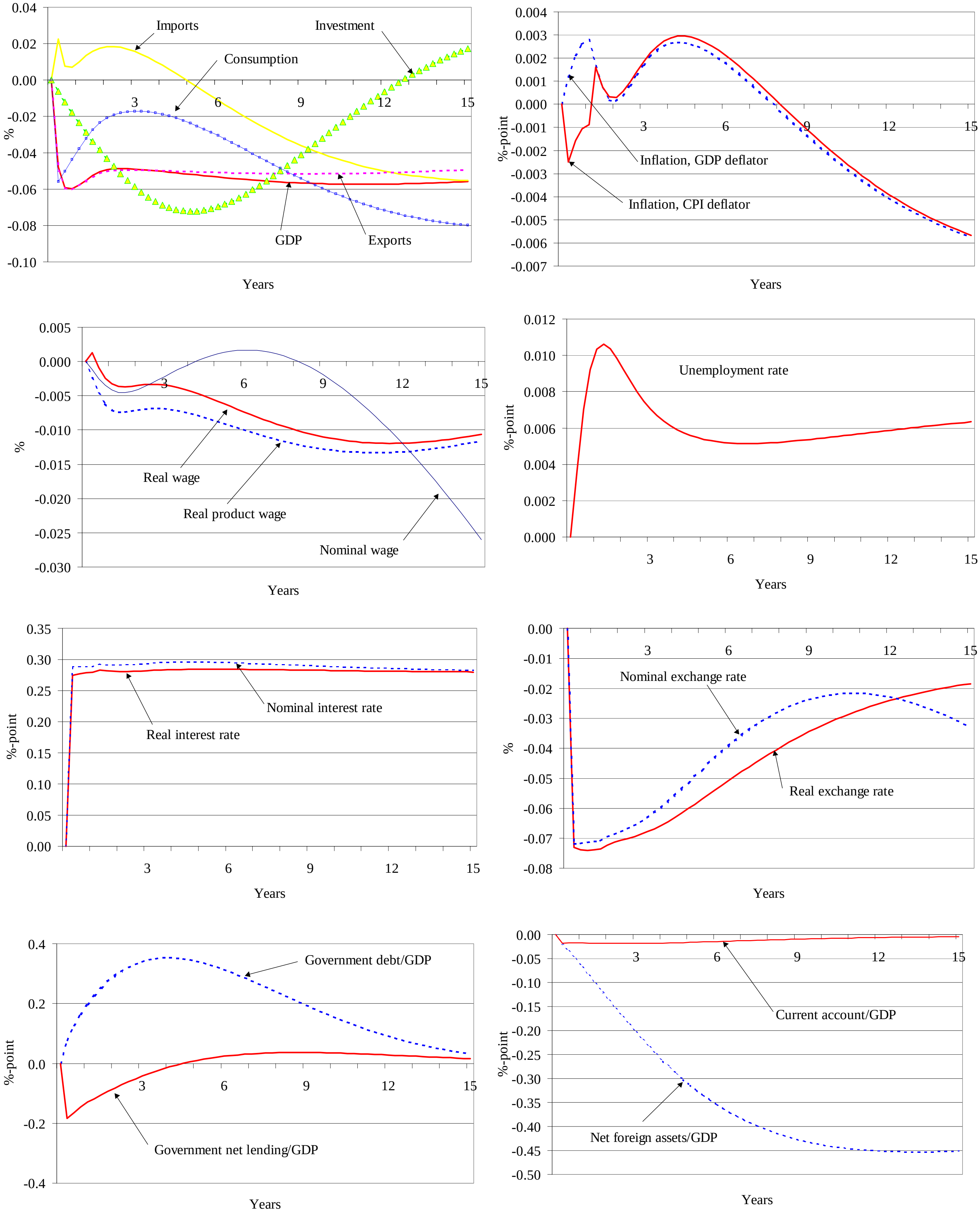

Figure 7a: An exploration of learning in the form of a 1%-point reduction in the real rate of interest when the central bank fails to realise it
Difference from baseline

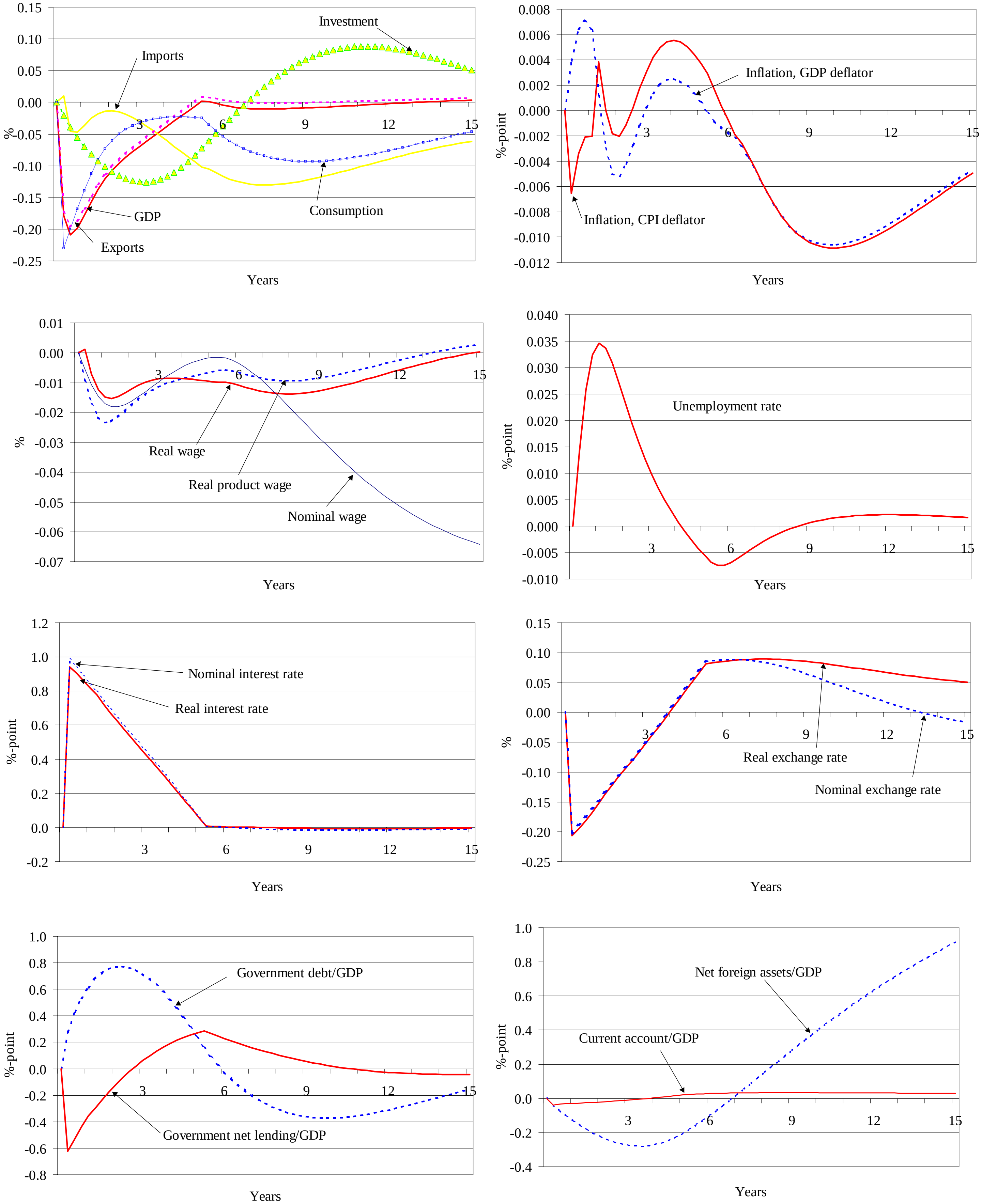

Figure 7b: An exploration of learning in the form of a1%-point reduction in the real rate of interest when the central bank and the private sector learn of the change linearly over 5 years, Difference from baseline

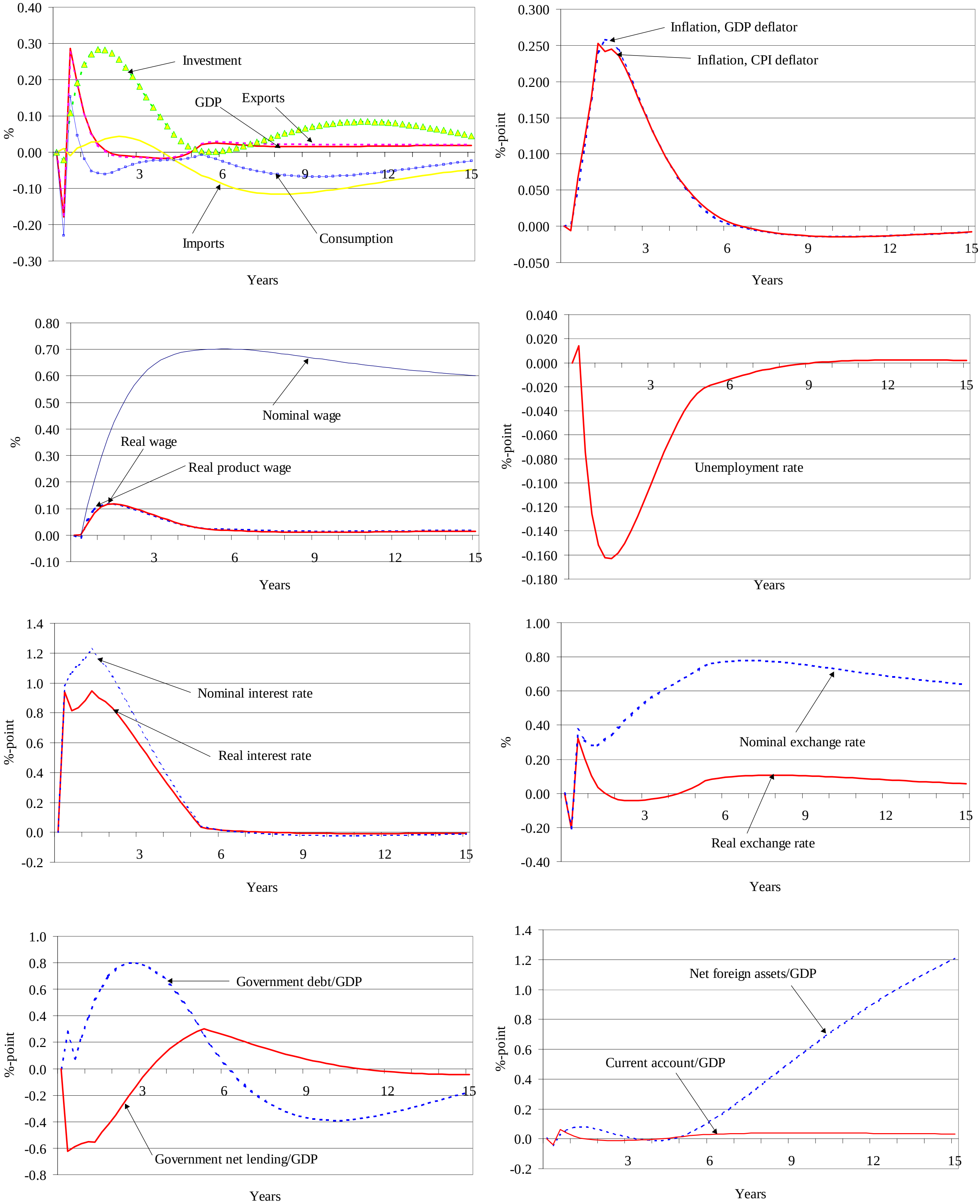

Table 1 Calibration of the steady-state model

Parameter	Value	Description
β	0.415726	The income share of capital
δ	0.01	The depreciation rate
χ	0.009	Equity premium
	0.6	The coefficient of the lead in consumption equation
	0.015	The coefficient of the fundament in consumption equation
g	0.005	Real growth in steady-state
ν	0.33	The share of profits that is paid to the public sector
k	0.883242	The ratio of the stock of inventories to real GDP
	1.2	The elasticity of exports with respect to the foreign demand
	-0.409181	The elasticity of exports with respect to the relative prices
	0.63	Constant in exports equation
	1.2	The elasticity of imports with respect to the domestic demand
	-0.9	The elasticity of imports with respect to the relative prices
	-3.9	Constant in imports equation
	0.32	The elasticity of export prices with respect to the domestic prices
	-0.05	Constant in export price equation
	0.48	The elasticity of import prices with respect to the export prices
	0.38	The elasticity of import prices with respect to the foreign prices
	-0.65	Constant in import price equation
	0.9	The elasticity of consumer prices with respect to the GDP deflator
	0.01	Constant in consumer price equation
	0.85	The elasticity of inv. prices w.r.t. the GDP deflator at factor cost
	0.10	Constant in investment price equation
	0.25	The coeffient of unemployment rate in transfers to GDP
	0.2	Constant in investment price equation
γ	0.2	The ratio of govenrment real consumption to GDP
ξ	0.028	The ratio of public real investment to GDP
ψ	0.7	The ratio of nominal public debt to GDP
b_4	0.2	The ratio of other public income to GDP

Table 2 **Ex post simulation accuracy of the steady-state model**

		MD	MAD	RMSE	MAPE
Real GDP	Y	-29567	29567	32625	0,0211
Private consumption	C	16561	20642	24245	0,0258
Fixed investment	I	-8593	9339	10262	0,0315
Exports	X	2756	9871	11679	0,0207
Imports	M	31290	31351	34806	0,0709
GDP deflator	P	0,0059	0,0059	0,0072	0,0057
Consumer price deflator	PC	0,0073	0,0073	0,0086	0,0070
Investment price deflator	PI	-0,0001	0,0036	0,0039	0,0035
Export price deflator	PX	0,0243	0,0257	0,0283	0,0255
Import price deflator	PM	0,0264	0,0264	0,0283	0,0262
Quarterly inflation rate	INFQ/100	0,0000	0,0026	0,0032	*
Annual inflation rate	INFY	1,0550	1,0550	1,0625	*
Real wages	WR	-0,0998	0,0998	0,1341	0,0165
Unemployment rate	U/100	-0,0003	0,0027	0,0031	*
Labour demand	L	30	349	399	0,0030
Nominal exchange rate	e	-0,0206	0,0339	0,0479	0,0326
Nominal interest rate	R	0,6659	0,6997	0,8997	*
Budget deficit to GDP	GLN/YEN	-0,0032	0,0034	0,0052	*
Public debt to GDP	GDN/YEN	-0,1427	0,1427	0,1489	*
Current account to GDP	CAN/YEN	-0,0112	0,0112	0,0139	*
Net foreign assets/GDP	NFA/YEN	-0,3271	0,4113	0,6244	*

* NA
MD = mean deviation
MAD = mean absolute deviation
RMSE = root mean square error
MAPE = mean average percentage error

Table 3 Calibration of the dynamic model

Value	Description
0.483	The coefficient of the lead in labour demand equation
0.492	The coefficient of the lag in labour demand equation
0.025	The coefficient of the fundament in labour demand equation
-0.324	The coefficient of the second lead in investment equation
0.986	The coefficient of the lead in investment equation
0.3378	The coefficient of the lag in investment equation
0.0005	The coefficient of the fundament in investment equation
0.49	The coefficient of the lead in wage equation
0.5	The coefficient of the lag in wage equation
0.01	The coefficient of the fundament in wage equation
0.485	The coefficient of the lead in price equation
0.495	The coefficient of the lag in price equation
0.02	The coefficient of the fundament in price equation
-0.5	The coef.of the deviation of production in inventories equation.
0.494	The coef.of the lead of the deviation in inventories equation.

Table 4 **Data Sources**

Model code	TROLL code	Explanation	Source
A	AST	Asset wealth	Own calculation
C	PCR	Real consumption	ECB Monthly Bulletin Table 5.1 c12
CA	CAN	Current account	- " - Table 8.1 c1
CG	GCR	Real public consumption	- " - Table 5.1 c13
DD	FDD	Real domestic demand	- " - Table 5.1 c11
e	EEN	Nominal effective exchange rate	- " - Table 10 c1
g	g	Real growth in steady-state	Own calculation
GCN	GCN	Nominal public consumption	ECB Monthly Bulletin Table 5.1 c4
GDN	GDN	Nominal public debt	- " - Table 7.2 c1
GIN	GIN	Nominal public investment	- " - Table 7.1 c11
GLN	GLN	Public net lending	GYN – GIN - GCN
GOY	GOY	Nominal public other income	ECB Monthly Bulletin Table 7.1 c8 + 7.1 c11 + 7.1 c12
GYN	GYN	Nominal public dispos. income	TAX + TIN + GOY - TRF - INN
I	ITR	Real investment	ECB Monthly Bulletin Table 5.1 c14
IG	GIR	Real public investment	GIN / PI
INN	INN	Nominal public inter. outlays	ECB Monthly Bulletin Table 7.1 2 c5
K	KSR	Fixed capital stock	(1-δ)•K(-1)+ I
ΔKI	DLSR	Change in inventories	ECB Monthly Bulletin Table 5.1 c15
KI	LSR	Inventories	KI(-1)+ ΔKI
N	LFN	Labour force	ECB Monthly Bulletin Table 5.4 c7 / 5.4 c8
L	LNN	Labour demand	N – Table 5.4 c7
M	MTR	Imports	ECB Monthly Bulletin Table 5.1 c18
NFA	NFA	Net foreign assets	- " - Table 8.7 c1
NFN	NFN	Net factor income from abroad	- " - Table 8.1 c4 + 8.1 c5
P	YED	GDP deflator	- " - Table 5.1 c1 / 5.1 c10
PC	PCD	Consumer price deflator	- " - Table 5.1 c3 / 5.1 c12
PC*	COMPR	World commodity prices	HWWA-Institut fur Wirtschaftsforschung, HWWA Raw materials price index, 1990=100, USD, rebased (1995=100)
PF	YFD	GDP deflator at factor price	P•(1- $\tau^{indirect}$)
P*	YWD	World GDP deflator	OECD Economic Outlook
PM	MTD	Import price deflator	ECB Monthly Bulletin Table 5.1 c9 / 5.1 c18
PI	ITD	Investment deflator	- " - Table 5.1 c5 / 5.1 c14
PX	XTD	Export price deflator	- " - Table 5.1 c8 / 5.1 c17
π	INFQ	Quarterly inflation rate	log (PC/PC(-1))
$\bar{\pi}$	INFT	Quarterly inflation target	Own calculation
R	STRQ	Domestic real interest rate	R / 400 – π
r*	STRQF	Foreign real interest rate	R* / 400 - log (P*/P*(-1))
R	STN	Domestic nominal interest rate	ECB Monthly Bulletin Table 3.1 c3
R*	STNF	Foreign nominal interest rate	- " - Table 3.1 c6
T	TFT	Technical progress	Solow residual
TAX	TAX	Direct taxes by households	ECB Monthly Bulletin Table 7.1 1 c3
τ^{direct}	TAR	Direct tax rate	TAX/YEN
$\tau^{indirect}$	TIR	Indirect tax rate	TIN/YEN
TIN	TIN	Indirect taxes	ECB Monthly Bulletin Table 7.1 1 c6
TRF	TRF	Public transfers	- " - Table 7.1 2 c6
U	URX	Unemployment	- " - Table 5.4 c8
$\bar{U}$	URT	NAIRU	Hodric-Prescott (1600) filtered U
WN	WIN/L	Nominal wages per employee	
	WIN	Nominal wage sum	Eurostat new_cronos
χ	χ	Equity premium	Own calculation
X	XTR	Exports	ECB Monthly Bulletin Table 5.1 c17
Y	YER	Real GDP	- " - Table 5.1 c10
Y*	YWR	Real World GDP	OECD Economic Outlook
YDN	YDN	Nominal private dispos. income	YFN-TAX+INN+TRF-GOY+NFN-δ•PI•K
YEN	YEN	Nominal GDP	ECB Monthly Bulletin Table 5.1 c10 * P
YFN	YFN	Nominal GDP at factor cost	Y•PF
ζ	ζ	Windfall gain	Own calculations