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## Actual and perceived monetary policy rules in a dynamic equilibrium model of the euro area

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# BANK OF FINLAND DISCUSSION PAPERS

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Mika Kortelainen  
Research Department  
12.3.2001

Actual and perceived  
monetary policy rules in a  
dynamic general equilibrium  
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Suomen Pankin keskustelualoitteita  
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The views expressed are those of the author and do not necessarily reflect the views of the Bank of Finland.

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# Actual and perceived monetary policy rules in a dynamic general equilibrium model of the euro area

Bank of Finland Discussion Papers 3/2001

Mika Kortelainen  
Research Department

## Abstract

We present a dynamic general equilibrium model with some nominal rigidities and calibrate it to euro area data. The most important features of the model include consumption/saving decisions according to Blanchard's 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 model is developed for use in analysing differences between perceived and actual monetary policy rules, which is then done as a means of evaluating the macroeconomic benefits of credibility in monetary policy. General properties of the model are analysed with a variety of simulation experiments.

Key words: EDGE, rational expectation, DGE models, nominal rigidities

# Odotettu ja toteutuva rahapolitiikan sääntö euroalueen dynaamisessa yleisen tasapainon mallissa

Suomen Pankin keskustelualoitteita 3/2001

Mika Kortelainen  
Tutkimusosasto

## Tiivistelmä

Tässä tutkimuksessa esitetään kalibroitu euroalueen dynaaminen yleisen tasapainon malli, jossa on nimellisiä jäykkyyksiä. Mallin tärkeimmät ominaisuudet sisältävät Blanchardin stokastisen eliniän kulutus-/säästämisspäätökset, yksityisen pääomavarallisuuden arvostamisen pääomatulojen nykyarvona, työmarkkinoiden limittäiset Calvo-sopimukset ja neoklassisen tarjonnan Cobb-Douglas hyötyfunktiolla. Malli on kehitetty, jotta voidaan arvioida odotetun ja toteutuvan rahapolitiikan sääntöjen eroja. Mallia hyödynnetään rahapolitiikan uskottavuuden makrotaloudellisten vaikutusten arvioinnissa. Mallin yleisiä ominaisuuksia tutkitaan joukolla simulointikokeita.

Asiasanat: EDGE, rationaaliset odotukset, dynaaminen yleisen tasapainon malli, nimelliset jäykkyydet

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# 1 Introduction

In this paper an Euro area Dynamic General Equilibrium (EDGE)-model is built and used to illustrate the analysis of monetary policy credibility in Europe. After the establishment of the EMU, it has become an object of study in applied macroeconomic modelling, see Coenen and Wieland (2000) and Fagan et al (2001). The particular ingredients of our model are the inclusion of microfoundations through an optimisation behaviour of representative agents and the explicit treatment of expectations through the assumption of rational expectations. We will show how the model can be used to analyse heterogeneous expectations, too, in the context of less than perfect credibility. Furthermore, the EDGE -model has nominal rigidities in the short run which allow monetary policy to have real effects. Hence, the model can be characterized as having a Keynesian short-run with some "non-Keynesian" properties due to forward-looking expectations while the long-run is neoclassical.

The EDGE -model is built upon the earlier experience gained with the forward looking BOF5-model of the Finnish economy, see Willman et al (1998). The most important features of the EDGE -model include consumption/saving decisions according to Blanchard's stochastic lifetimes approach, the 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. In addition, the exchange rate is determined by the uncovered interest rate parity and the monetary policy is described by the Taylor rule.

As the diagnostic simulations in this paper show the economy according to the EDGE -model adjusts rapidly back to the long-run equilibrium after different shocks. It seems that the Keynesian features namely the price and wage rigidities are short-lived and thus the behaviour of the model is fairly New Classical even in the short run. The immediate adjustment to transitory shocks is fast, as is the return to the long-run equilibrium of the economy. With permanent shocks the steady-state may shift as well, which causes the adjustment process to be significantly slower than with the temporary shocks. In particular, the stock adjustment of different assets and especially the adjustment of net foreign assets to the new equilibrium is slow.

The model is used to analyze the effects of less than perfect credibility of monetary policy, taken here to imply systematic misperceptions by the public of the central bank's inflation target. The results illustrate the macroeconomic effects of lack of credibility.

The paper is organised as follows. Section 2 presents the derivation of key behavioural equations. Section 3 considers how the model is calibrated. Section 4 reviews some diagnostic simulations with the model. Section 5 analyses credibility effects of monetary policy. Section 6 concludes.

## 2 The model specification

In this section, we describe in more detail the theory behind the EDGE model. We start with the key behavioural equations which establish the core of the dynamic model. First, we show how consumption is derived from the household maximisation problem. Next, we analyse the problem of the firm and obtain investment demand, labour demand and inventory demand equations. Furthermore, we show how prices are derived from the firm's pricing problem. In analysing the firm's problem we assume that above problems can be solved separately. Households and firms determine together wages as overlapping Calvo contracts in the labour market. In addition to these, trade and price equations of the core model are presented briefly. Finally, some of the identities and policy rules needed to complete the model are presented.

After describing the dynamic model in detail we show the key principles according to which the companion steady-state model is derived. This steady-state model is used to obtain the necessary terminal points for solving the EDGE model. In principle, the steady-state model can be used separately to analyse the long-run of the economy. The steady-state model is also helpful in stock-flow considerations since it defines explicitly the stock equilibrium for private financial assets, capital stock, government debt and net foreign assets. The short-run flow equilibrium of consumption, investment, government net lending and the current account is described by the dynamic model. In this flow equilibrium the stock equilibrium may still be incomplete but in the long-run stocks of assets will adjust fully to the steady-state stock equilibrium.

### 2.1 The dynamic model

#### 2.1.1 Consumption

Consumption is modelled as in Blanchard's stochastic lifetime approach, Blanchard (1985). We model the consumption in discrete time. The interest rate is not assumed to be constant and we do not impose perfect foresight into the model. Thus, our formulation follows closely the derivation of consumption function by Sefton and in't Veld (1999).

We assume that the representative agent maximises the discounted value of lifetime consumption:

$$\max E_t \sum_{j=0}^{\infty} \theta^j (1-p)^j \log c_{s,t+j}$$

where  $\theta = (1 + \varphi)^{-1}$  is the subjective discount factor and  $\varphi$  is the rate of time preference.  $c_{s,t}$  is the consumption of an agent born at time  $s$ , at period  $t$ . In each period the agent faces a constant probability of death  $p$ .  $E_t$  is the expectations operator conditional on information at time  $t$ .

The periodic budget constraint at time  $t$ :

$$c_{s,t} + w_{s,t} = \frac{1 + z_{t-1} + \zeta_t}{1 - p} w_{s,t-1} + y_{s,t}$$

where  $w_{s,t}$  and  $y_{s,t}$  are the financial wealth and labour income of an agent born at time s, at period t.  $E_{t-1}z_{t-1}$  and  $\zeta_t = z_{t-1} - E_{t-1}z_{t-1}$  are the expected return on wealth and windfall gain (unexpected return on wealth) between periods t-1 and t. Thus,  $E_t z_{t-1} = z_{t-1}$ ,  $E_{t-1} \zeta_t = E_{t-1}(z_{t-1} - E_{t-1}z_{t-1}) = 0$  and  $E_t \zeta_t = E_t(z_{t-1} - E_{t-1}z_{t-1}) = z_{t-1} - E_{t-1}z_{t-1} = \zeta_t$ .

The lifetime budget constraint is:<sup>1</sup>

$$\sum_{j=0}^{\infty} \frac{(1-p)^j}{\prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} c_{s,t+j} = h_{s,t} + \frac{1 + z_{t-1} + \zeta_t}{1 - p} w_{s,t-1}$$

where  $h_{s,t} = \sum_{j=0}^{\infty} \frac{(1-p)^j}{\prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} y_{s,t+j}$  is the human wealth of an agent

born at time s, at period t. In addition, a transversality condition is imposed to prevent agents from going infinitely in debt:

$$\lim_{T \rightarrow \infty} E_t \left( \frac{(1-p)^T}{\prod_{k=0}^{T-1} (1 + z_{t+k} + \zeta_{t+k+1})} w_{s,t+T} \right) = 0$$

The Euler equation corresponding to the above problem may be written as:

$$\theta E_t \left( \frac{1}{c_{s,t+1}} \right) = \frac{1}{c_{s,t}} E_t \left( \frac{1}{1 + z_t + \zeta_{t+1}} \right)$$

Let us take a second order Taylor approximation of the Euler equation around points  $E_t c_{s,t+1}$  and  $E_t(1 + z_t + \zeta_{t+1}) = 1 + E_t z_t = E_t Z_t$  :

$$\theta E_t \left( \frac{1}{c_{s,t+1}} \right) - \frac{1}{c_{s,t}} E_t \left( \frac{1}{Z_t} \right) = \theta \left\{ \underbrace{\left( \frac{1}{E_t c_{s,t+1}} \right) \left[ 1 + \frac{E_t (c_{s,t+1} - E_t c_{s,t+1})^2}{(E_t c_{s,t+1})^2} \right]}_{\text{risk premium in expected consumption}} \right\} - \frac{1}{c_{s,t}} \left\{ \underbrace{\left( \frac{1}{E_t Z_t} \right) \left[ 1 + \frac{E_t (Z_t - E_t Z_t)^2}{(E_t Z_t)^2} \right]}_{\text{risk premium in expected return}} \right\}$$

---

<sup>1</sup>If j=0 we define  $\frac{1}{\prod_{k=0}^{-1} (1 + z_{t+k} + \zeta_{t+k+1})} = 1$

We shall assume that both the risk premium in expected consumption and the risk premium in expected return are zero. Hence, the Euler equation reduces to:

$$\theta E_t(1 + z_t)c_{s,t} = E_t c_{s,t+1}$$

Inserting the Euler equation in the slackness condition yields the consumption function at the micro level:<sup>2</sup>

$$c_{s,t} = (1 - \theta(1 - p)) \left( E_t h_{s,t} + \frac{1 + z_{t-1} + \zeta_t}{1 - p} w_{s,t-1} \right)$$

In order to obtain the aggregate consumption we first define some aggregation functions:  $C_t = \sum_{s=-\infty}^t p(1 - p)^{t-s} c_{s,t}$  i.e. aggregate consumption is obtained summing over each cohort  $s$ . Similar aggregation applies to human and financial wealth:  $H_t = \sum_{s=-\infty}^t p(1 - p)^{t-s} h_{s,t} =$

$$\sum_{j=0}^{\infty} \frac{(1-p)^j}{\prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} \underbrace{\sum_{s=-\infty}^t p(1-p)^{t-s} y_{s,t+j}}_{Y_{t+j}} =$$

$$\sum_{j=0}^{\infty} \frac{(1-p)^j}{\prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} Y_{t+j} \quad \text{and} \quad W_t = \sum_{s=-\infty}^t p(1-p)^{t-s} w_{s,t} \quad \text{and}$$

$$\begin{aligned} &^2 \text{The budget constraint may be written as: } E_t h_{s,t} + \frac{1 + z_{t-1} + \zeta_t}{1 - p} = \\ &E_t \sum_{j=0}^{\infty} \frac{(1-p)^j}{\prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} c_{s,t+j} \\ &= c_{s,t} + E_t \left( \frac{1-p}{1 + z_t + \zeta_{t+1}} \right) E_t c_{s,t+1} + E_t \left( \frac{(1-p)^2}{(1 + z_t + \zeta_{t+1})(1 + z_{t+1} + \zeta_{t+2})} \right) E_t c_{s,t+2} + \\ &\dots \end{aligned}$$

Assuming that the right hand side may be expanded by Taylor approximations and that the successive total returns  $Z_t = 1 + z_t + \zeta_{t+1}$  are uncorrelated we may write the discount factor as:

$$\begin{aligned} &E_t \sum_{j=0}^{\infty} \left( \frac{(1-p)^j}{\prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} \right) = \sum_{j=0}^{\infty} \left( \frac{(1-p)^j}{E_t \prod_{k=0}^{j-1} (1 + z_{t+k} + \zeta_{t+k+1})} \right) = \\ &\sum_{j=0}^{\infty} \left( \frac{(1-p)^j}{\prod_{k=0}^{j-1} E_t (1 + z_{t+k} + \zeta_{t+k+1})} \right) \end{aligned}$$

Hence, the right hand side may be written as:

$$\begin{aligned} &= c_{s,t} + \frac{1-p}{E_t (1 + z_t)} \theta E_t (1 + z_t) c_{s,t} + \frac{(1-p)^2}{E_t (1 + z_t) E_t (1 + z_{t+1})} \theta^2 E_t (1 + z_t) E_t (1 + z_{t+1}) c_{s,t} + \\ &\dots \\ &= (1 + (1-p)\theta + (1-p)^2\theta^2 + \dots) c_{s,t} = (1 - \theta(1-p))^{-1} c_{s,t} \end{aligned}$$

$$W_{t-1} = \sum_{s=-\infty}^t p(1-p)^{t-s-1} w_{s,t-1}.$$

Thus, we may write the aggregate budget constraint:

$$C_t + W_t = (1 + z_{t-1} + \zeta_t)W_{t-1} + Y_t$$

Aggregated consumption function is thus:

$$C_t = \Lambda (E_t H_t + (1 + z_{t-1} + \zeta_t)W_{t-1})$$

where the marginal propensity to consume  $\Lambda = 1 - \theta(1 - p)$ . Leading consumption, taking expectations at time  $t$  and subtracting from above yields:

$$C_t = E_t C_{t+1} + \Lambda (E_t (H_t - H_{t+1}) + (1 + z_{t-1} + \zeta_t)W_{t-1} - E_t (1 + z_t)W_t)$$

After some manipulations<sup>3</sup> we may write the aggregated consumption function as:

$$\begin{aligned} C_t = & \left( \frac{1-p}{1 - (1-p)\Lambda} \right) \left( \frac{E_t C_{t+1}}{E_t (1 + z_t)} \right) \\ & + \left( \frac{p\Lambda}{(1 - (1-p)\Lambda)} \right) ((1 + z_{t-1} + \zeta_t)W_{t-1} + Y_t) \end{aligned}$$

Next, let us define that the disposable income is  $YD_t = z_{t-1}W_{t-1} + Y_t$ . Thus the consumption is written as:

$$C_t = \left( \frac{1-p}{1 - (1-p)\Lambda} \right) \left( \frac{E_t C_{t+1}}{E_t (1 + z_t)} \right) + \left( \frac{p\Lambda}{(1 - (1-p)\Lambda)} \right) ((1 + \zeta_t)W_{t-1} + YD_t)$$

Defining  $W_{t-1} = \frac{A_{t-1}}{PC_t}$ ,  $YD_t = \frac{YDN_t}{PC_t}$  and  $E_t(1 + z_t) = 1 + r_t + \chi$ , where  $r_t$  is the real interest rate and  $\chi$  is the equity premium.  $PC$  is the private consumption deflator and  $YDN$  is the private nominal disposable income:

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

<sup>3</sup>Leaded aggregated human wealth may be written as  $H_{t+1} = Y_{t+1} + \left( \frac{1-p}{1 + z_{t+1} + \zeta_{t+2}} \right) Y_{t+2} + \left( \frac{1-p}{1 + z_{t+1} + \zeta_{t+2}} \right) \left( \frac{1-p}{1 + z_{t+2} + \zeta_{t+3}} \right) Y_{t+3} + \dots$ . Multiplying by  $\left( \frac{1-p}{1 + z_t + \zeta_{t+1}} \right)$  and adding  $Y_t$  on both sides yields  $\left( \frac{1-p}{1 + z_t + \zeta_{t+1}} \right) H_{t+1} + Y_t = \left[ Y_t + \left( \frac{1-p}{1 + z_t + \zeta_{t+1}} \right) Y_{t+1} + \left( \frac{1-p}{1 + z_t + \zeta_{t+1}} \right) \left( \frac{1-p}{1 + z_{t+1} + \zeta_{t+2}} \right) Y_{t+2} + \dots \right] = H_t$ . Hence, the expected change in human wealth when inserting the aggregate consumption  $E_t H_t = \Lambda^{-1} C_t - (1 + z_{t-1} + \zeta_t)W_{t-1}$  can be expressed as  $E_t (H_t - H_{t+1}) = \left( 1 - \frac{E_t(1 + z_t)}{1-p} \right) \frac{C_t}{\Lambda} - \left( 1 - \frac{E_t(1 + z_t)}{1-p} \right) (1 + z_{t-1} + \zeta_t)W_{t-1} + \frac{E_t(1 + z_t)}{1-p} Y_t$ .

which is the value of GDP at factor cost net of government transaction minus the depreciation of capital stock plus the interest income from net foreign assets.  $\delta$  is the depreciation rate. These enables us to write the consumption function in the following form which is actually used in the EDGE model:

$$C_t = \left( \frac{1-p}{1-(1-p)\Lambda} \right) \left( \frac{E_t C_{t+1}}{1+r_t+\chi} \right) + \left( \frac{p\Lambda}{(1-(1-p)\Lambda)} \right) \left( (1+\zeta_t) \cdot \frac{A_{t-1}}{PC_t} + \frac{YDN_t}{PC_t} \right)$$

and Windfall gain:

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

where  $\pi_t$  is the inflation rate. The asset accumulation equation is:

$$A_t = \frac{1}{1+R_t/400+\chi} E_t(A_{t+1} - GDN_{t+1} - NFA_{t+1}) + (PF_t \cdot Y_t - WN_t \cdot L_t - \delta \cdot PI_t \cdot K_{t-1} - \nu \cdot GOY_t) + GDN_t + NFA_t$$

This equation simply defines the value of current nominal assets as the discounted net present value of capital income.  $NFA_t$  is the net present value of capital income from abroad and  $GDN_t$  is the net present value of an interest income from government bonds.  $PF_t \cdot Y_t - WN_t \cdot L_t - \delta \cdot PI_t \cdot K_{t-1} - \nu \cdot GOY_t$  is the net present value of capital income from firms.  $PF_t \cdot Y_t$  is the value of production at the factor cost,  $WN_t \cdot L_t$  is total wages,  $\delta \cdot PI_t \cdot K_{t-1}$  is the depreciation and  $\nu \cdot GOY_t$  is the share of profits that is paid to the public sector in return for the public investments.

### 2.1.2 Firm behaviour

#### Investment

Investment demand is derived along the lines of Hubbard et al. (1993). We make some simplifying assumptions, namely we assume no taxes and no bond financing. The real dividend of the firm  $d_t = D_t/P_t^I$  in terms of the price of the investment good  $P_t^I$ , is expressed as:

$$d_t = p_t F(K_t, N_t) - w_t N_t - \Gamma(K_t, K_{t-1}, K_{t-2}) - I_t$$

where  $p_t = P_t/P_t^I$  is the relative price of output,  $F(K_t, N_t)$  is the production function where  $K_t$  is the capital stock and  $N_t$  is the labour input,  $WN_t$  is the nominal wage, and  $w_t = WN_t/P_t^I$  is the real wage rate.  $\Gamma(K_t, K_{t-1}, K_{t-2})$  is an adjustment cost function, which allows adjustment costs to be associated both with the changes in the capital stock and with the rate at which capital stock is changed.  $I_t$  is the real investment.

A representative firm  $i$  maximises the discounted value of expected real dividends:

$$E_t \sum_{j=0}^{\infty} \left[ \prod_{h=0}^{t+1} \rho_h \right] d_{i,t+j}$$

subject to the capital accumulation equation:

$$K_{i,t} = I_{i,t} + (1 - \delta)K_{i,t-1}$$

where  $\rho$  is the discount factor and  $\delta$  is the rate of depreciation. The first order condition may be written as:

$$\begin{aligned} & \frac{\partial \Gamma(K_{i,t}, K_{i,t-1}, K_{i,t-2})}{\partial K_{i,t}} + \rho E_t \frac{\partial \Gamma(K_{i,t+1}, K_{i,t}, K_{i,t-1})}{\partial K_{i,t}} \\ & + \rho^2 E_t \frac{\partial \Gamma(K_{i,t+2}, K_{i,t+1}, K_{i,t})}{\partial K_{i,t}} \\ & = p_t \frac{\partial F(K_{i,t}, N_{i,t})}{\partial K_{i,t}} \underbrace{-1 + \rho(1 - \delta)}_{-\frac{r + \chi + \delta}{1 + r + \chi}} \end{aligned}$$

where  $\rho = (1 + r + \chi)^{-1}$  and  $r$  is the real interest rate and  $\chi$  is the equity premium. The adjustment cost function is assumed to be of the following form as in The BOF4 Quarterly Model of Finnish Economy (1990):

$$\begin{aligned} \Gamma(K_{i,t}, K_{i,t-1}, K_{i,t-2}) &= \frac{a_1 (\Delta K_{i,t} - b_1 \Delta K_{i,t-1})^2}{2 K_{i,t-1}} \\ &\approx \frac{a_1}{2} \Delta K_{i,t} \Delta \log K_{i,t} + \frac{a_1 b_1^2}{2} \Delta K_{i,t-1} \Delta \log K_{i,t-1} \\ &\quad - a_1 b_1 \Delta K_{i,t} \Delta \log K_{i,t-1} \end{aligned}$$

where  $0 < b_1 < 1$  and  $\Delta \log K_t = \log K_t - \log K_{t-1}$ .

Taking the partial derivatives of this function, inserting these in the first order condition, defining  $\Delta k_{i,t} = \Delta \log K_{i,t}$  and dividing by  $a_1$  yields the capital stock equation:

$$\begin{aligned} & \rho^2 b_1 \Delta k_{t+2} - (\rho^2 b_1^2 + \rho(1 + b_1)) \Delta k_{t+1} + (\rho b_1(1 + b_1) + 1) \Delta k_t - b_1 \Delta k_{t-1} \\ & = \frac{1}{a_1} \left( p_t \frac{\partial F(K_t, N_t)}{\partial K_t} - \frac{r + \chi + \delta}{1 + r + \chi} \right) \end{aligned}$$

this is used in EDGE, with marginal product of capital given by the Cobb-Douglas production function of the model.



## Labour Demand

We assume that the representative firm derives its labour demand by minimising a loss function of changes in employment and deviation of employment from the optimal employment. The Cobb-Douglas production function:

$$Y = T \cdot K^\beta \cdot L^{1-\beta}$$

is inverted and this is defined as the optimal labour input:

$$l_t^* = \left( \frac{Y_t}{TK_t^\beta} \right)^{\frac{1}{1-\beta}}$$

The loss function for firm  $i$  governing the adjustment of the labour input is:

$$\frac{1}{2} E_t \sum_{j=0}^{\infty} \rho^j \left[ (l_{i,t+j} - l_{i,t+j-1})^2 + b (l_{i,t+j} - l_{t+j}^*)^2 \right]$$

Taking the first order condition, and inserting the optimal labour input yields the labour demand equation:

$$l_t = \frac{1}{1+b+\rho} l_{t-1} + \frac{\rho}{1+b+\rho} E_t l_{t+1} + \frac{b}{1+b+\rho} \left( \frac{Y_t}{T \cdot K_t^\beta} \right)^{\frac{1}{1-\beta}}$$

This is applied directly at the aggregate level in EDGE.

## Inventory demand

The modelling of inventory demand is based on the idea that firms can deviate from the normal level of production derived by the production function, but only at a cost. Define production as a sum of the change in inventories and the sales  $Q_t = SALE_t + \Delta K I_t$  while the normal level of production with the existing inputs is given by the Cobb-Douglas production function:  $Q_t^* = T \cdot K_t^\beta L_t^{1-\beta}$  and the target inventory is assumed to be fixed relative output  $K I_t^* = k \cdot Q_t^*$ .

Assume that a firm minimises a quadratic loss function with respect to the level of inventories. This loss function for firm  $i$  is combination of deviations of level of inventories from the target level of inventories and deviations of the production from the normal level of production:

$$\frac{1}{2} E_t \sum_{j=0}^{\infty} \rho^j \left[ \varpi (K I_{i,t+j} - K I_{t+j}^*)^2 + (Q_{i,t+j} - Q_{t+j}^*)^2 \right]$$

where  $\rho$  is the discount factor and  $\varpi$  is the adjustment parameter.

The aggregated first order condition gives the inventory demand:

$$K I_t = k Q_t^* - \frac{1}{\varpi} (Q_t - Q_t^*) + \frac{\rho}{\varpi} E_t (Q_{t+1} - Q_{t+1}^*)$$

### 2.1.3 Prices and wages

#### Price formation

Perfect competition, which is assumed to prevail, ensures that prices equal marginal costs in the long-run:  $p_t^* = \frac{WN_t \cdot L_t}{(1 - \tau_t^{indirect})(1 - \beta)Y_t}$  where  $\tau_t^{indirect}$  is the indirect tax rate,  $WN_t$  is the nominal wage per employee. In the short-run we assume that firm  $i$  ( $i=1, \dots, m$ ) smooths its price by minimizing a Rothembergian quadratic loss function:

$$\frac{1}{2} E_t \sum_{j=0}^{\infty} \rho^j \left[ (p_{i,t+j} - p_{i,t+j-1})^2 + a (p_{i,t+j} - p_{t+j}^*)^2 \right]$$

where  $\rho$  is the discount factor and  $a$  is the adjustment parameter. This implies that facing "menu" costs, firms balance the costs of adjusting prices with the costs of being out of equilibrium. Solving for the first order condition, aggregating and inserting the optimal long-run price yields the price equation:

$$P_t = \frac{1}{1 + a + \rho} P_{t-1} + \frac{\rho}{1 + a + \rho} E_t P_{t+1} + \frac{a}{1 + a + \rho} \frac{WN_t \cdot L_t}{(1 - \tau_t^{indirect})(1 - \beta)Y_t}$$

This is directly used in EDGE to model the value added deflator.

#### Wage formation

Wages are modeled as a Calvo-contract, see Calvo (1983). Assume that firms make new wage contracts infrequently and that the arrival of these new contracts can be characterized as a Poisson-process. Thus, new wage contracts are made at each period with the constant probability  $q$ . Since new wage contracts occur randomly also the interval between new contracts is a random variable. Firm  $i$  minimises a quadratic loss function where the loss arises whenever a new wage contract by firm  $i$  at time  $t$ ,  $wn_{i,t}$  deviates from an optimal wage  $wn_t^*$  subject to a Poisson-process of making new wage contracts.  $\rho$  is the discount factor. Assume further that  $1-q$  is the probability that firm does not make new wage contract at time  $t+1$  and that the existing contracts made at time  $t$  prevail. The loss function is hence:

$$\frac{1}{2} \sum_{j=0}^{\infty} (1 - q)^j \rho^j E_t (wn_{i,t+j} - wn_{t+j}^*)^2$$

Aggregating the first order condition yields:

$$wn_t = (1 - (1 - q)\rho) wn_t^* + (1 - q)\rho E_t wn_{t+1}$$

Next, we assume that the optimal wage contract in real terms is negotiated so that it is equivalent to marginal product of labour and the current state of

business which is approximated by the unemployment gap. In nominal terms this amounts to:

$$wn_t^* = p_t \frac{(1 - \beta)Y_t}{N_t} \cdot (1 - \eta \cdot (U_t - \bar{U}_t))$$

where  $\bar{U}_t$  is the NAIRU unemployment,  $U_t$  is unemployment and  $\frac{(1 - \beta)Y_t}{N_t}$  is the marginal product of labour.

When there exist a large number of firms, a fraction of  $q$  negotiate new wage contracts at time  $t$  while the rest stick with the old contracts. Thus, the observed nominal wages per employee  $WN_t$  at time  $t$  can be expressed as:

$$WN_t = q \cdot wn_t + (1 - q) \cdot WN_{t-1}$$

Inserting the first order condition and the optimal wage contract enables us to write the wage equation as:

$$\begin{aligned} WN_t = & \frac{1 - q}{1 + (1 - q)(1 - q)\rho} WN_{t-1} + \frac{(1 - q)\rho}{1 + (1 - q)(1 - q)\rho} E_t WN_{t+1} \\ & + \frac{q(1 - (1 - q)\rho)}{1 + (1 - q)(1 - q)\rho} \left[ p_t \frac{(1 - \beta)Y_t}{N_t} \cdot (1 - \eta \cdot (U_t - \bar{U}_t)) \right] \end{aligned}$$

#### 2.1.4 Rest of the dynamic model

Unlike the derivation of equations in the previous subsections we merely list the trade equations here. This part of the model is not derived directly from the optimising behaviour of economic agents and is thus one of the weak parts of the EDGE -model. Furthermore, we employ no dynamic aspects in these equations. As an additional difficulty in interpreting these equations we found that the exports in the euro area are not extracted from the total exports in the available euro area data. Thus, the total exports include both the exports in the euro area and exports outside the euro area. This is problematic and we proceeded to include domestic demand in our export equation to capture the exports in the euro area. Similar solution to the same problem is presented in Fagan et al (2001). Likewise, the export price equation includes a domestic price deflator to capture the pricing of exports in the euro area.

Exports  $X_t$  are assumed to depend both on foreign  $Y_t^*$  and domestic demand  $DD_t$  and on relative prices  $\frac{PX_t}{P_t^* \cdot e_t}$ , where  $PX_t$  is export prices,  $P_t^*$  is foreign prices and  $e_t$  is the exchange rate and  $f_{X_t}$  is the functional form of exports:

$$X_t = f_{X_t} \left( Y_t^*, DD_t, \left( \frac{PX_t}{P_t^* \cdot e_t} \right) \right)$$

The dependence on domestic demand is because the export data includes also the exports in the euro area. Imports  $M_t$  are assumed to depend on domestic demand and relative prices  $\frac{PM_t}{P_t}$ , where  $PM_t$  is import prices and  $P_t$  is the output deflator and  $f_{M_t}$  is the functional form of imports:

$$M_t = f_{M_t} \left( DD_t, \left( \frac{PM_t}{P_t} \right) \right)$$

Since the exports include the exports to the euro area also the export prices are assumed to be defined by both domestic and foreign prices and  $f_{PX_t}$  is the functional form of export prices:

$$PX_t = f_{PX_t}(P_t, P_t^* \cdot e_t)$$

Import prices are assumed to depend on export prices, foreign prices and foreign commodity prices and  $f_{PM_t}$  is the functional form of import prices:

$$PM_t = f_{PM_t}(PX_t, P_t^* \cdot e_t, PC_t^* \cdot e_t)$$

Consumer price deflator  $PC_t$  and investment deflator depend on domestic prices and import prices while the weight on import prices is higher with the investment good deflator and  $f_{PC_t}$  is the functional form of consumer prices:

$$PC_t = f_{PC_t}(P_t, PM_t)$$

The above equations form the core of the dynamic model. In addition, there are some identities and policy variables. One interesting equation is the uncovered interest rate parity which defines the exchange rate:

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

where  $R_t^*$  is the foreign nominal interest rate and  $R_t$  is the domestic nominal interest rate. Of course, the model user may apply exogenous foreign exchange risk premia when seen necessary.

Policy rules are needed in the model to ensure the existence of a unique long-run equilibrium. Monetary policy is endogenized by the Taylor rule. On the fiscal policy side, the long run budget balance is implemented by a closure rule which endogenizes the income tax rate.

Public sector disclosure rule for the direct tax rate is as follows:

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

where  $\Delta \tau_t^{direct}$  is the change in the direct tax rate. This assumes that taxes are adjusted to deviations of debt/ nominal GDP -ratio ( $GDN_t/YEN_t$ ) from

the steady-state level  $\psi$  and similarly deviations of the ratio of public net lending to nominal GDP ( $GLN_t/YEN_t$ ) from the steady-state level of debt to nominal GDP -ratio  $\psi$  multiplied by the nominal growth rate of the economy ( $\pi_{t-1} + g$ ), where  $\pi_{t-1}$  is the inflation rate and  $g$  is the real growth rate in the steady-state and  $f_{\tau_t^{direct}}$  is the functional form of tax rule.

The Taylor rule, see Taylor (1993), applied here assumes that the nominal interest rate  $R_t$  is adjusted for the deviations of actual inflation  $\pi_t$  from the target inflation  $\bar{\pi}_t$  as well as for the output gap measured as unemployment gap  $(1 - \beta) \cdot (U_t - \bar{U}_t)$ , where  $U_t$  is the actual unemployment rate  $\bar{U}_t$  is the NAIRU and  $(1 - \beta)$  is the labour share of income and  $f_{R_t}$  is the functional form of interest rate rule:

$$R_t = f_{R_t}(\pi_t - \bar{\pi}_t, (1 - \beta) \cdot (U_t - \bar{U}_t))$$

The complete listing of the equations of the dynamic model is presented in Appendix 1.

## 2.2 The steady-state model

The above dynamic model has also a companion steady-state model which enables us to solve the model forward. That is the steady-state model explicitly defines the long-run equilibrium of the dynamic model.

In general the equations of the dynamic model are transformed to steady-state equation by defining for real variables:

$$x_{t+1} = (1 + g)x_t$$

where  $g$  is the real (equilibrium) growth rate of the economy.

The real growth rate of the economy is derived from the Cobb-Douglas production function<sup>4</sup>

$$Y = T \cdot K^\beta \cdot L^{1-\beta}$$

Taking the total differential of the Cobb-Douglas production function yields:

$$dY = \underbrace{\frac{\partial Y}{\partial K}}_{\frac{\beta \cdot Y}{K}} \cdot dK + \underbrace{\frac{\partial Y}{\partial L}}_{\frac{(1 - \beta) \cdot Y}{L}} \cdot dL + \underbrace{\frac{\partial Y}{\partial T}}_{\frac{Y}{T}} \cdot dT$$

thus

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<sup>4</sup>We choose to use Cobb-Douglas production function for its analytical comprehensibility. Nevertheless, it is possible to extend this analyse by allowing for a CES production function which can incorporate explanations for the new economy. For a recent treatment of CES function see Dimitz (2000) and Ripatti and Vilmunen (2000).

$$\underbrace{\frac{dY}{Y}}_g = \beta \cdot \underbrace{\frac{dK}{K}}_g + (1 - \beta) \cdot \underbrace{\frac{dL}{L}}_{=0} + \frac{dT}{T}$$

and

$$g = \frac{1}{1 - \beta} \cdot \Delta \log T$$

Government debt and net foreign assets are proportional to output in the long-run. Thus taking a derivative of the government debt to GDP ratio yields:

$$d\left(\frac{GDN}{YEN}\right) = \frac{dGDN \cdot YEN - dYEN \cdot GDN}{YEN^2} = 0$$

where YEN is the nominal GDP. This equals to

$$\frac{-GLN}{YEN} - \underbrace{\frac{dYEN}{YEN}}_{g+\bar{\pi}} \cdot \frac{GDN}{YEN} = 0$$

or equivalently to:

$$GDN = \frac{-GLN}{g + \bar{\pi}}$$

where  $g + \bar{\pi}$  is the nominal growth rate. The net foreign assets equation is derived in the analogous manner. In the steady-state solution we set the ratio of Government debt to nominal GDP while the ratio of net foreign assets to nominal GDP is solved endogenously by the model. The complete listing of the equations of the steady-state model is presented in Appendix 2.

### 3 Calibration

Calibration is used instead of estimation as the euro area is new. Its behaviour can only be inferred from its past rather than readily directly estimated from its previous joint behaviour of its component parts. Furthermore, compatible euro area data are only a recent construction and their quality may not be especially good at the moment. Moreover, other countries will join the euro area in the near future which will mean additional adjustments to data.

The EDGE -model version reported here is calibrated to available euro area data with base year 1990, see Fagan et al (2001).<sup>5</sup> In calibrating the

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<sup>5</sup>Subsequently, an updated version of the model has been developed, calibrated to publicly available data with 1995 as the base year.

model the most emphasis is put on to have reasonable simulation properties. As secondary objectives, the model is calibrated to reflect aspects of the euro area data and also so that it could be used for forecasting exercises.

In calibrating the model we apply the earlier experience gained from previous work in the field. In addition, we look other countries, USA being a natural candidate for a comparison, which might be relevant to our case. The calibration followed roughly the following procedure. First, the steady-state model is calibrated to approximately reflect the euro area data in the 1990's. Emphasis is put on calibrating the steady-state so that the dynamic model will start close to its actual values of the data in post-data simulations. This would be a nice property if the model is used for forecasting purposes. Second, the dynamic model is calibrated to match up with the steady-state model. Finally, some adjustments are made in calibration to ensure that the results of diagnostic simulations are reasonable.

In below, we explain some choices made in calibration.

### 3.1 Parameter choices

*The capital share of income  $\beta$*  is calibrated to equal 0.41 which is the average of the data.

*The rate of depreciation  $\delta$*  is 1% per quarter.

*The equity premium  $\chi$*  is calibrated to be close to the US equity premium. With the US data for years 1800-1990 Siegel (1992), finds that the geometric real US short return is 2.95 and the geometric real US stock return is 6.2 which would correspond to roughly 3% annual equity premium. In the EDGE -model the equity premium  $\chi$  is calibrated to be 0.85% per quarter which is roughly 3.5% per annum.

*The real growth rate  $g$*  is calibrated to be 0.55% per quarter while the historical average is 0.8% per quarter in 1980-1997. This is done to calibrate the steady-state values of consumption and investment closer to data at the end of data.

The coefficient of the fundament in *the consumption equation*  $\left(\frac{p\Lambda}{1 - (1 - p)\Lambda}\right)$  is calibrated to be 0.015 per quarter and the coefficient of the lead variable  $\left(\frac{1 - p}{1 - (1 - p)\Lambda}\right)$  is calibrated to be 0.6. These values give a steady-state consumption which is somewhat lower than the data at the end of the data. However, when simulating the model forward the start with respect to consumption is very close to data, which is a nice property if the model is used for forecasting purposes.

For *the labour demand, wages and GDP deflator equations* the coefficients of the fundamentals, i.e.  $\frac{b}{1 + b + \rho}$ ,  $\frac{q(1 - (1 - q)\rho)}{1 + (1 - q)(1 - q)\rho}$  and  $\frac{a}{1 + a + \rho}$ , are calibrated so that the adjustment speed (to a change in the fundamental) of labour demand is fastest and the adjustment speed of prices is faster than wages. Furthermore, the coefficient of unemployment gap  $\eta$  is calibrated to be 3 in the Phillips curve.

The net present value of capital income from firms to households is reduced by taking a part of this income to the government. This is seen as a reward to public investment which is not separated in total investments. Thus, we calibrate  $\nu$  equal to 0.33. *The Government other income to nominal GDP ratio* is fixed to the average of the data.

*The long-run change in inventories* is approximated as a fixed ratio to GDP, i.e.  $k$  is calibrated to 1.05.

*Foreign trade equations* are calibrated to the available data so that the nominal exchange rate is fairly close to data in the end period of the actual data. We notice that these parameter choices also fulfill the Marshall-Lerner-condition.

For *consumer price deflator* and *investment price deflator* the parameters are obtained by a Nonlinear Least Squares estimation.

*The Government transfers to nominal GDP ratio* is estimated by the Ordinary Least Squares estimation

*Ratios of Government debt to nominal GDP*  $\psi$ , *Government real consumption to real GDP*  $\gamma$  and *Government real investment to real GDP*  $\xi$  are fixed to the levels that prevail at the end of the data (1997).

*The NAIRU* is a Hodrick-Prescott filtered unemployment series (with smoothing parameter 1600) and the final observation in the data is fixed to prevail in post data periods.

*The reaction function* of the monetary authority is assumed to be a Taylor rule, see Taylor (1993) ie we fix the nominal interest rate to be equal to the foreign real interest rate, the domestic inflation rate and the deviation of inflation from the inflation target with the weight of  $\frac{1}{2}$  and the deviation of the unemployment gap multiplied by the labour share of income with the weight of  $\frac{1}{2}$ . We have not smoothed the interest rate response ie the parameter  $\Omega$  equals one.

## 3.2 Solving the model

Before going to any simulation results we discuss briefly how we solve the model. The EDGE-model is coded and solved in the Troll-simulation software. We employ the new stacktime (Laffarque-Boucekkine-Juillard) algorithm to solve the model forward. In a typical simulation we run first the steady-state model for over 800 periods i.e. 1998q1/2200q4. This steady-state run defines the endpoints for the dynamic model. After having solved the terminal points we run the dynamic model forward for 800 periods i.e. from 1998q1 to 2197q4.

In solving the dynamic model forward we exploit a terminal dummy which we place in the last period to be solved i.e. 2197q4. In this last period we modify our model by implementing a terminal dummy to those forward looking equations which describe nominal variables (i.e. nominal wage, nominal assets, GDP deflator and nominal exchange rate equations). The steady-state solution to these variables is corrected by the difference of the previous periods dynamic price level multiplied by the inflation target and the steady-state price level. As a result our nominal variables do not necessarily and in most cases never converge to the steady-state while the real variables do converge.



When solving the model we find no problems of convergence. If we look the model adjustment in the long-run we observe that the EDGE -model is dynamically stable. It converges to equilibrium in the long-run. Hence, we feel confident to use model for demanding policy simulations.

## 4 Diagnostic simulations

In analysing the success of calibration of the EDGE -model most emphasis is put on the results of diagnostic simulations. In this section the EDGE -model is analysed through a series of diagnostic simulations. All simulations considered here are illustrating model responses to unanticipated shocks. With this type of model it is also possible to simulate what is anticipated to happen in the future. Some of the shocks analyzed in the diagnostic simulations are of temporary nature while others are permanent. In all simulations presented here both the interest rate and exchange rate have been endogenous, nevertheless, most of the shocks have also been simulated with exogenous interest and exchange rates (not reposted here).

In general, the results show that the EDGE -model adjusts quickly back to the long-run equilibrium after different shocks. The speed of adjustment is especially high with the transitory shocks. With permanent shocks the adjustment takes a little bit longer which is understandable since the long-run equilibrium has also changed. Nominal rigidities are surprisingly weak which suggest that the EDGE -model is more akin to the RBC -models.

### 4.1 A permanent increase in public consumption

The effects of a permanent increase of 1% of GDP in public consumption are shown in Figure 1 and in Table 1. In the very short run this has an expansionary effect on output. This is however very small and short-lived. In the long-run the adjustment of prices and wages works to adjust the economy towards an equilibrium output which is defined by the supply side.

In this simulation the shift of resources from private sector to government sector yields a decrease in average productivity which lowers marginally the output relative to baseline in the long-run. Furthermore, the private consumption is crowded out in the long-run. The nominal interest rate increase about a quarter of a percentage point in the first year and start to converge to baseline thereafter. The expected real interest falls immediately but then turns positive and starts to converge towards the baseline. The nominal exchange rate jumps immediately and appreciates more than 1%. In the long-run the real exchange rate returns to baseline. The increase in output in the short run generates increase in real wages and in inflation rate. However, inflation and unemployment do return to baseline in the long-run.

Government finances the increase in public consumption by issuing new debt which is shown by the immediate fall of Government net lending to nominal GDP-ratio by nearly a percentage point. This increases Government debt

to nominal GDP-ratio but there is no long-run effects. Current account to nominal GDP-ratio falls by a half percentage point permanently. Net foreign assets to nominal GDP-ratio falls sharply to a new steady-state level which is lower since consumption falls permanently.

## 4.2 A temporary depreciation of the exchange rate

The shock to the nominal exchange rate is a depreciation of 10 percentages in the first quarter (Figure 2 and Table 2). Thereafter, the shock is removed. This shock can be interpreted as a temporary loss of confidence in euro dominated assets.

In order to damp the inflationary effects the central bank increases nominal interest immediately by 0.75%-points. Because the initial shock in the exchange rate is only transitory and as the monetary policy is tightened accordingly the inflationary effects are short-lived.

The real depreciation increases export demand by some 4% and decreases imports by some 8% immediately. The effects on investment and consumption are much smaller. The total effect is that the output increases by some two percent. These real effects are only temporary and the output returns to baseline in about one year. A sudden hike in inflation lowers temporarily real wages which leads to the fall in unemployment. These effects are only transitory.

Government debt to nominal GDP -ratio decreases due to inflationary peak but this effect is transitory. As trade balance improves in the first period this is reflected to current account. As can be seen all real variable converge back to baseline in the case of a temporary shock.

## 4.3 A temporary increase in the interest rate

The nominal interest rate is increased by 1%-point above to the baseline level for two years thereafter the Taylor rule determines the nominal interest rate (Figure 3 and Table 3). This shock can be interpreted as a temporary hike in the foreign real interest rate.

An increase in the nominal interest rate immediately appreciates both nominal and real exchange rates. The real exchange rate returns to baseline after the shock is removed. The temporary increase in nominal interest rate dampen both the inflation and real wages by less than a half percentage for next two years. This reduction in inflation rate yields accordingly a higher domestic real interest rate which peaks around 1.5%-point above baseline at the end of the first year.

The rise in real interest rate causes a sharp but temporary fall in production. Consumption falls immediately by 1.7% while the investment demand reacts more sluggishly and falls by a one and half percentage only after one year. Exports fall by over 2% and the output falls equally. The real effects are however only short-lived and after three years the real variables are near to the

baseline. The sudden fall in output increases unemployment by 0.75%-point in the first year despite the lower real wages. Unemployment also returns to baseline after three years time.

The sudden increase in the nominal interest rate increases the borrowing cost of the government and the debt is accumulated correspondingly. These are however temporary and the government balances quickly as the interest rate returns to baseline. The current account deteriorates for two years as the exports fall more than the imports. This feeds in to the net foreign assets which decrease first but then slowly start to converge toward the steady-state.

#### 4.4 A permanent increase in labour force

The total labour force is increased by 1% permanently (Figure 4 and Table 4). This shock can be interpreted as a sudden impulse to the immigration rate.

Nominal interest rate falls by a quarter of %-point. This is because most of the increase in labour force is first shifted in to the unemployment rate. The real interest rate falls also in the first year after the shock but then starts to converge to baseline quite rapidly. Both nominal and real exchange rates depreciate immediately by roughly 0.4%. Depreciation of both real and nominal exchange rates stabilises in the long-run. Inflation rate falls immediately by 0.1%-point and converges then back to baseline. Real wages fall first so that after three years this decrease is 0.3% but thereafter real wages converge to baseline.

Consumption, exports ,imports and all rise immediately by 0.8% and then slowly converge toward 1%. Investments increase first more slowly but after two year it has passed the adjustment speed of other real variables in convergence toward 1%. Unemployment increases in the first period by 0.65%-point which means that 35% of the labour force increase in employed in the first quarter. Convergence towards the full employment of this increase is rapid taking only about 3 years.

Government net lending is slightly increased by increased taxes generated by accelerated economic activity in the first year then reversed and in the long-run this returns to the baseline. Government debt to nominal GDP-ratio decreases mainly because of the hike in output. Current account remains balanced in this shock. The net foreign assets to nominal GDP-ratio decreases by the amount of increase in output in the long-run.

#### 4.5 A temporary increase in direct tax rate

The direct tax rate is increased by 1%-point for next ten years (Figure 5 and Table 5). This can be seen as a part of a temporary fiscal policy shock. Notice, however, that the labour force is exogenous in the model so that the tax shock does not have an effect on labour supply here.

Both nominal and real interest rate increase in the first year somewhat to kill of inflation but remain constant for next ten years but then after ten

years fall again. After this second reaction real interest rate converges toward baseline. Both nominal and real exchange rate decrease by  $\frac{1}{2}\%$  immediately and thereafter decrease an additional  $\frac{1}{2}\%$  in next ten years. However, after ten years the real exchange starts to converge toward the baseline. Inflation rate picks up for the first year but then starts to decline as the interest rate cools of the economy. After ten years the inflation rate has fallen some 0.25%-point relative to baseline. Thereafter the inflation rate converges towards the baseline. Real wages decrease somewhat in the first ten years but after ten years real wages really pick up before falling back to baseline in the long-run.

Depreciating exchange rate increases exports which pick up the output in the short run. Thereafter the falling consumption and investment demand drag the output down to baseline. Investment demand increases in advance to the decrease of direct tax rate in year ten. After ten years investment demand starts to fall and consumption demand starts to increase towards the baseline in the long-run. Unemployment falls marginally for first ten years picks up thereafter and falls back to baseline in the long-run.

Government net lending is increased by increased tax receipts for first ten years and decreased thereafter. This reflects to decreased government debt which starts to increase again after ten years. For the first ten years, current account is slightly positive which is cumulated to net foreign assets.

## 4.6 A permanent increase in world demand

World demand is increased permanently by 1% (Figure 6 and Table 6).

Both real and nominal interest rate fall marginally in the short-run and then return to baseline in the long-run. Both nominal and real exchange rate jump immediately and appreciate by little less than 0.5% and then stabilise at these levels in the long-run. CPI inflation decreases first marginally and then reverts to baseline. Real wage increase marginally.

The effects on real side variables is marginal excepts that imports jump directly by 0.4% and exports by 0.3% above baseline. Unemployment decreases marginally but this effect is almost zero.

The effect on government net lending and on government debt is almost non existent. The effect on current account is marginally negative which cumulates to decrease in net foreign assets.

## 4.7 A permanent increase in indirect tax rate

The indirect tax rate is increased by 1%-point permanently (Figure 7 and Table 7). This has potentially big effects since it changes relative prices.

Nominal and real interest rates increase to match the increase in the inflation rate. Inflation falls in the second year which also allows the nominal interest rate to adjust to a lower level. The real interest falls also below the baseline but after three years the real interest rate starts to converge towards the baseline. Both nominal and real exchange rate jump and depreciate by one

percent in the first period after which the real exchange rate start to converge towards the baseline. The real wage rate falls permanently by 1%.

The increase in the interest rate induced by the inflation development decreases consumption sharply by over 1%-point in the short-run. Also output falls by 0.5% in the short-run. Imports fall sharply by over 2% in the short run. All real variables converge to baseline in the long-run. Unemployment rises in the first year less than 0.2%-point and starts to converge back to baseline thereafter.

The increase in the indirect tax rate raises tax income and thus the government net lending increase in the first five years. This is reflected in government debt which decreases during the first five years and then converges back to old levels. Depreciation of the exchange rate created a small current account surplus relative to baseline and this cumulates to higher net foreign assets.

#### 4.8 A permanent increase in equity premium

Equity premium is increased by 1%-point permanently (Figure 8 and Table 8). This can be seen as a negative wealth shock which is caused by the increase in the corporate risk.

Nominal interest rate increases in the first period to match corresponding increase in CPI inflation. Thereafter the inflation fall rapidly so that at the end of first year inflation has decreased by 1.5%-point relative to baseline. Nominal interest fall also. The expected real interest rate rises in the first period up 1.5%-point over the baseline where after it falls so that after two years it has decreased 1%-point relative to baseline. Thereafter real interest rate starts to converge towards baseline. Exchange rate depreciates immediately by ten per cent and the real exchange rate starts slowly to converge back to baseline. Real wages fall 0.7% immediately and converge to lower steady-state level.

Consumption falls immediately by almost 8% but start then to move back to baseline levels. Investment falls slowly but steadily to lower levels. The sudden depreciation in exchange rate induce more exports and much less imports. All together GDP falls by 2% in a long-run. Despite lower real wages, damped economic activity leads to increase in unemployment rate by about 0.2%-point.

Government net lending increases as interest rates fall and this lowers debt in the short run. However, in the long run the debt rises to new steady-state level. Positive current account and negative consumption demand accumulate net foreign assets which balance to a new steady state.

#### 4.9 A permanent increase in inflation target

The inflation target is increased permanently by 1%-point (Figure 9 and Table 9). This may be interpreted as a monetary policy shock where the inflation target is raised.

This shock increases permanently the nominal interest rate by one percent

in one years time The real interest rate falls first sharply about one percent in the short run but returns then to baseline. The inflation rate increases 1%-point in a couple of years time. Real exchange rate fall first one percent but converges then to baseline. Real wages increase by 0.08% permanently.

Consumption, exports and GDP increase immediately by a half percent but revert then back to baseline. Investment increases little slowly by 0.2% but return also to baseline. Unemployment falls first by less than 0.1%-point and starts then to increase again.

Government net lending decreases sharply as the interest rate burden increases. This accumulates to higher debt levels. Increase in GDP lowers the government debt to nominal GDP ratio in the short run. Current account increases in the first years somewhat and this cumulates net foreign assets somewhat.

## 5 Analysis of monetary policy credibility

In the previous subsection we showed the effect of a 1%-point change with inflation target by a credible central bank ie a change that is believed. In this section we consider two cases in which the inflation target of the central bank differs from that expected by the private sector ie the change is not believed. As baseline we assume that the inflation target starts 1%-point higher than that used in the previous section. We consider what happens when the central bank adopts a new inflation target which is 1%-point lower than with baseline. We look at two different cases. In the first case the central bank and the private sector act simultaneously while in the second the central bank act first.

### 5.1 Case I: Central bank sets interest rates on the basis of actual economic situation

In this first case we assume that the central bank sets the interest rate by the Taylor rule and that the private sector simultaneously optimises in each period. The private sector's belief about the central bank's inflation target differs permanently from the central bank's actual inflation target. The private sector uses a 1%-point higher inflation target when it forms expectations on future monetary policy. This situation is repeated in every period. Thus, the private sector is always surprised by the tightness of the monetary policy in the current period.

Clearly we could run a more complex simulation where the private sector learns and comes to believe the new target. Our aim here, however, is to show what happens when this belief is absent in order to measure the "costs" of lack of credibility. This also shows the costs of peso problems, see Vilmunen (1998) and Mattila (1998).

The simulation results of this case are presented in Figure 10 and in Table 10. The simulation results indicate that real GDP falls by 0.1% and consumption falls by 0.2% relative to baseline. Real wages and inflation fall only

marginally. Unemployment increases but only marginally. Nominal and real interest rate rise by a half percentage point. Nominal and real exchange rate depreciate immediately by 0.15% but thereafter start to appreciate. The real exchange rate converges towards baseline. The Government borrowing to GDP ratio increases by 0.3%-points immediately but converges then to baseline. This increased borrowing increases the Government debt to GDP ratio somewhat but this also converges to baseline. The current account to GDP ratio is permanently slightly higher than in the baseline. The net foreign assets to GDP ratio increases since consumption falls permanently.

## 5.2 Case II: Central bank sets interest rate on the basis of its forecast and assumes that it is credible

We now assume that the central bank sets interest rate by the Taylor rule first and that the private sector optimises next in each period. Thus, the central bank forecasts the economy with the assumption of lower inflation target and fixes the interest rate in the first period accordingly. Because the central bank has set interest rates with expectation that it will be believed it anticipates a partly offsetting fall in output and hence raises interest rates by less than in case I. Private sector's belief of central bank's inflation target is still assumed to differ permanently from the central bank's actual inflation target. Thus, in each period, the private sector optimises with fixed interest rate in the first period but uses a 1%-point higher inflation target when it forms expectations on future monetary policy. In this case central bank always makes forecast errors in the first period. This situation is repeated in every period.

The simulation results of this case are presented in Figure 11 and in Table 11. The simulation results indicate that this type of solution looks similar to previous case. Nevertheless, for most of the variables the effects are about the half of the size compared to the previous case. For the exchange rate however, the effect is now much bigger, the deviation is almost twice that in the previous case.

In both simulations the cost of the lack of credibility is a permanently higher real interest rate and hence an output loss but in the second case the effect is considerably smaller.

## 6 Conclusions

In this paper, we combine some well established economic theories and label this mixture the Euro area Dynamic General Equilibrium (EDGE)-model. The advantage of this strategy is that the model should be easy to understand. We calibrate this model to available euro area data. We find that the model responses to different diagnostic simulations with post data period make sense in economic terms. Therefore, we feel confident that the EDGE-model even in its current form is helpful for monetary policy simulations.

It would be preferable to use stochastic simulations in monetary policy

simulation exercises. However, as a first step of analysis the current simulations are run as deterministic simulations. The lack of credibility is analysed under two different assumptions and in both cases it is assumed that the private sector's perception of the central bank's inflation target is higher than the actual. In the first case, it is assumed that the central bank sets interest rate on the basis of actual economic situation applying the Taylor rule to current data. In the second case, the central bank sets interest rate on the basis of its forecast and assumes that it is credible. In both simulations the cost of the lack of credibility is a permanently higher real interest rate and hence an output loss. However, this loss is smaller in the case where the central bank sets interest rate on the basis of its forecast and assumes that it is credible.



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# Figures 1–11

Figure 1

**A permanent increase of 1% of real GDP in public consumption. Difference from baseline.**

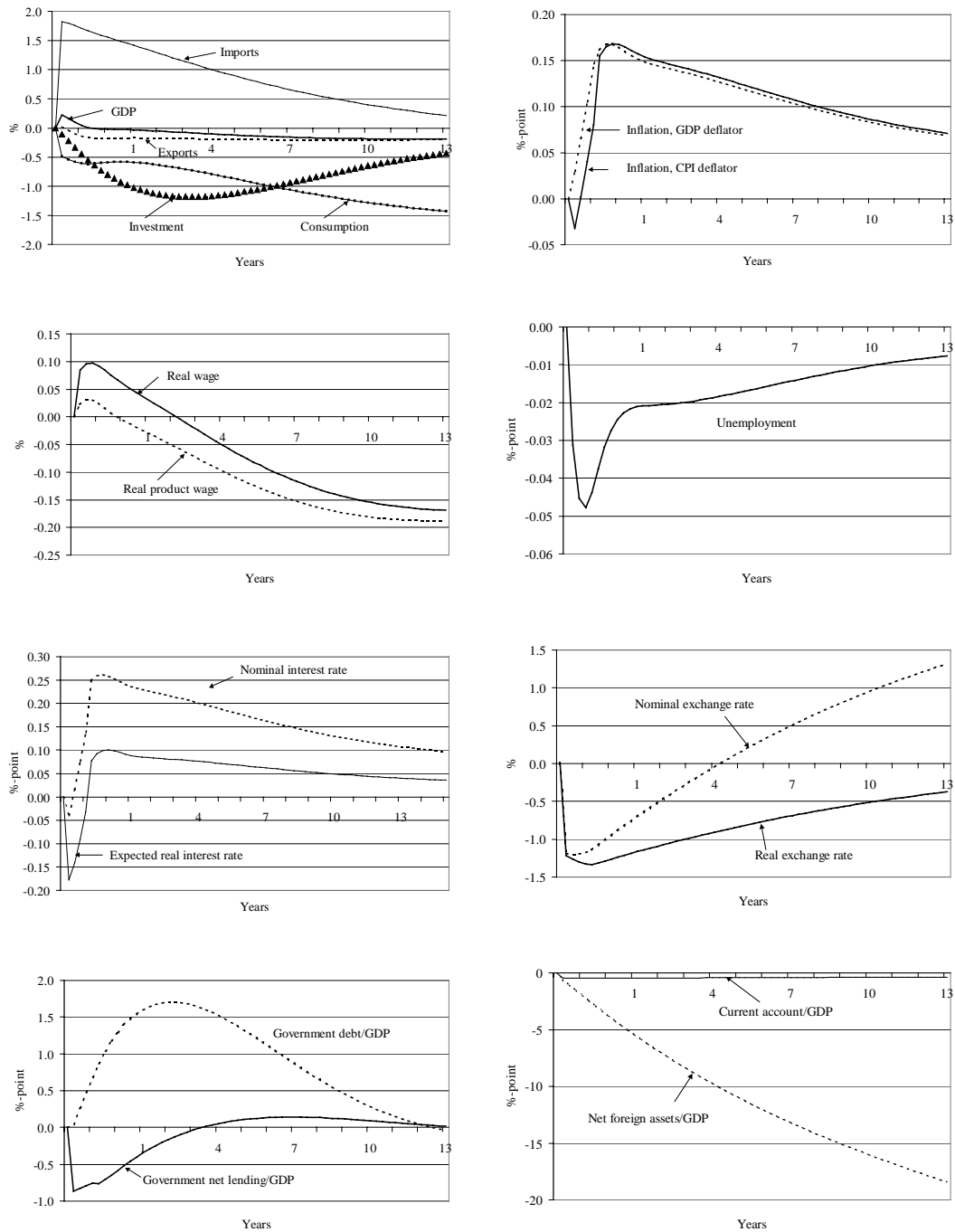


Figure 2

**A temporary (one quarter) depreciation of exchange rate by 10%. Difference from baseline.**

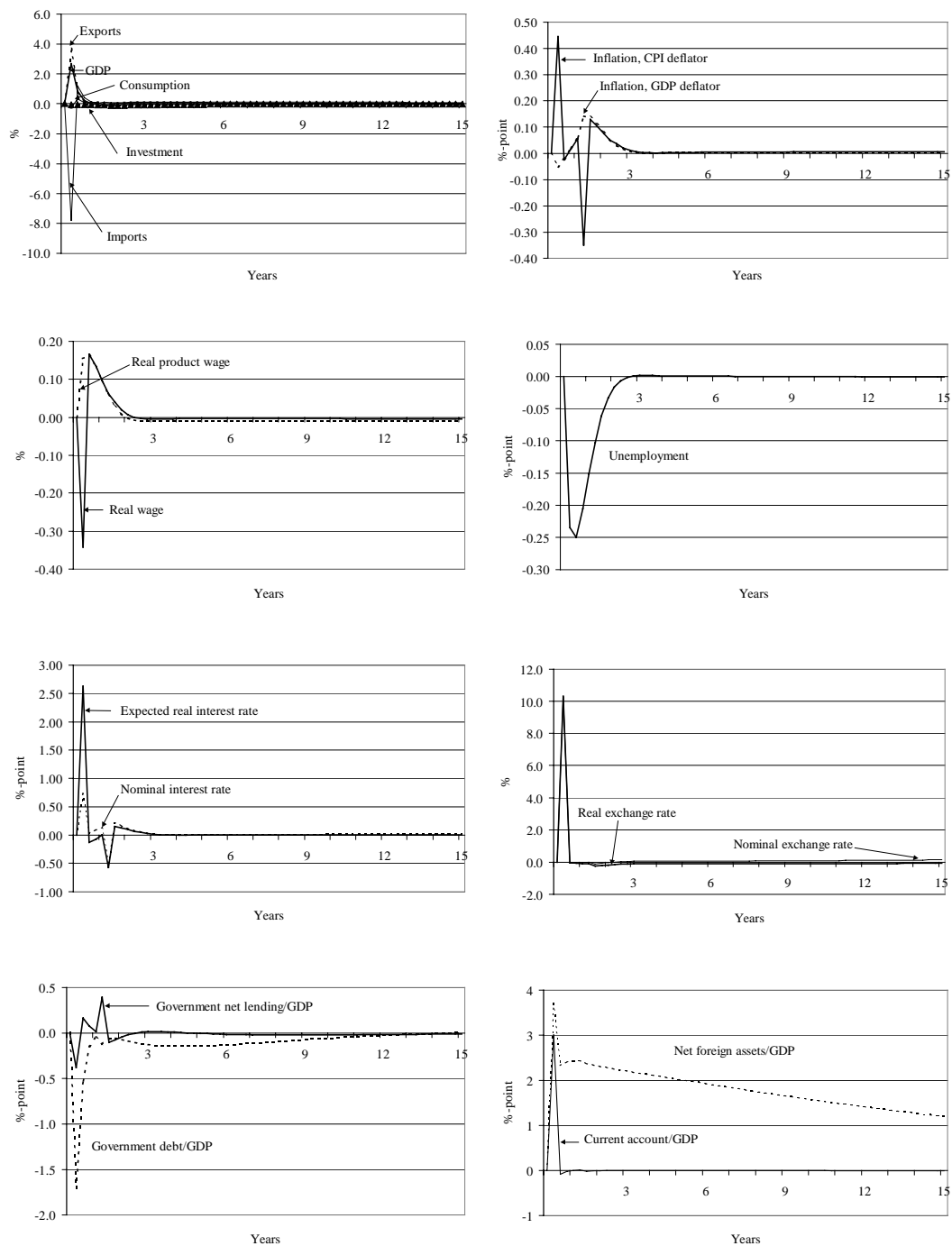


Figure 3

**A temporary (two years) increase in interest rates by 1%-point. Difference from baseline.**

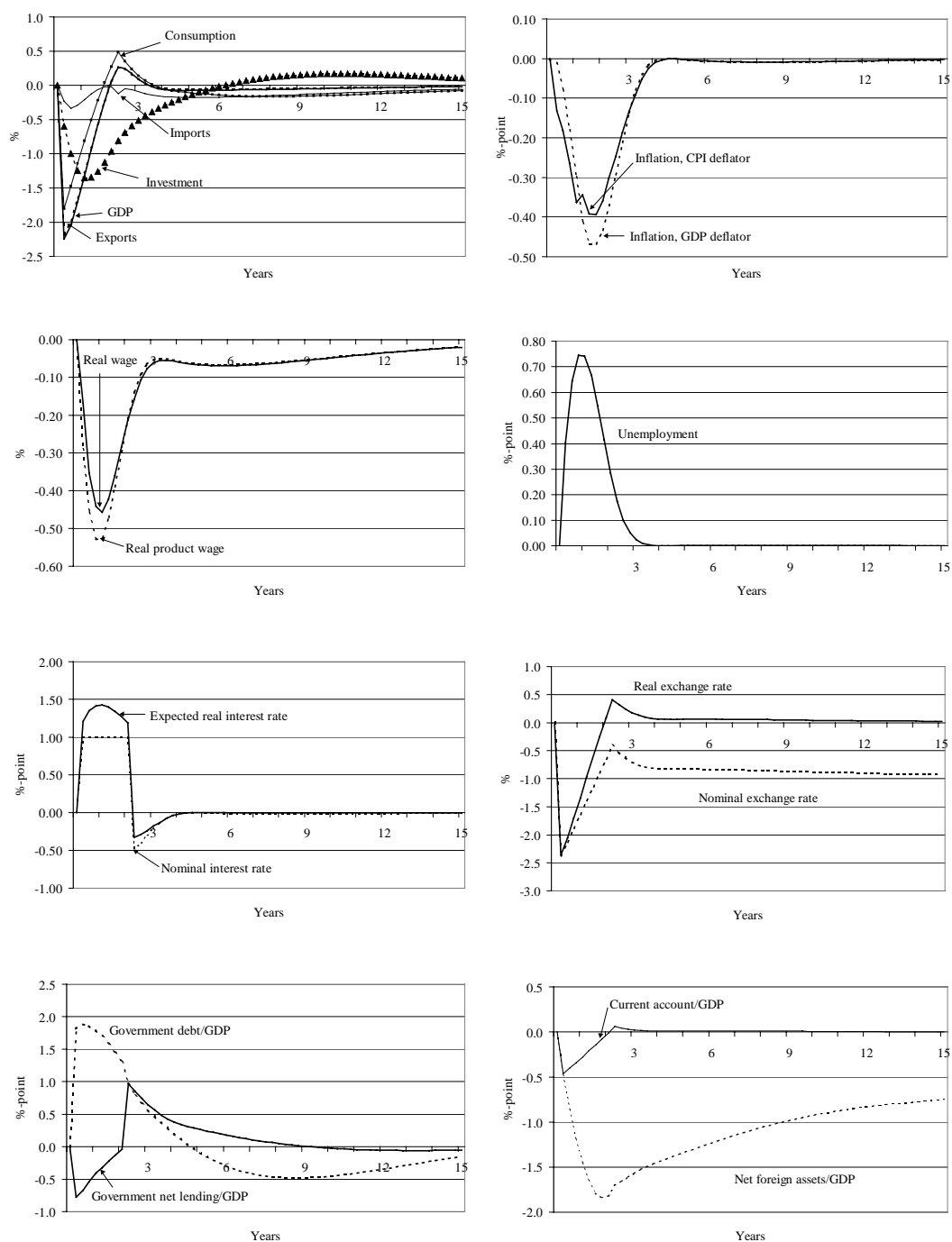


Figure 4

**A permanent increase in total labour force by 1%.  
Difference from baseline.**

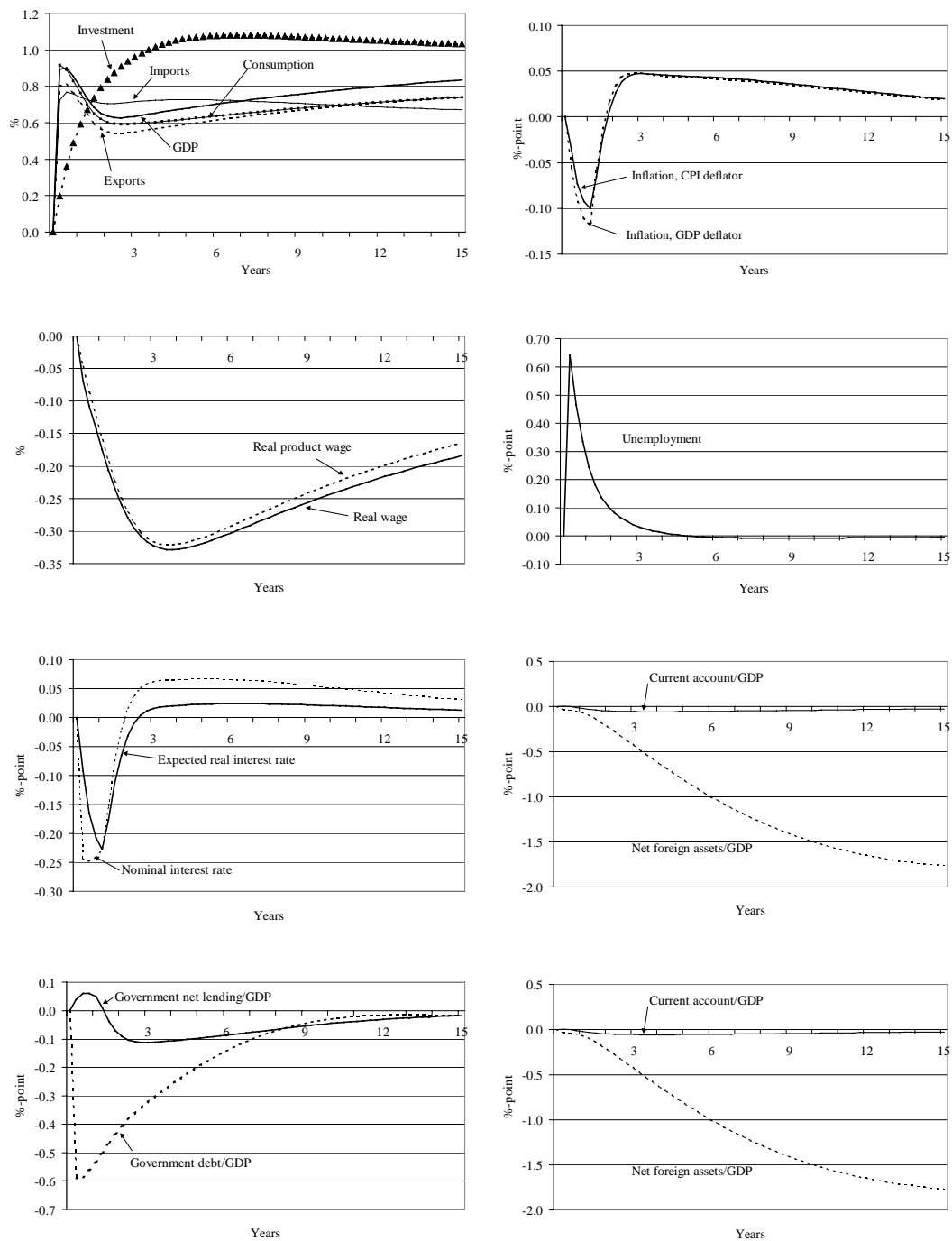


Figure 5

**A temporary (10 years) increase in direct tax rate by 1%-point. Difference from baseline.**

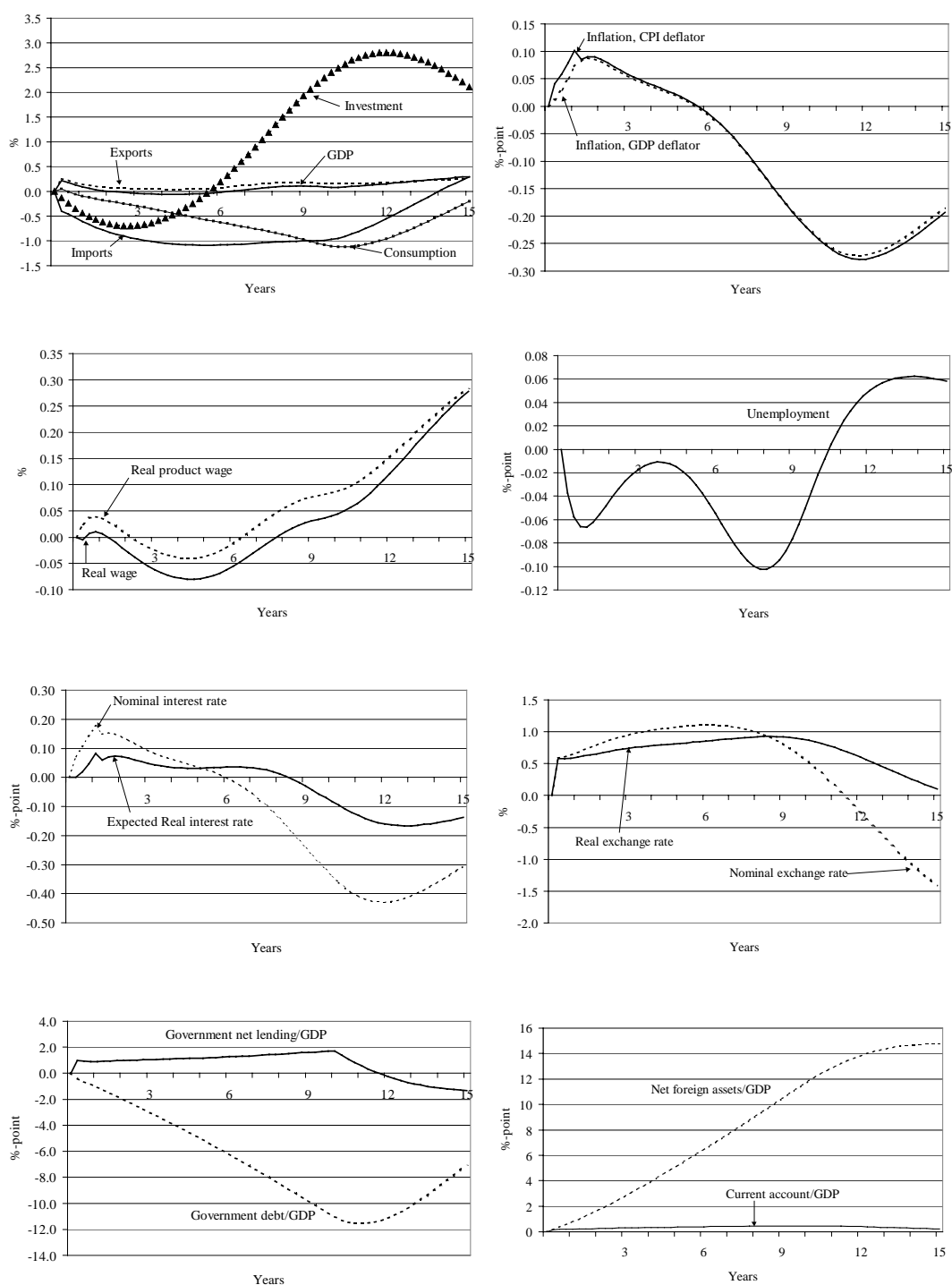


Figure 6

# **A permanent increase of World demand by 1%. Difference from baseline.**

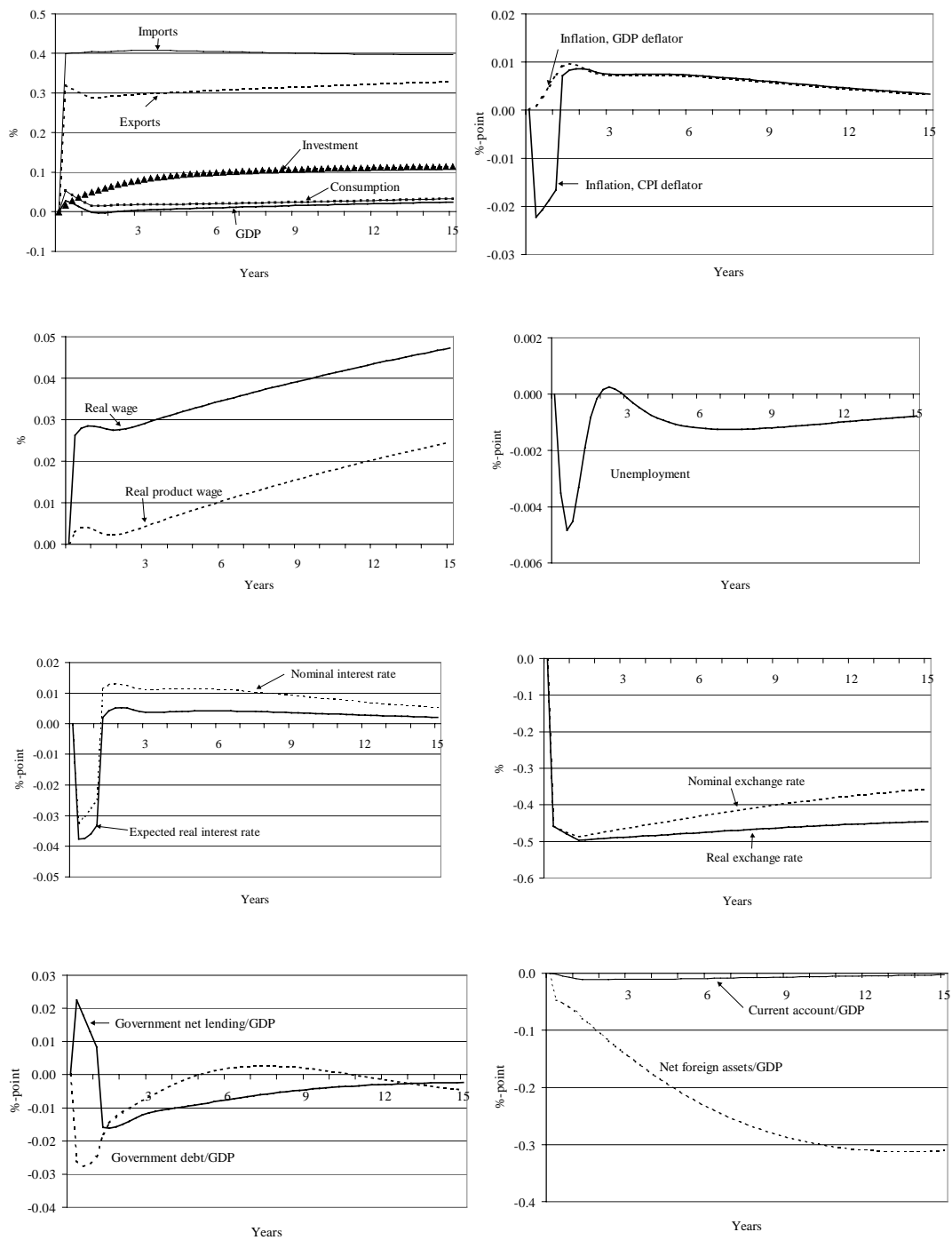


Figure 7

**A permanent increase in indirect tax rate by 1%-point. Difference from baseline.**

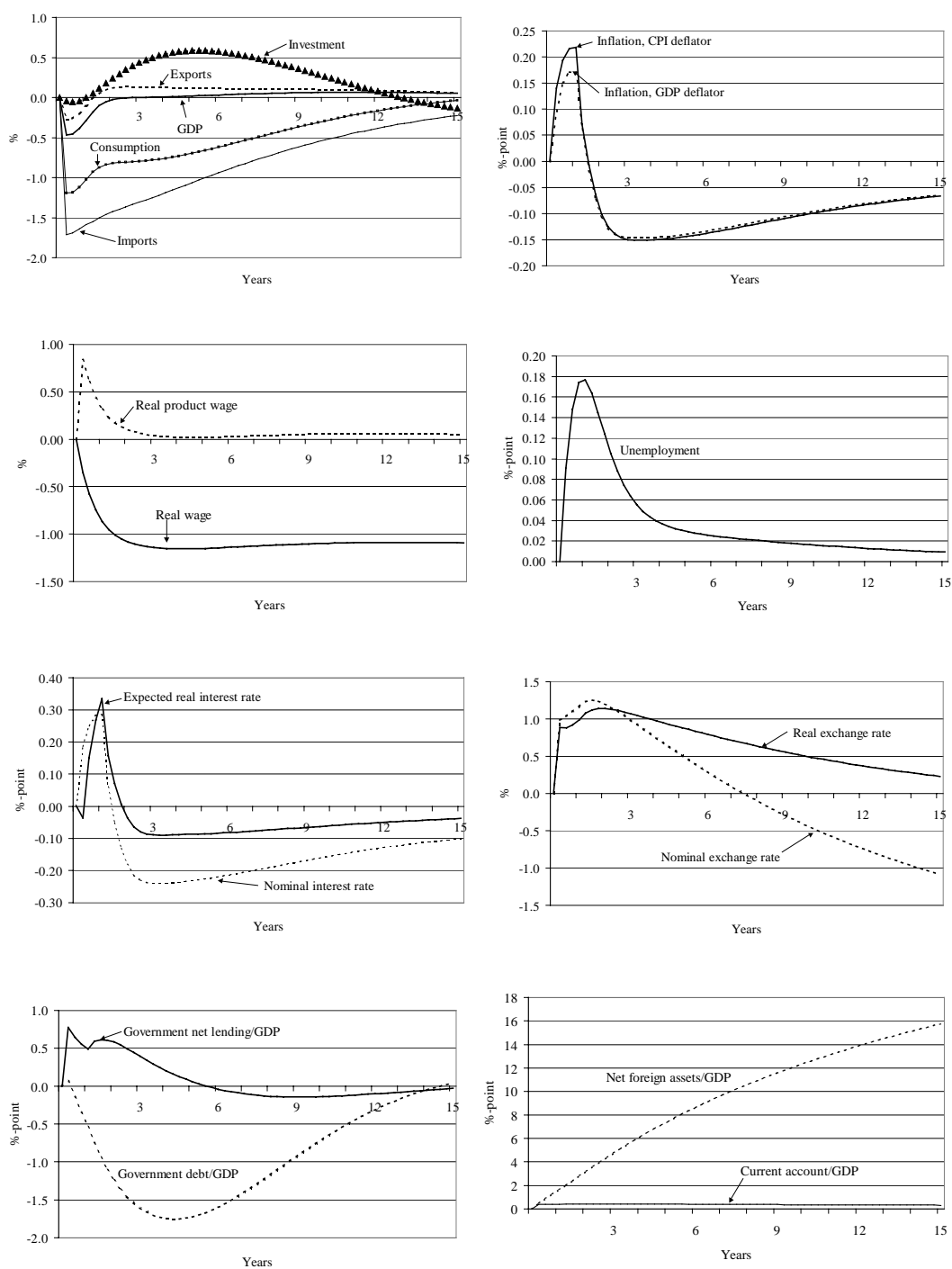




Figure 8

**A permanent increase in equity premium by 1%-point. Difference from baseline.**

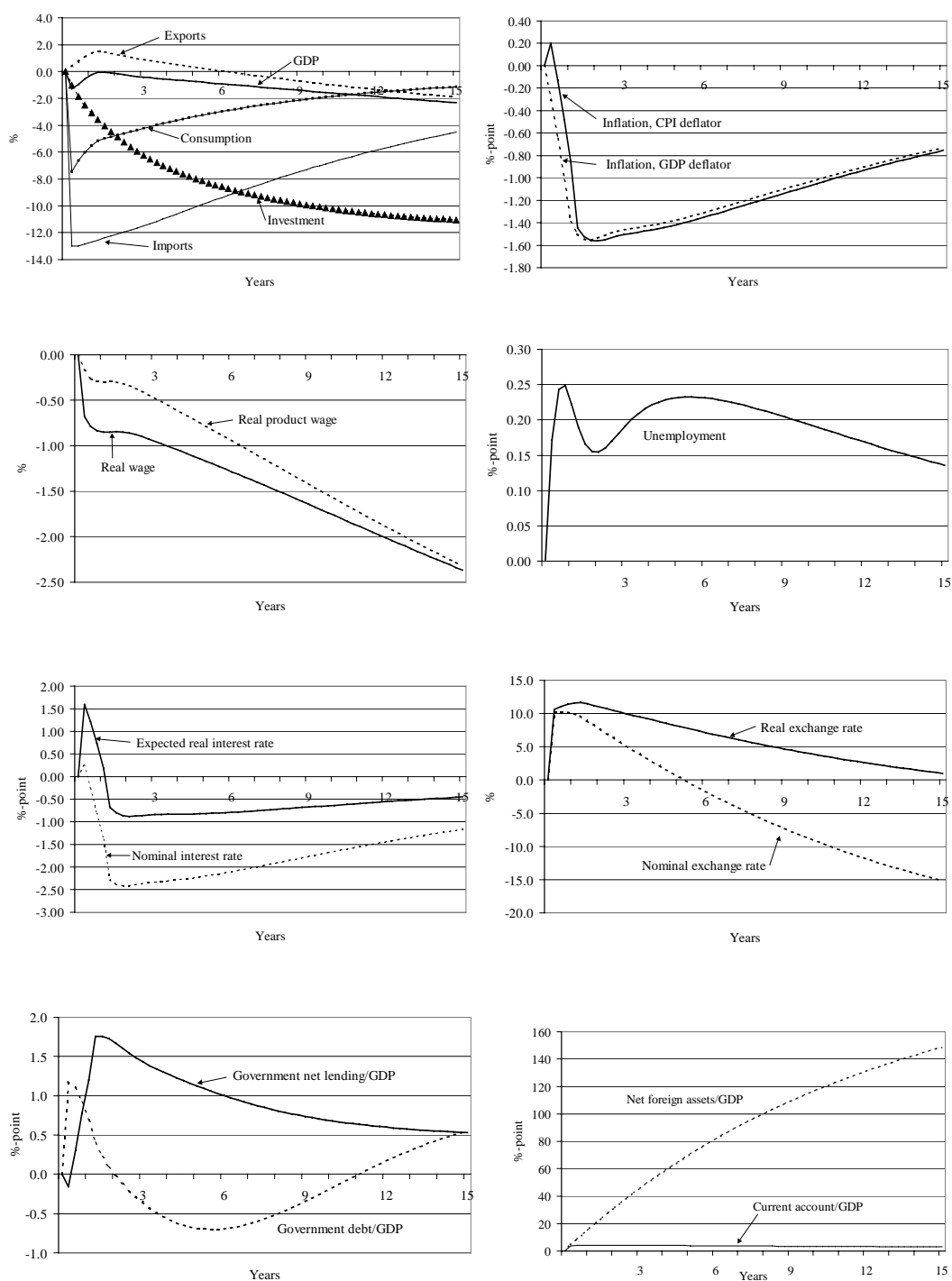


Figure 9

**A permanent increase in the inflation target by 1%-point. Difference from baseline.**

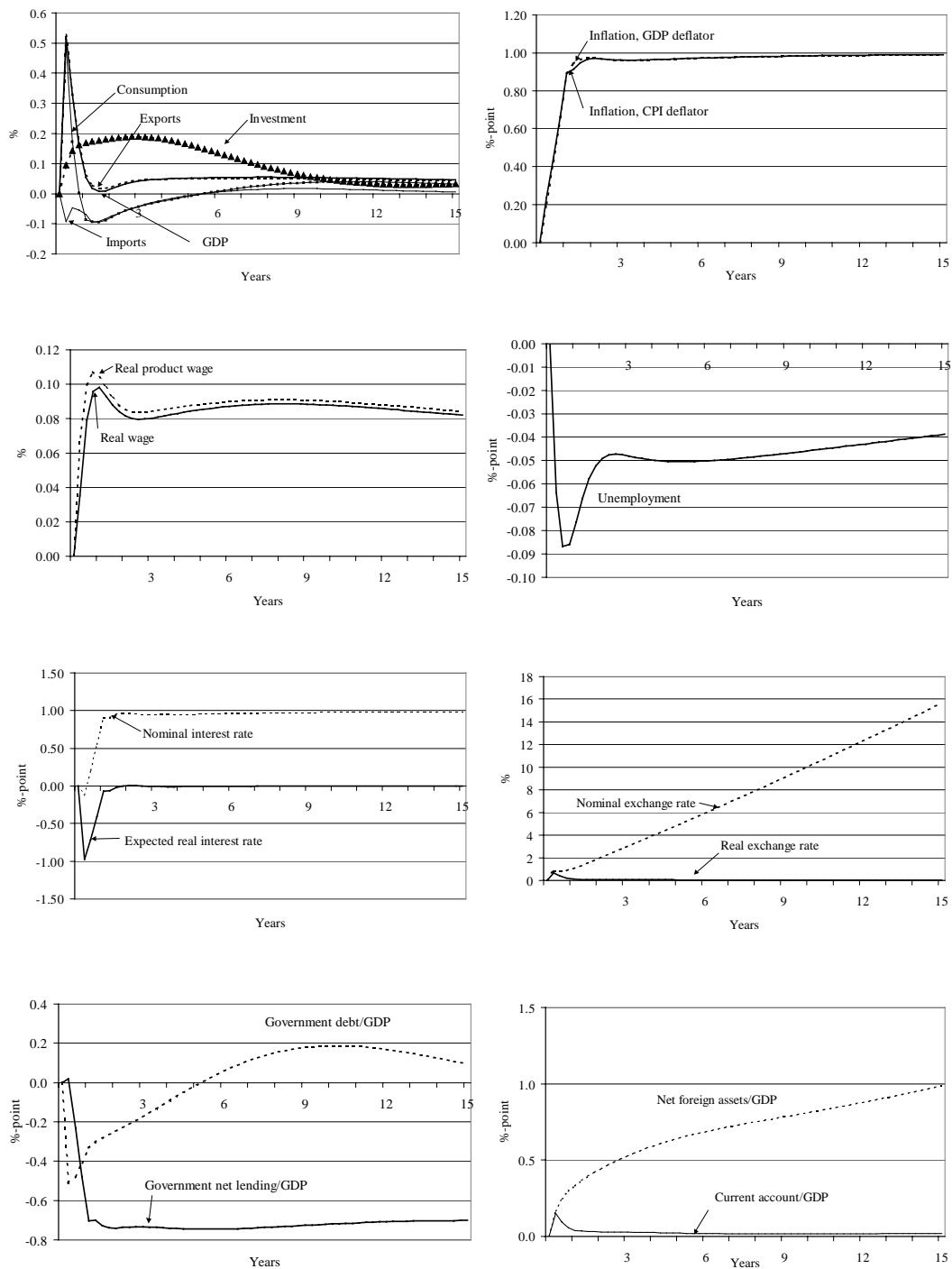


Figure 10

**CB sets interest rate on the basis of actual economic situation. Difference from baseline.**

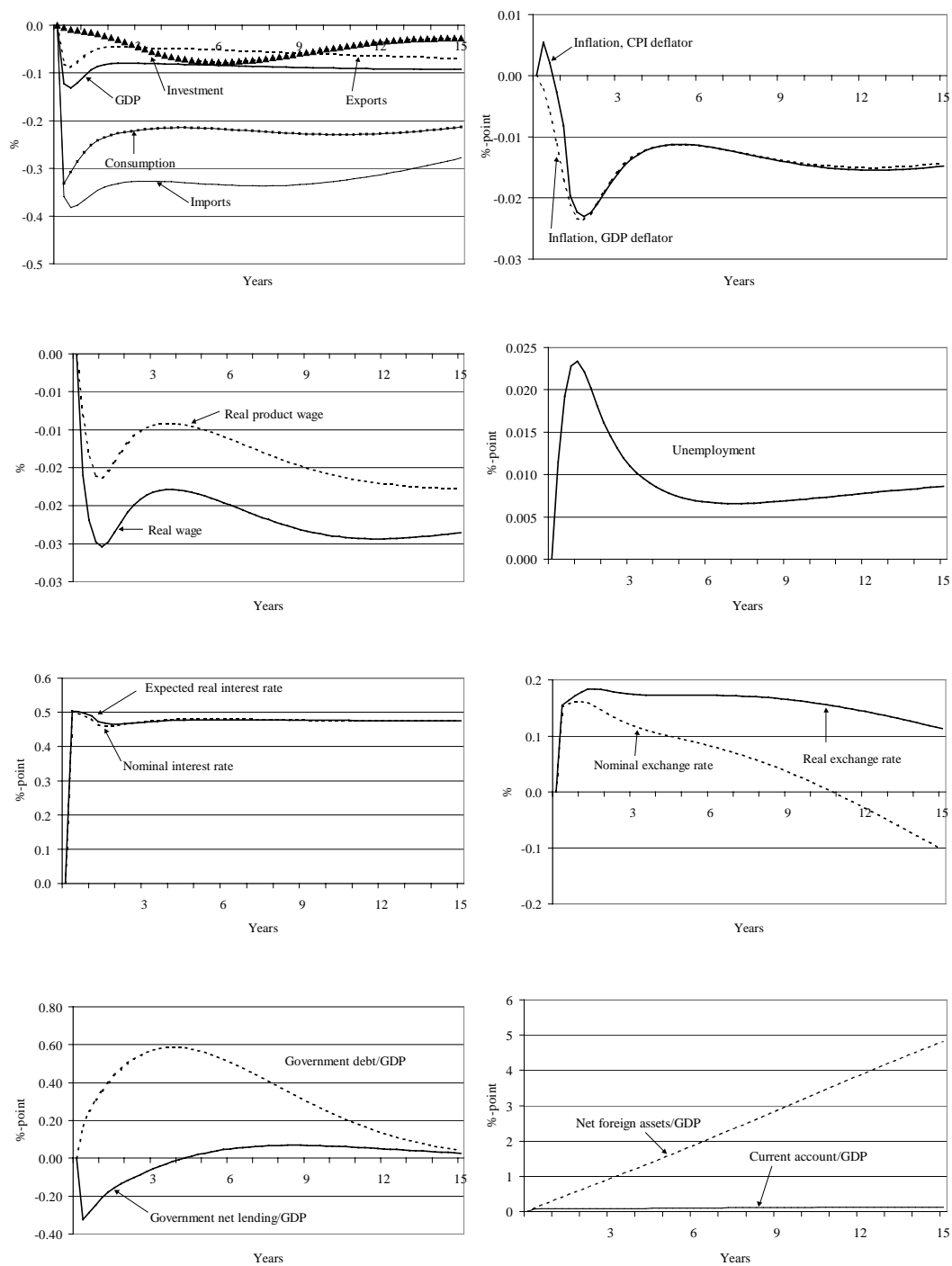
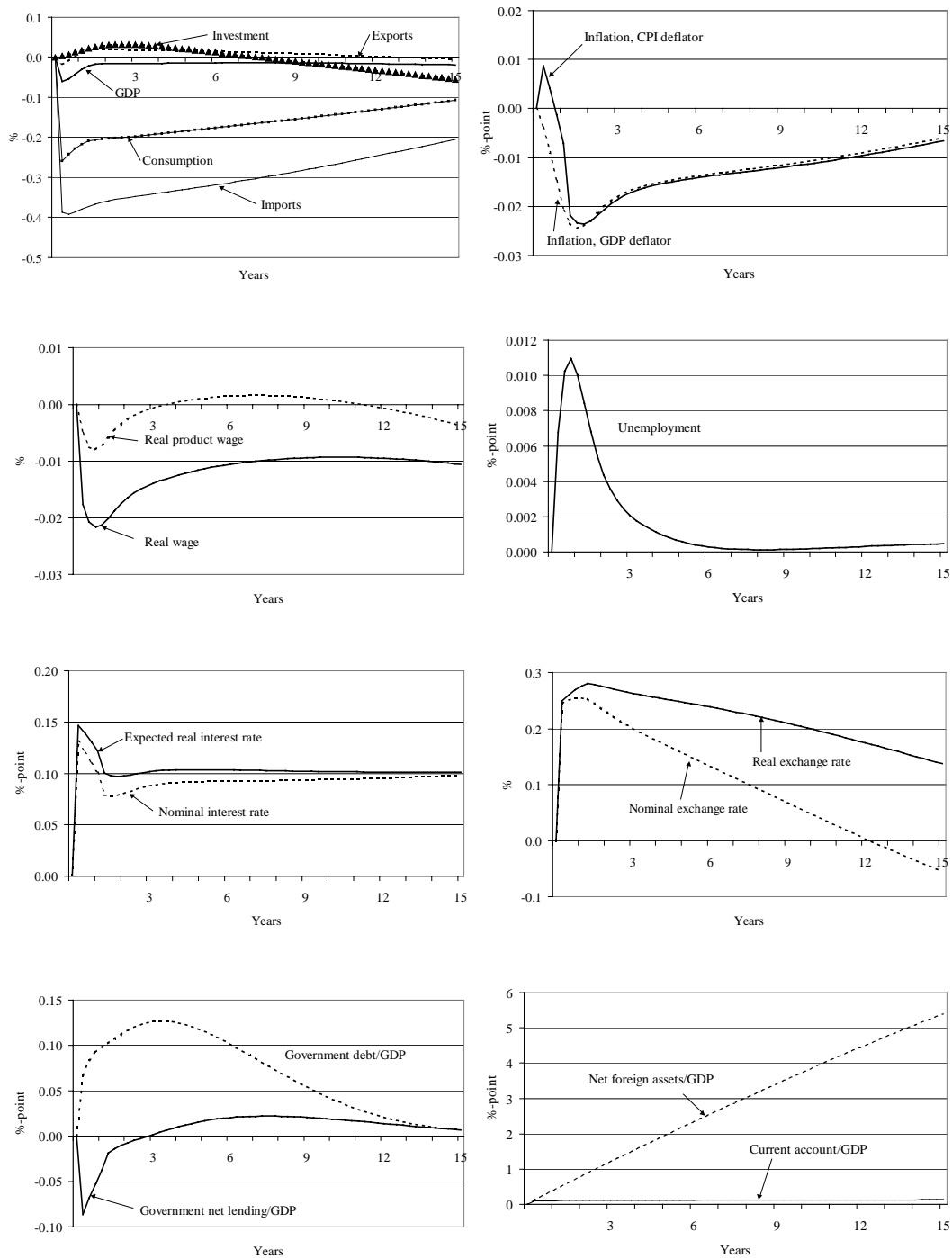


Figure 11

**CB sets interest rate on the basis of its forecast and assuming that it is credible. Difference from baseline.**



# Tables 1–11

Table 1 **Increase in public consumption**

Public consumption is unexpectedly and permanently increased by 1% of GDP.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	0.22	0.16	0.10	0.04	-0.02	-0.03	-0.08	-0.17	-0.07
Imports, %	1.82	1.80	1.76	1.71	1.55	1.42	1.14	0.56	-0.58
Exports, %	0.02	-0.03	-0.09	-0.14	-0.18	-0.17	-0.18	-0.21	-0.06
Private consumption, %	-0.49	-0.54	-0.58	-0.61	-0.59	-0.59	-0.71	-1.14	-1.83
Private fixed investment, %	-0.11	-0.22	-0.34	-0.45	-0.80	-1.02	-1.18	-0.84	-0.09
Inflation, GDP defl., %-points	0.03	0.07	0.11	0.15	0.16	0.15	0.13	0.10	0.01
Inflation, consumpt. defl., %-points	-0.03	0.00	0.04	0.08	0.17	0.15	0.14	0.10	0.01
Real wage, %	0.08	0.10	0.10	0.09	0.06	0.03	-0.02	-0.13	-0.09
Real product wage, %	0.02	0.03	0.03	0.02	-0.01	-0.03	-0.07	-0.16	-0.07
Unemployment, %-points	-0.03	-0.05	-0.05	-0.04	-0.02	-0.02	-0.02	-0.01	0.00
Nominal interest rate, %-points	-0.04	0.02	0.08	0.14	0.26	0.24	0.21	0.15	0.01
Real interest rate, %-points	-0.18	-0.14	-0.09	-0.03	0.10	0.09	0.08	0.06	0.01
Nominal exchange rate, %	-1.19	-1.20	-1.19	-1.18	-0.95	-0.70	-0.25	0.67	3.16
Real exchange rate, %	-1.22	-1.26	-1.30	-1.33	-1.26	-1.16	-0.99	-0.62	0.33
Government debt/GDP, %-points	0.04	0.26	0.48	0.68	1.29	1.60	1.67	0.66	-0.01
Government net lending/GDP, %-points	-0.86	-0.83	-0.79	-0.76	-0.58	-0.35	-0.03	0.13	-0.01
Net foreign assets/GDP, %-points	-0.59	-1.05	-1.52	-1.98	-3.78	-5.45	-8.43	-14.20	-31.35
Current account/GDP, %-points	-0.45	-0.47	-0.48	-0.49	-0.48	-0.47	-0.45	-0.41	-0.33

Table 2 Depreciation of exchange rate

Exchange rate depreciates unexpectedly and temporarily (for one quarter) by 10%.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	2.68	0.84	0.21	0.02	-0.09	-0.02	-0.01	-0.01	0.00
Imports, %	-7.82	1.22	0.39	0.14	0.08	0.11	0.11	0.10	0.01
Exports, %	3.67	0.70	0.17	0.01	-0.10	-0.03	-0.02	-0.02	0.00
Private consumption, %	-0.26	0.34	0.08	0.07	0.02	0.07	0.06	0.05	0.00
Private fixed investment, %	-0.04	-0.04	-0.05	-0.06	-0.11	-0.08	-0.04	-0.02	0.00
Inflation, GDP defl., %-points	-0.05	-0.02	0.02	0.06	0.08	0.01	0.00	0.01	0.00
Inflation, consumpt. defl., %-points	0.45	-0.02	0.02	0.06	0.08	0.01	0.00	0.01	0.00
Real wage, %	-0.34	0.17	0.13	0.10	0.01	0.00	0.00	0.00	0.00
Real product wage, %	0.16	0.16	0.13	0.09	0.00	-0.01	-0.01	-0.01	0.00
Unemployment, %-points	-0.23	-0.25	-0.21	-0.15	-0.02	0.00	0.00	0.00	0.00
Nominal interest rate, %-points	0.74	0.04	0.09	0.13	0.12	0.02	0.00	0.01	0.00
Real interest rate, %-points	2.62	-0.13	-0.07	0.00	0.10	0.01	0.00	0.00	0.00
Nominal exchange rate, %	10.25	-0.06	-0.05	-0.03	-0.03	0.04	0.06	0.09	0.30
Real exchange rate, %	10.30	-0.04	-0.07	-0.09	-0.17	-0.11	-0.10	-0.09	-0.01
Government debt/GDP, %-points	-1.71	-0.52	-0.15	-0.05	-0.07	-0.12	-0.14	-0.05	0.00
Government net lending/GDP, %-points	-0.38	0.17	0.08	0.02	-0.04	0.01	0.00	-0.02	0.00
Net foreign assets/GDP, %-points	3.71	2.33	2.40	2.42	2.31	2.21	2.02	1.57	0.15
Current account/GDP, %-points	3.01	-0.08	-0.02	0.00	-0.01	0.00	0.00	-0.01	0.00

Table 3

**Increase in interest rates**

Foreign real interest rates increase unexpectedly and temporarily (for two years) by 1%-point.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	-2.25	-2.04	-1.70	-1.32	0.06	0.09	-0.07	-0.05	0.00
Imports, %	-0.24	-0.34	-0.29	-0.21	-0.02	-0.09	-0.18	-0.12	-0.01
Exports, %	-2.19	-1.98	-1.65	-1.28	0.06	0.10	-0.06	-0.03	0.00
Private consumption, %	-1.80	-1.47	-1.14	-0.81	0.27	0.14	-0.11	-0.15	-0.01
Private fixed investment, %	-0.60	-1.00	-1.24	-1.35	-0.97	-0.51	-0.13	0.17	0.00
Inflation, GDP defl., %-points	-0.01	-0.08	-0.18	-0.30	-0.43	-0.14	0.00	-0.01	0.00
Inflation, consumpt. defl., %-points	-0.13	-0.18	-0.26	-0.36	-0.36	-0.13	0.00	-0.01	0.00
Real wage, %	-0.17	-0.35	-0.44	-0.46	-0.21	-0.06	-0.07	-0.05	0.00
Real product wage, %	-0.29	-0.46	-0.53	-0.52	-0.21	-0.05	-0.07	-0.05	0.00
Unemployment, %-points	0.40	0.64	0.75	0.74	0.28	0.02	0.00	0.00	0.00
Nominal interest rate, %-points	1.00	1.00	1.00	1.00	1.00	-0.21	0.00	-0.01	0.00
Real interest rate, %-points	1.21	1.35	1.42	1.43	1.19	-0.18	0.00	0.00	0.00
Nominal exchange rate, %	-2.38	-2.13	-1.89	-1.64	-0.65	-0.70	-0.82	-0.88	-0.96
Real exchange rate, %	-2.37	-2.05	-1.71	-1.34	0.09	0.18	0.06	0.04	0.01
Government debt/GDP, %-points	1.81	1.89	1.86	1.79	1.31	0.57	-0.09	-0.45	0.00
Government net lending/GDP, %-points	-0.77	-0.67	-0.54	-0.41	-0.04	0.64	0.26	-0.02	0.00
Net foreign assets/GDP, %-points	-0.48	-0.86	-1.19	-1.46	-1.82	-1.57	-1.33	-0.92	-0.17
Current account/GDP, %-points	-0.46	-0.40	-0.34	-0.28	-0.01	0.02	0.01	0.01	0.00

Table 4 **Increase in total labour force**

Total labour force is increased unexpectedly and permanently by 1%.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	0.89	0.90	0.86	0.80	0.64	0.64	0.68	0.77	0.96
Imports, %	0.72	0.77	0.76	0.74	0.71	0.72	0.73	0.70	0.73
Exports, %	0.80	0.81	0.76	0.71	0.55	0.55	0.60	0.68	0.85
Private consumption, %	0.92	0.89	0.83	0.76	0.60	0.59	0.62	0.69	0.89
Private fixed investment, %	0.20	0.36	0.49	0.59	0.84	0.96	1.07	1.07	0.91
Inflation, GDP defl., %-points	-0.06	-0.09	-0.11	-0.12	0.03	0.05	0.04	0.03	0.00
Inflation, consumpt. defl., %-points	-0.04	-0.07	-0.09	-0.10	0.03	0.05	0.04	0.03	0.00
Real wage, %	-0.07	-0.11	-0.14	-0.18	-0.28	-0.32	-0.32	-0.24	-0.07
Real product wage, %	-0.05	-0.09	-0.12	-0.16	-0.27	-0.32	-0.31	-0.23	-0.04
Unemployment, %-points	0.64	0.47	0.34	0.24	0.08	0.03	0.00	-0.01	0.00
Nominal interest rate, %-points	-0.24	-0.25	-0.24	-0.23	0.02	0.06	0.07	0.05	0.00
Real interest rate, %-points	-0.09	-0.16	-0.21	-0.23	-0.03	0.02	0.02	0.02	0.00
Nominal exchange rate, %	0.37	0.30	0.24	0.18	0.06	0.10	0.23	0.54	0.91
Real exchange rate, %	0.42	0.40	0.36	0.30	0.15	0.14	0.18	0.31	0.47
Government debt/GDP, %-points	-0.59	-0.59	-0.56	-0.53	-0.41	-0.32	-0.19	-0.03	0.00
Government net lending/GDP, %-points	0.04	0.06	0.06	0.05	-0.09	-0.11	-0.10	-0.05	0.00
Net foreign assets/GDP, %-points	-0.04	-0.04	-0.05	-0.07	-0.23	-0.43	-0.83	-1.51	-0.82
Current account/GDP, %-points	0.01	0.00	-0.01	-0.02	-0.05	-0.06	-0.06	-0.04	0.00



Table 5

**Increase in the direct tax rate**

Direct tax rate in unexpectedly and temporarily (for next 10 years) increased by 1%-point.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	0.22	0.18	0.13	0.09	0.00	-0.04	-0.05	0.08	-0.02
Imports, %	-0.40	-0.46	-0.53	-0.61	-0.83	-0.96	-1.08	-0.97	0.24
Exports, %	0.26	0.23	0.18	0.15	0.08	0.06	0.05	0.16	-0.01
Private consumption, %	0.05	-0.01	-0.06	-0.10	-0.20	-0.30	-0.52	-1.11	0.15
Private fixed investment, %	-0.13	-0.24	-0.35	-0.44	-0.66	-0.69	-0.25	2.40	-0.08
Inflation, GDP defl., %-points	0.01	0.03	0.05	0.07	0.08	0.06	0.02	-0.23	0.01
Inflation, consumpt. defl., %-points	0.04	0.06	0.08	0.10	0.09	0.06	0.02	-0.23	0.01
Real wage, %	0.00	0.01	0.01	0.01	-0.03	-0.06	-0.08	0.04	-0.01
Real product wage, %	0.02	0.04	0.04	0.04	0.00	-0.02	-0.04	0.09	-0.02
Unemployment, %-points	-0.04	-0.06	-0.07	-0.07	-0.04	-0.02	-0.02	-0.02	0.00
Nominal interest rate, %-points	0.07	0.11	0.14	0.18	0.14	0.09	0.03	-0.34	0.02
Real interest rate, %-points	0.00	0.02	0.05	0.08	0.07	0.05	0.03	-0.08	0.01
Nominal exchange rate, %	0.59	0.61	0.64	0.67	0.83	0.95	1.08	0.53	-1.68
Real exchange rate, %	0.58	0.58	0.58	0.60	0.67	0.74	0.82	0.86	-0.18
Government debt/GDP, %-points	-0.40	-0.62	-0.84	-1.05	-2.00	-3.00	-5.09	-11.03	0.01
Government net lending/GDP, %-points	0.96	0.95	0.92	0.88	0.98	1.05	1.18	1.72	-0.01
Net foreign assets/GDP, %-points	0.20	0.38	0.57	0.77	1.71	2.78	5.18	11.83	3.76
Current account/GDP, %-points	0.16	0.17	0.19	0.20	0.25	0.30	0.36	0.47	-0.02



Table 7

**Increase in the indirect tax rate**

Indirect tax rate is unexpectedly and permanently increased by 1%-point.  
 Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	-0.47	-0.46	-0.39	-0.28	-0.03	0.00	0.02	0.06	-0.12
Imports, %	-1.71	-1.69	-1.64	-1.59	-1.43	-1.31	-1.06	-0.53	0.34
Exports, %	-0.27	-0.26	-0.20	-0.11	0.12	0.13	0.12	0.10	-0.11
Private consumption, %	-1.19	-1.19	-1.12	-1.03	-0.82	-0.80	-0.70	-0.29	0.21
Private fixed investment, %	-0.04	-0.06	-0.04	0.00	0.24	0.43	0.59	0.26	-0.37
Inflation, GDP defl., %-points	0.10	0.15	0.17	0.17	-0.11	-0.15	-0.14	-0.10	-0.01
Inflation, consumpt. defl., %-points	0.14	0.19	0.22	0.22	-0.10	-0.15	-0.15	-0.10	-0.01
Real wage, %	-0.35	-0.58	-0.74	-0.87	-1.08	-1.14	-1.15	-1.09	-1.23
Real product wage, %	0.83	0.60	0.43	0.32	0.10	0.04	0.02	0.06	-0.12
Unemployment, %-points	0.09	0.15	0.17	0.18	0.10	0.06	0.03	0.02	0.00
Nominal interest rate, %-points	0.19	0.25	0.28	0.29	-0.18	-0.24	-0.23	-0.15	-0.01
Real interest rate, %-points	-0.04	0.15	0.27	0.33	-0.04	-0.09	-0.09	-0.06	0.00
Nominal exchange rate, %	0.99	1.03	1.10	1.17	1.21	0.99	0.51	-0.45	-2.53
Real exchange rate, %	0.89	0.88	0.92	0.99	1.14	1.07	0.88	0.49	-0.36
Government debt/GDP, %-points	0.07	-0.14	-0.34	-0.54	-1.24	-1.61	-1.72	-0.70	0.01
Government net lending/GDP, %-points	0.78	0.64	0.55	0.49	0.58	0.39	0.06	-0.14	0.01
Net foreign assets/GDP, %-points	0.50	0.87	1.25	1.63	3.23	4.75	7.46	12.41	24.97
Current account/GDP, %-points	0.37	0.38	0.39	0.40	0.43	0.43	0.41	0.35	0.26

Table 8

**Increase in the equity premium**

Equity premium is unexpectedly and permanently increased by 1%-point.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	-1.29	-0.94	-0.56	-0.25	-0.17	-0.42	-0.75	-1.56	-4.34
Imports, %	-12.98	-12.99	-12.86	-12.71	-12.11	-11.50	-10.09	-6.87	0.44
Exports, %	0.37	0.73	1.10	1.37	1.28	0.91	0.34	-0.92	-3.83
Private consumption, %	-7.47	-6.65	-6.03	-5.54	-4.73	-4.23	-3.34	-1.90	-0.09
Private fixed investment, %	-1.03	-1.85	-2.51	-3.08	-4.89	-6.24	-7.99	-10.16	-10.65
Inflation, GDP defl., %-points	-0.31	-0.65	-1.02	-1.39	-1.54	-1.46	-1.37	-1.03	-0.04
Inflation, consumpt. defl., %-points	0.20	-0.13	-0.48	-0.85	-1.56	-1.51	-1.42	-1.07	-0.04
Real wage, %	-0.68	-0.79	-0.84	-0.85	-0.86	-0.95	-1.17	-1.77	-4.10
Real product wage, %	-0.17	-0.26	-0.29	-0.30	-0.34	-0.47	-0.78	-1.57	-4.34
Unemployment, %-points	0.17	0.24	0.25	0.22	0.15	0.19	0.23	0.19	0.01
Nominal interest rate, %-points	0.26	-0.27	-0.82	-1.40	-2.41	-2.33	-2.20	-1.66	-0.06
Real interest rate, %-points	1.59	1.21	0.73	0.19	-0.88	-0.84	-0.82	-0.63	-0.02
Nominal exchange rate, %	10.24	10.31	10.24	10.01	7.70	5.17	0.48	-8.86	-26.36
Real exchange rate, %	10.58	11.04	11.40	11.61	10.98	9.97	8.06	3.94	-4.69
Government debt/GDP, %-points	1.18	1.10	0.91	0.68	-0.02	-0.36	-0.68	-0.17	0.07
Government net lending/GDP, %-points	-0.16	0.31	0.78	1.20	1.67	1.43	1.13	0.68	0.04
Net foreign assets/GDP, %-points	4.83	8.70	12.63	16.57	31.77	45.85	70.73	117.31	220.95
Current account/GDP, %-points	3.71	3.89	4.00	4.08	4.08	4.02	3.86	3.40	2.25

Table 9

**Increase in the inflation target**

Inflation target is unexpectedly and permanently increased by 1%-point. This is assumed to be credible.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	0.52	0.33	0.16	0.05	0.02	0.04	0.05	0.05	0.02
Imports, %	-0.09	-0.05	-0.05	-0.07	-0.07	-0.04	0.00	0.02	0.02
Exports, %	0.53	0.33	0.16	0.06	0.02	0.05	0.05	0.05	0.02
Private consumption, %	0.49	0.17	0.00	-0.09	-0.08	-0.04	-0.01	0.04	0.03
Private fixed investment, %	0.10	0.14	0.16	0.17	0.18	0.19	0.16	0.05	0.01
Inflation, GDP defl., %-points	0.20	0.43	0.66	0.89	0.97	0.96	0.97	0.98	1.01
Inflation, consumpt. defl., %-points	0.24	0.45	0.67	0.89	0.97	0.96	0.97	0.98	1.01
Real wage, %	0.04	0.08	0.10	0.10	0.08	0.08	0.09	0.09	0.07
Real product wage, %	0.07	0.10	0.11	0.10	0.09	0.08	0.09	0.09	0.07
Unemployment, %-points	-0.06	-0.09	-0.09	-0.08	-0.05	-0.05	-0.05	-0.05	-0.02
Nominal interest rate, %-points	-0.12	0.20	0.55	0.90	0.97	0.95	0.96	0.97	0.99
Real interest rate, %-points	-0.98	-0.72	-0.41	-0.07	0.01	-0.01	-0.01	0.00	0.00
Nominal exchange rate, %	0.88	0.85	0.90	1.04	1.98	2.96	4.94	10.14	63.11
Real exchange rate, %	0.67	0.41	0.22	0.12	0.08	0.08	0.06	0.05	0.01
Government debt/GDP, %-points	-0.51	-0.48	-0.41	-0.33	-0.25	-0.17	-0.01	0.19	0.03
Government net lending/GDP, %-points	0.02	-0.23	-0.48	-0.70	-0.74	-0.73	-0.74	-0.72	-0.73
Net foreign assets/GDP, %-points	0.16	0.25	0.30	0.33	0.44	0.53	0.65	0.81	1.32
Current account/GDP, %-points	0.15	0.09	0.06	0.04	0.03	0.03	0.02	0.02	0.01

Table 10 **Central Bank sets interest rate according to economic situation**

Central Bank lowers inflation target by 1%-point. Private sector does not believe this.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	-0.12	-0.13	-0.12	-0.11	-0.08	-0.08	-0.08	-0.09	-0.11
Imports, %	-0.36	-0.38	-0.38	-0.37	-0.33	-0.33	-0.33	-0.33	-0.09
Exports, %	-0.08	-0.09	-0.08	-0.07	-0.04	-0.05	-0.05	-0.06	-0.10
Private consumption, %	-0.33	-0.31	-0.29	-0.27	-0.23	-0.22	-0.21	-0.23	-0.11
Private fixed investment, %	-0.01	-0.01	-0.01	-0.01	-0.03	-0.05	-0.07	-0.05	-0.11
Inflation, GDP defl., %-points	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.01	0.00
Inflation, consumpt. defl., %-points	0.01	0.00	0.00	-0.01	-0.02	-0.02	-0.01	-0.01	0.00
Real wage, %	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03
Real product wage, %	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.01	-0.02	-0.03
Unemployment, %-points	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Nominal interest rate, %-points	0.50	0.50	0.49	0.48	0.46	0.47	0.48	0.48	0.50
Real interest rate, %-points	0.50	0.50	0.50	0.49	0.47	0.47	0.48	0.48	0.48
Nominal exchange rate, %	0.15	0.16	0.16	0.16	0.14	0.12	0.09	0.02	-0.37
Real exchange rate, %	0.15	0.16	0.17	0.18	0.18	0.17	0.17	0.16	-0.05
Government debt/GDP, %-points	0.17	0.25	0.31	0.36	0.50	0.57	0.56	0.24	0.05
Government net lending/GDP, %-points	-0.32	-0.29	-0.25	-0.21	-0.12	-0.06	0.03	0.06	0.00
Net foreign assets/GDP, %-points	0.10	0.18	0.26	0.33	0.64	0.94	1.55	3.21	8.49
Current account/GDP, %-points	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.12	0.13

Table 11 **Central Banks sets interest rate according to its forecast**

Central Bank lowers inflation target by 1%-point. Private sector does not believe this.  
Floating exchange rate regime.

Differences from baseline case.

Q/Y	Q1	Q2	Q3	Y1	Y2	Y3	Y5	Y10	Y50
GDP, %	-0.06	-0.05	-0.04	-0.03	-0.02	-0.02	-0.01	-0.01	-0.05
Imports, %	-0.39	-0.39	-0.39	-0.38	-0.36	-0.35	-0.33	-0.27	-0.03
Exports, %	-0.02	-0.01	0.00	0.01	0.02	0.02	0.02	0.01	-0.04
Private consumption, %	-0.26	-0.24	-0.23	-0.22	-0.20	-0.20	-0.18	-0.15	-0.01
Private fixed investment, %	0.00	0.01	0.01	0.02	0.03	0.03	0.02	-0.02	-0.14
Inflation, GDP defl., %-points	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.01	0.01
Inflation, consumpt. defl., %-points	0.01	0.00	0.00	-0.01	-0.02	-0.02	-0.01	-0.01	0.01
Real wage, %	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.03
Real product wage, %	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	-0.03
Unemployment, %-points	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Nominal interest rate, %-points	0.13	0.12	0.11	0.10	0.08	0.09	0.09	0.09	0.12
Real interest rate, %-points	0.15	0.14	0.13	0.12	0.10	0.10	0.10	0.10	0.11
Nominal exchange rate, %	0.25	0.25	0.25	0.25	0.23	0.20	0.16	0.05	-0.18
Real exchange rate, %	0.25	0.26	0.27	0.28	0.27	0.26	0.25	0.20	-0.03
Government debt/GDP, %-points	0.07	0.08	0.09	0.10	0.12	0.13	0.12	0.04	0.02
Government net lending/GDP, %-points	-0.09	-0.07	-0.05	-0.04	-0.01	0.00	0.02	0.02	-0.01
Net foreign assets/GDP, %-points	0.12	0.22	0.32	0.42	0.82	1.21	1.96	3.77	9.01
Current account/GDP, %-points	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.13	0.14

## Appendix 1. List of equations of EDGE-model

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:

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

Nominal wages:

$$\begin{aligned} WN_t = & 0.49 \cdot E_t WN_{t+1} + 0.5 \cdot WN_{t-1} \\ & + 0.01 \cdot [0.59 \cdot Y_t / N_t \cdot PF_t \cdot (1 - 3 \cdot (U_t - \bar{U}_t))] \end{aligned}$$

GDP deflator:

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

Consumption:

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

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:

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

Inventories:

$$\begin{aligned} KI_t = & 1.05 \cdot T \cdot L_t^{0.59} K_t^{0.41} - 0.5 \cdot (Y_t - T \cdot L_t^{0.59} K_t^{0.41}) \\ & + 0.494 \cdot E_t (Y_{t+1} - T \cdot L_{t+1}^{0.59} K_{t+1}^{0.41}) \end{aligned}$$

Exports:

$$\log X_t = 0.48 \cdot \log Y_t^* + 0.72 \cdot \log DD_t - 0.41 \cdot \log \left( \frac{PX_t}{P_t^* \cdot e_t} \right) + 0.5$$



Imports:

$$\log M_t = 1.2 \cdot \log DD_t - 0.9 \cdot \log\left(\frac{PM_t}{P_t}\right) - 4.1$$

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:<sup>6</sup>

$$\log PC_t = 0.96 \cdot \log P_t + 0.04 \cdot \log PM_t + 0.11$$

Investment deflator:

$$\log PI_t = 0.81 \cdot \log P_t + 0.19 \cdot \log PM_t + 0.08$$

## 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:

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

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<sup>6</sup>We present here the newly estimated versions of the consumer and investment price deflators as well as the transfers equation. The simulations were done with earlier versions of these equations.

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

$$GOY_t = 0.185 \cdot YEN_t$$

Public real consumption

$$CG_t = \gamma \cdot YEN_t$$

### Policy parameters

Transfers:

$$TRF_t/YEN_t = 0.54 \cdot U_t + 0.16$$

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:

$$\bar{\pi}_t = 0.004$$

Taylor rule:

$$R_t = (1 - \Omega) \cdot R_{t-1} + \Omega \cdot \begin{bmatrix} 400 \cdot r^* + 100 \cdot \log(PC_t/PC_{t-4}) \\ +50 \cdot [\log(PC_t/PC_{t-4}) - 4 \cdot \bar{\pi}_t] \\ -50 \cdot 0.59 \cdot (U_t - \bar{U}_t) \end{bmatrix}$$

## 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	$\pi$	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	$\tau^{direct}$	Direct tax rate
$I$	Investment, real	$\tau^{indirect}$	Indirect tax rate
$IG$	Public investment, real	$TIN$	Indirect taxes
$INN$	Public interest outlays, nominal	$TRF$	Public transfers
$K$	Capital stock	$U$	Unemployment rate
$\Delta KI$	Change in inventories	$\bar{U}$	NAIRU
$KI$	Inventories	$W$	Real wages
$N$	Labour force	$WN$	Nominal wages per employee
$L$	Labour demand	$\chi$	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	$\zeta$	Windfall gain

## List of parameters

<i>Symbol</i>	<i>Explanation</i>
$\beta$	The factor share of capital in production
$\psi$	Steady-state government debt to nominal GDP ratio
$\omega_1$ and $\omega_2$	Steady-state transfers equation parameters
$\xi$	Steady-state government real investments to GDP ratio
$\gamma$	Steady-state government real consumption to GDP ratio

## Appendix 2. List of equations of steady state of EDGE-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:

$$\Delta KI = 1.05 \cdot g \cdot Y$$

Exports:

$$\log X = 0.48 \cdot \log Y^* + 0.72 \cdot \log(C + CG + I + X + \Delta KI) - 0.41 \cdot \log(PX / (P^* \cdot e)) + 0.5$$

Imports:

$$\log M = 1.2 \cdot \log(C + CG + I + X + \Delta KI) - 0.64 \cdot \log(PM / P) - 4.1$$

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:

$$\log PC = 0.96 \cdot \log P + 0.04 \cdot \log PM + 0.11$$

Investment deflator:

$$\log PI = 0.81 \cdot \log P + 0.19 \cdot \log PM + 0.08$$

## 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:

$$GOY = 0.185 \cdot YEN$$

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:

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

Inflation rate:

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

## 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	$\pi$	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	$\tau^{direct}$	Direct tax rate
$I$	Investment, real	$\tau^{indirect}$	Indirect tax rate
$IG$	Public investment, real	$TIN$	Indirect taxes
$INN$	Public interest outlays, nominal	$TRF$	Public transfers
$K$	Capital stock	$U$	Unemployment rate
$\Delta KI$	Change in inventories	$\bar{U}$	NAIRU
$KI$	Inventories	$W$	Real wages
$N$	Labour force	$WN$	Nominal wages per employee
$L$	Labour demand	$\chi$	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	$\zeta$	Windfall gain

## List of parameters

<i>Symbol</i>	<i>Explanation</i>
$\beta$	The factor share of capital in production
$\psi$	Steady-state government debt to nominal GDP ratio
$\omega_1$ and $\omega_2$	Steady-state transfers equation parameters
$\xi$	Steady-state government real investments to GDP ratio
$\gamma$	Steady-state government real consumption to GDP ratio



## Appendix 3

### **Comments on “Actual and Perceived Monetary Policy Rules in a Dynamic General Equilibrium Model of the Euro Area by Mika Kortelainen”**

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Prepared for the Bank of Canada workshop on  
“Advances in Econometric Model Building”

August 2000

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<sup>1</sup> Economic Modeling and External Adjustment Division, Research Department, International Monetary Fund. The author would like to thank Susanna Mursula and Dawn Heaney for their excellent technical assistance.

## **Introduction**

It's a pleasure to offer comments on a paper written about a macroeconomic model with such good modeling foundations. The EDGE model presented in the paper has a dynamic adjustment structure derived from an intertemporal optimizing framework. This makes the model's dynamic adjustment tractable, increasing its usefulness for both economic forecasting and policy analysis. Further, this dynamic structure has been solved to derive the model's steady-state representation which enhances the model's usability by providing the terminal conditions that allow for fast robust solutions of rational expectations models. Having both a steady-state and dynamic model also allows for a clear distinction to be made between a shock's implications for the model economy's steady state and its implications for the dynamic adjustment required to achieve that new steady state, again enhancing the model's tractability. The specification of the decision-making framework leads to a model with consistent stock-flow accounting. This eliminates the possibility for the free lunches that can often arise in models that characterize behavior only in terms of flows. Specifying that agents form rational expectations goes some way towards addressing the Lucas critique thereby providing more confidence in model analysis of alternative policy strategies. Finally, overlaying rational expectations with real world contracting elements achieves the sluggish adjustment observed in prices and wages that allows a meaningful role for policy.

Given its foundation, the author should feel confident that the EDGE model has all the basic elements that will make it a very useful forecasting and policy analysis tool. However, this excellent modeling foundation does make it more difficult to offer helpful comments. Those that follow are focussed on two areas; understanding the simulation properties of the model and the simulation experiments designed to examine the macroeconomic costs of disinflations when the monetary authority lacks credibility.

## **The model's properties**

After presenting the theoretical structure and the parameterization of the model, the author presents a series of simulation experiments designed to illustrate the model's dynamic adjustment properties. As noted above, a strength of models derived from optimizing frameworks is their tractability. In the section of the paper describing these simulations, the author may be able to exploit this feature more to trace through the causal forces and behavioral linkages underlying the model's the dynamic adjustment paths.

To consider the appropriateness of a calibrated model's properties it is often useful to have a benchmark for comparison. The simulation properties of the European block of the IMF's macroeconomic model MULTIMOD may provide such a benchmark. Although MULTIMOD is larger and specified at an annual frequency, it shares many of the design properties of the EDGE model. MULTIMOD's response to seven of the first eight shock experiments done in the paper are presented in the appendix. The shocks are done using a monetary policy reaction function similar to the one used in

the paper. If one accepts MULTIMOD as a useful benchmark, a comparison of the two models' properties suggests that the author's claim that the EDGE model's structure and calibration lead to sensible dynamic adjustment properties is well founded. In general the macroeconomic adjustment properties of the two models are quite similar. However, a couple of minor differences are worthy of note. First, MULTIMOD exhibits faster adjustment to permanent disturbance and slower adjustment to temporary shocks than does the EDGE model. Also, for the labor supply shock and the labor income tax shock, the inflation response in the two models is somewhat different.<sup>2</sup>

One possible source of these property differences may be the differences in the wage-price nexus in the models. To test this, it might be useful to examine the implications of different calibrations of the relative speeds of adjustment in wages and prices in the EDGE model. The calibration of the wage equation appears to imply a plausible average duration of wage contracts (2.5 years). However, the calibration of the price equation suggests that in their loss calculations firms place a fairly low weight (roughly 0.04) on being away from their optimal price relative to the weight they place on smoothing prices (1).

There is also a minor point worth noting about the coefficient on the unemployment gap in the model's policy rule. In the standard Taylor rule, the coefficient that appears on the output gap is 0.5. In general, unemployment gaps for most industrial countries tend to be 2 to 3 times smaller than output gaps over the cycle. This suggests that replacing an output gap with an unemployment gap in a Taylor rule would require increasing the size of the response coefficient in proportion to the Okun relationship. In the EDGE model the Taylor rule gap coefficient of 0.5 is multiplied by 0.59 rather than something in the neighborhood of 2 or 3.

### **The policy credibility experiments**

Once the EDGE model's properties have been illustrated, the author conducts some simulation experiments designed to illustrate the cost of a policymaker attempting to reduce inflation when private agents do not believe the inflation reduction to be credible. The first simulation traces out how the economy would evolve if private agents believed the change in the monetary authority's inflation target. Two further simulations are conducted in which private agents do not believe the change in the inflation target to be credible. The difference between the latter two simulations is the way in which the policymaker forecasts the current inflation rate and the current unemployment gap that are used as the basis for policy actions. In one case the policymaker factors in private agents' disbelief in the new inflation target. In the other case it does not.

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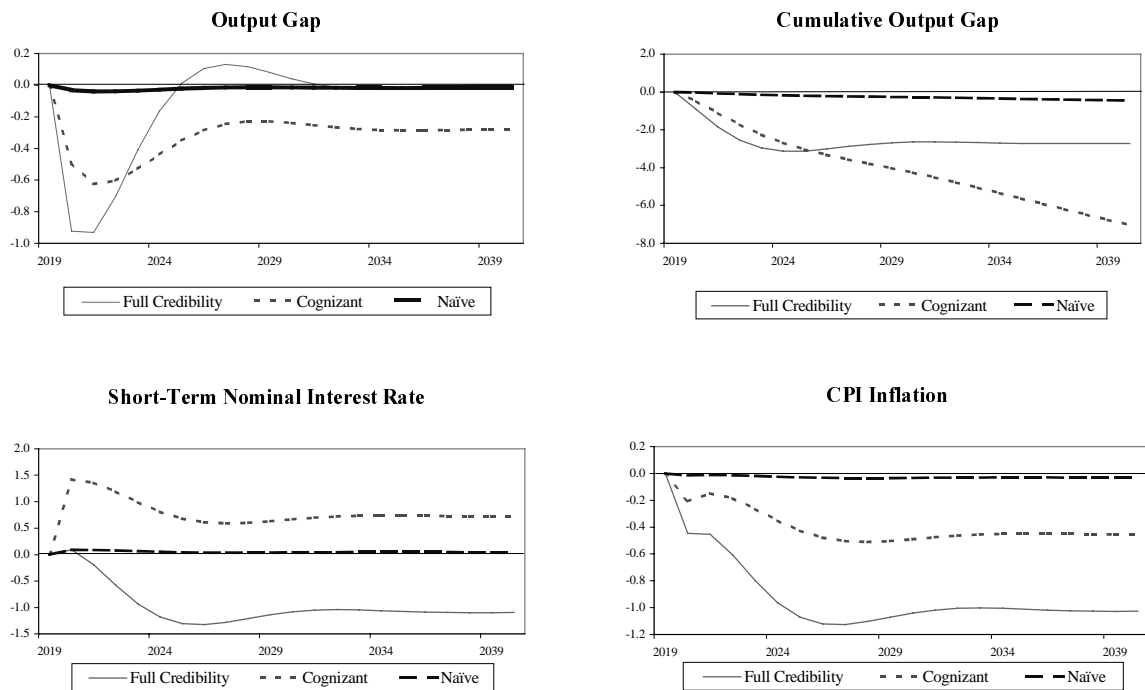
<sup>2</sup> The indirect tax shock cannot be done in MULTIMOD as the standard Mark IV version does not incorporate indirect taxes.

Before looking at the cases where the new inflation target is not credible, it is worth noting that the experiment in which the target change is credible suggests that the model is not super neutral with respect to the rate of inflation. When inflation is increased permanently by one percentage point, the new equilibrium has a higher real wage and appears to have a higher level of output as well. It would be worth understanding why this non super neutrality arises.

The two experiments where private agents do not believe the new inflation target are interesting because they result in equilibria in which the new target is never achieved and the economy never returns to its previous path. The author interprets the cost of a lack of credibility as the permanent increases in real interest rates and the permanent reductions in real output that occur. The author concludes that the losses are lower when policy is set on the basis of an inflation forecast that assumes policy is credible because the permanent increase in interest rates and the permanent decline in output are lower.

The simulation results in the lack-of-credibility cases do not stem from particular model properties, but rather they arise from the simulation technique. In these simulations expectations are permanently anchored at an inflation rate different than the policymaker's target and the policymaker persists in trying to achieve its target. Replicating these two experiments with the Euro block of MULTIMOD yields qualitatively similar results. Figure 1 presents the results of three MULTIMOD simulations. The solid line traces out the model's response to a credible 1 percentage point reduction in the inflation target. The dotted line illustrates the model's response when the inflation reduction is not believed by private agents and the policymaker recognizes this (cognizant). The dashed line traces out the model's response when the change in the inflation target is not credible, but the policymakers behaves as if it is (naive).

**Figure 1: MULTIMOD replication of the disinflation simulations**



Using these simulation results to quantify the costs of a lack of credibility may have one fundamental weakness; the policymaker never achieves the new target. Historical experience suggests that if policymakers have instrument independence and their objective is to reduce inflation, they can do so. Given that both of these conditions are satisfied in these simulation experiments a technique that incorporates some learning on the part of private sector agents and the policymaker may produce more plausible estimates of the cost of low credibility.

Figure 2 presents an alternative simulation technique for the two scenarios where the policymaker's lower inflation target is initially not believed by private agents. Again the solid lines represents the case of full credibility. In the case presented by the dotted line, the policymaker is always cognizant of the fact that its credibility is low. Private agents' perceived inflation target is based on the inflation outcome achieved by the policymaker the previous year. In other words the policymaker must earn some credibility (earned credibility). In the case traced out by the dashed line, the policymaker initially assumes its target is credible, but after two years it realizes that private agents don't believe the target and in all subsequent periods the policymaker incorporates this information into its policy setting. Again private agents base their expectation of the inflation target on the previous year's inflation outcome. Figure 3 presents a similar set of simulations in which private agents' view of the inflation target is even slower to respond to actual inflation outcomes (hard earned credibility).

Figure 2: Disinflations incorporating learning

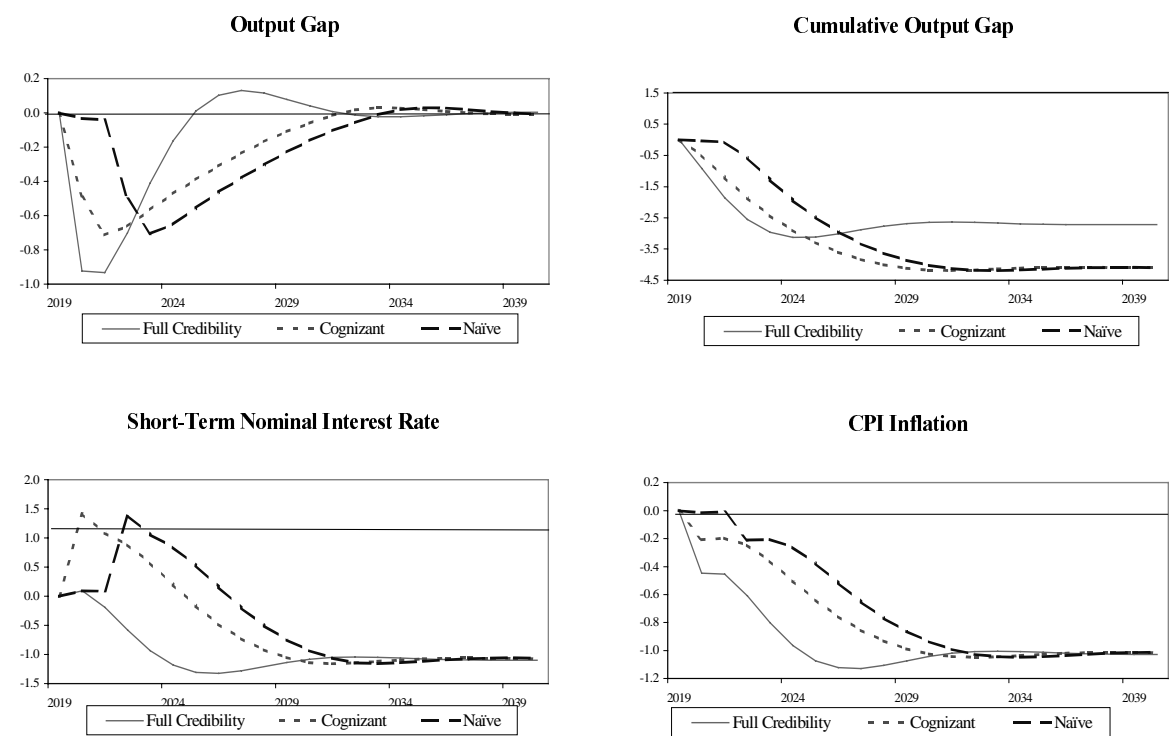
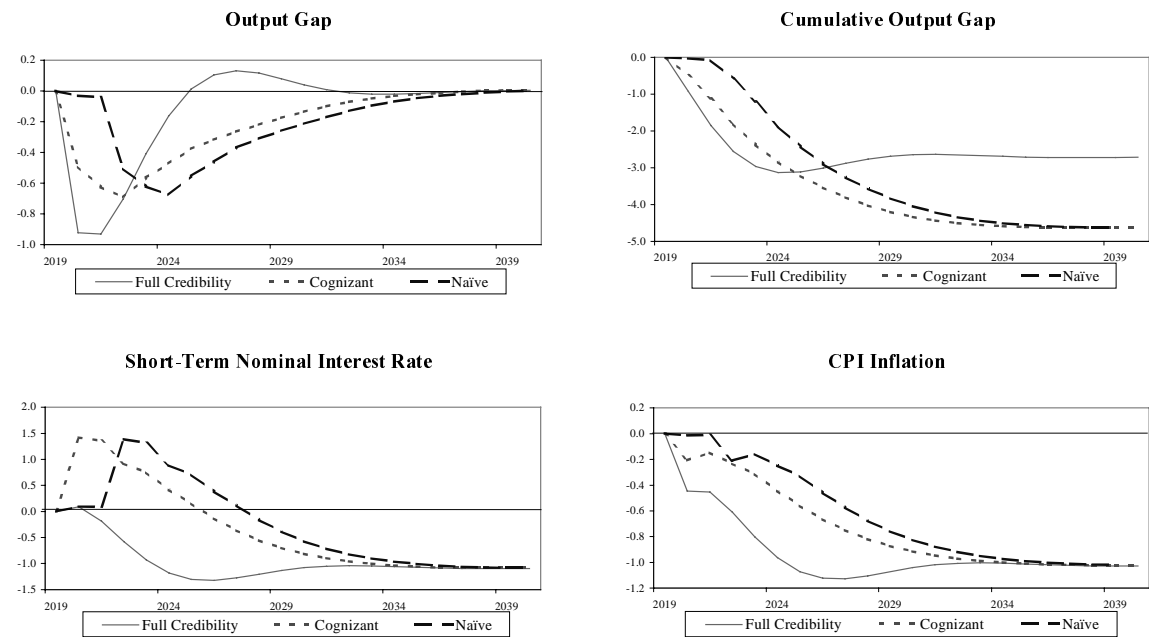


Figure 3: Disinflations incorporating slow learning



These simulation results afford a number of conventional measures of the cost of low credibility. The cumulative output gaps in the poor credibility scenarios can be compared to the cumulative output gap when the new inflation target is credible. Conventional quadratic losses in inflation and output can also be compared. The cumulative output gaps presented in table 1 indicate that when credibility must be earned the amount of output that needs to be sacrificed increases by over 1 percentage and by almost 2 percentage points when credibility is hard earned. The amount of output that needs to be sacrificed does not change when the policymaker initially behaves naively and assumes its new target is immediately credible. The losses presented in table 2 suggest that the loss increases by roughly 40% when credibility must be earned and the policymaker recognizes this and by almost 100% when the policymaker initially believes its new target is immediately credible. The losses increase by more when credibility is hard earned.

Unlike the conclusion that the author draws from the simulation experiments presented in the paper, these simulation results do not suggest that the loss is lowest when the policymaker behaves naively and assumes that it has immediate credibility. The cumulative output gaps are identical in both cases and the quadratic losses suggest that behaving naively is more costly. In addition to the output implications the quadratic loss also incorporates the time that inflation is away from target. Initially behaving naively means that it takes the policymaker longer to anchor inflation expectations at the new target level, thereby increasing the loss.

**Table 1 Cumulative Output Loss**

<b>Central Bank</b>	<b>Private Agents</b>		
	Immediate Credibility	Earned Credibility	Hard Earned Credibility
Cognizant	2.72	4.09	4.62
Naive	2.72	4.10	4.62

**Table 2 Quadratic Loss**

<b>Central Bank</b>	<b>Private Agents</b>		
	Immediate Credibility	Earned Credibility	Hard Earned Credibility
Cognizant	3.6	5.22	5.68
Naive	3.6	7.03	7.47

## **Summary**

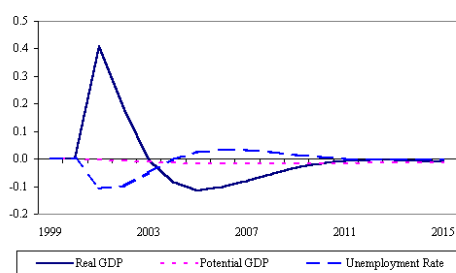
The EDGE model should prove to be a very useful tool at the Finnish central bank. Using MULTIMOD as a reference point, the model appears to have very plausible overall dynamic properties. However, developing a better understanding of the source of a couple of its properties might be worthwhile. With respect to the policy analysis experiments that the author presents, I would recommend incorporating some learning on the part of private agents and the policymaker in the poor credibility simulations. Incorporating learning means that the policymaker eventually achieves its objective. Conventional measures of the cost of poor credibility then yield the intuitively appealing result that when the policymaker behaves naively, assuming that it has full credibility, the cost are not lower than when it is cognizant of the fact that its credibility is low.



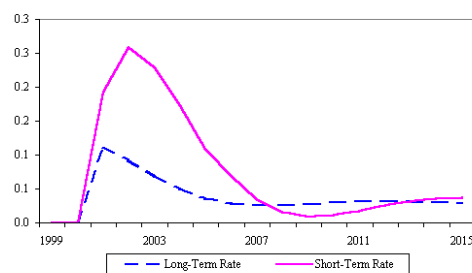
# EURO Area

## A 1% of GDP Permanent Increase in Government Expenditure

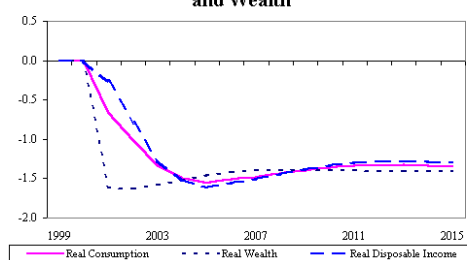
**Real, Potential GDP, and Unemployment**



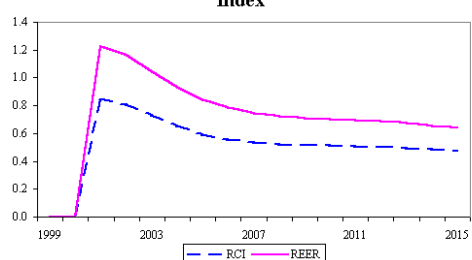
**Interest Rates**



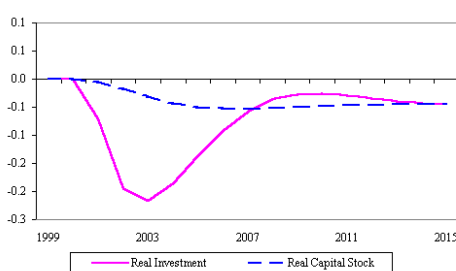
**Consumption, Disposable Income, and Wealth**



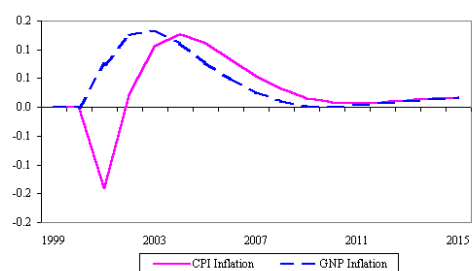
**Real Eff. Exchange Rate and Real Comp. Index**



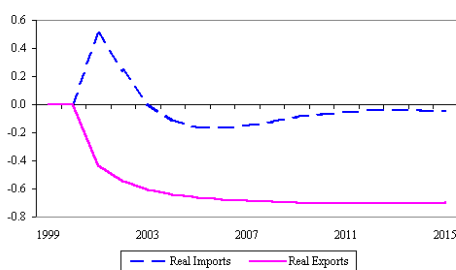
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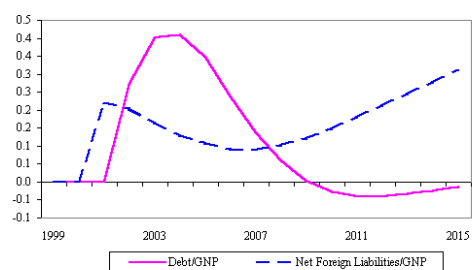
**CPI and GNP Inflation**



**Exports and Imports**



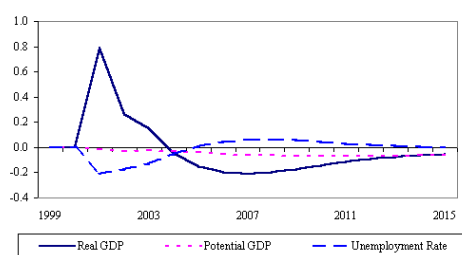
**Debt and Net Foreign Liabilities**



# EURO Area

## A Temporary 1 Year 10% Depreciation in the Real Exchange Rate

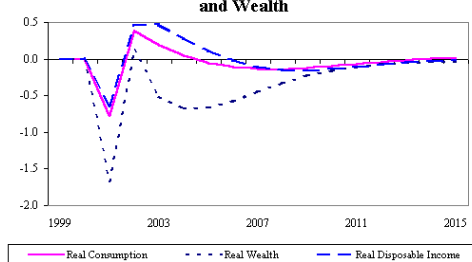
**Real, Potential GDP, and Unemployment**



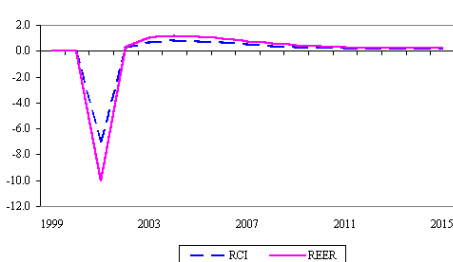
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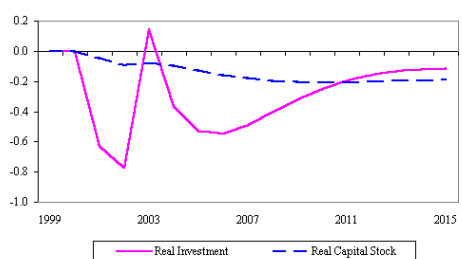
**Consumption, Disposable Income, and Wealth**



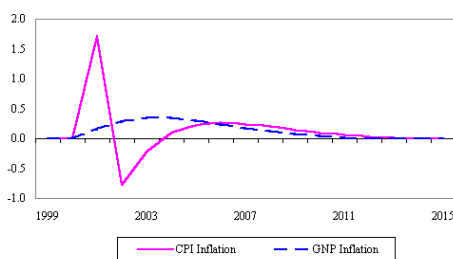
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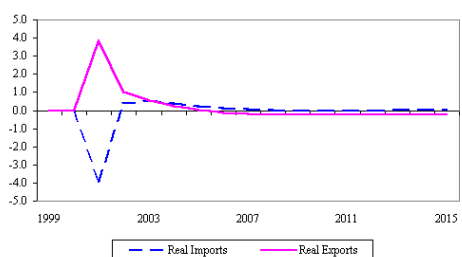
**Investment and Capital Stock**



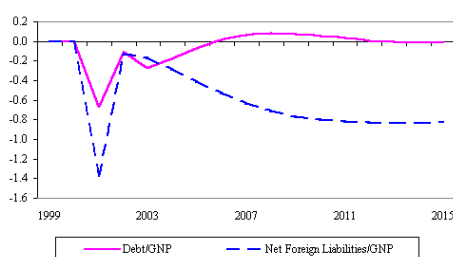
**CPI and GNP Inflation**



**Exports and Imports**



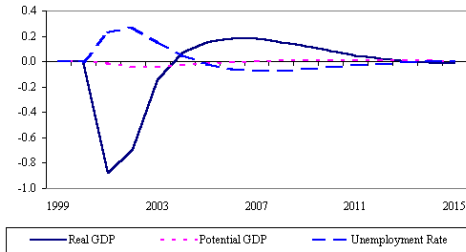
**Debt and Net Foreign Liabilities**



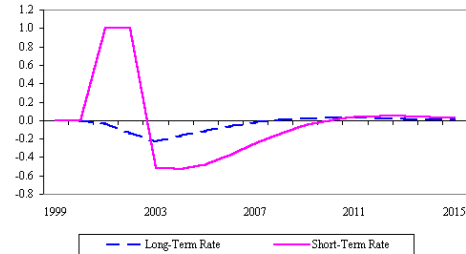
# EURO Area

## A 1 Percentage Point Increase in the Nominal Short Term Interest Rate for 2 Years

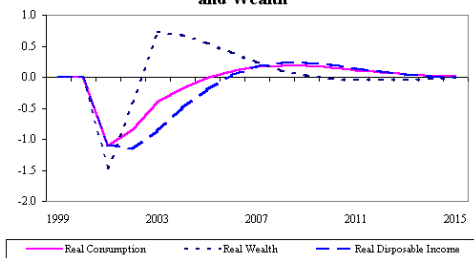
**Real, Potential GDP, and Unemployment**



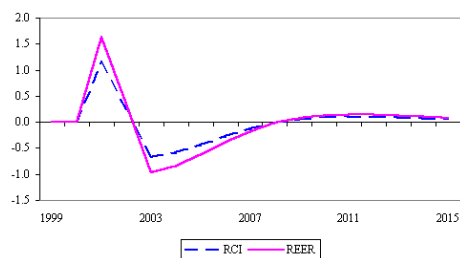
**Interest Rates**



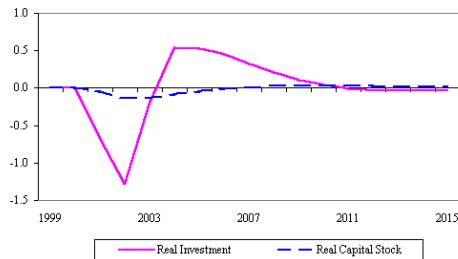
**Consumption, Disposable Income, and Wealth**



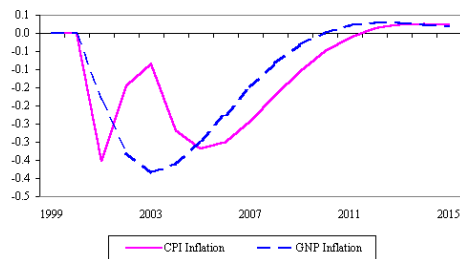
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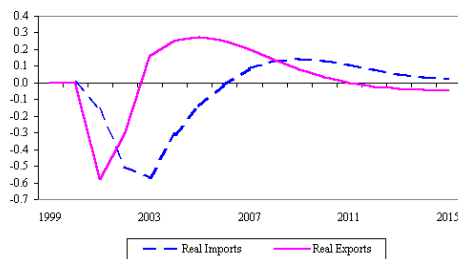
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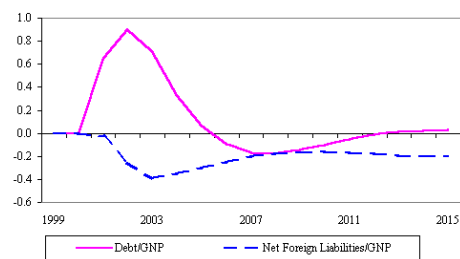
**CPI and GNP Inflation**



**Exports and Imports**

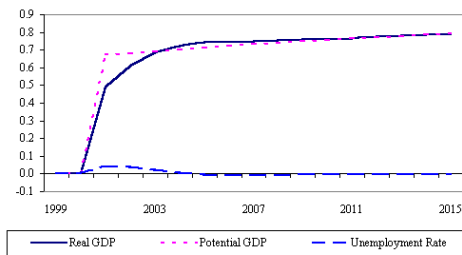


**Debt and Net Foreign Liabilities**

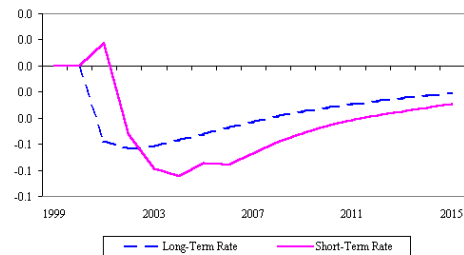


## EURO Area A Permanent 1% Increase in the Labor Force

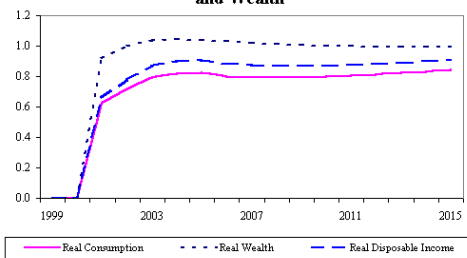
**Real, Potential GDP, and Unemployment**



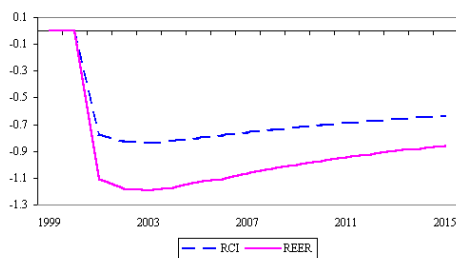
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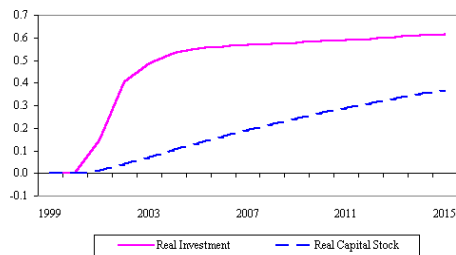
**Consumption, Disposable Income, and Wealth**



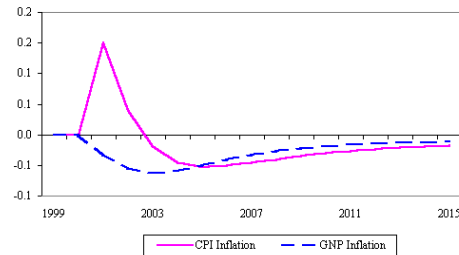
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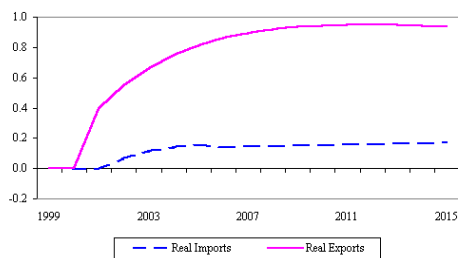
**Investment and Capital Stock**



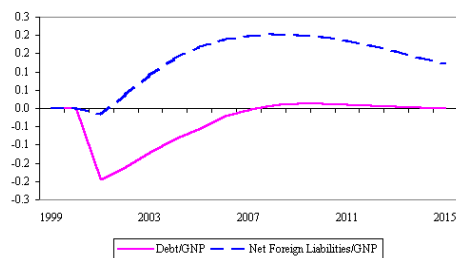
**CPI and GNP Inflation**



**Exports and Imports**



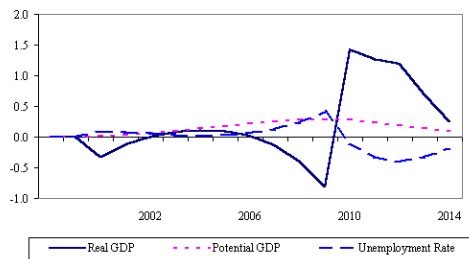
**Debt and Net Foreign Liabilities**



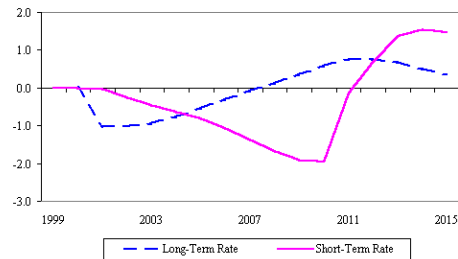
# EURO Area

## A 1%, 10Year Increase in the Labor Income Tax Rate

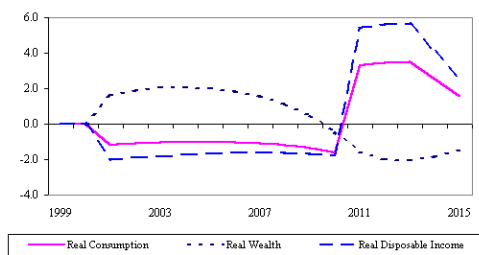
Real, Potential GDP, and Unemployment



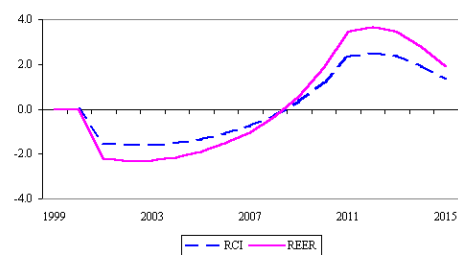
Interest Rates



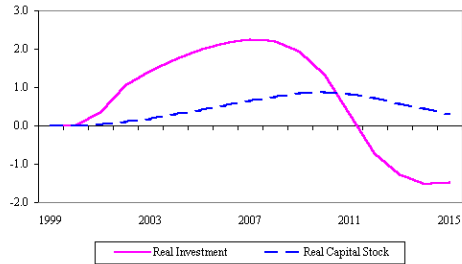
Consumption, Disposable Income, and Wealth



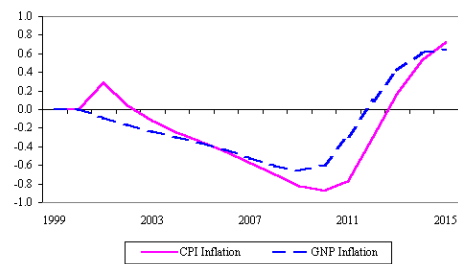
Real Eff. Exchange Rate and Real Comp. Index



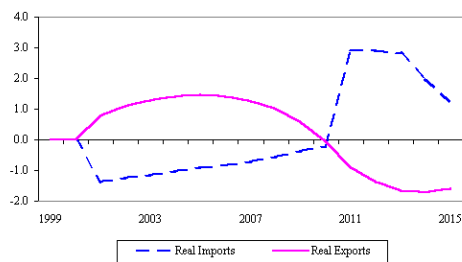
Investment and Capital Stock



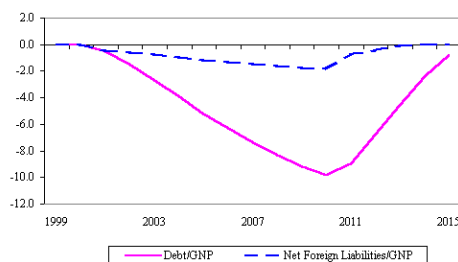
CPI and GNP Inflation



Exports and Imports

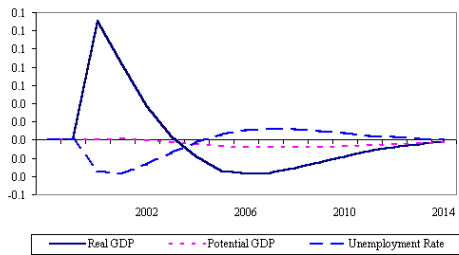


Debt and Net Foreign Liabilities

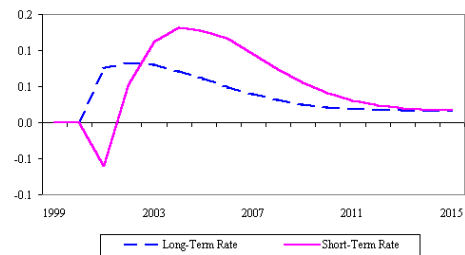


## EURO Area A 1% Permanent Increase in World Demand

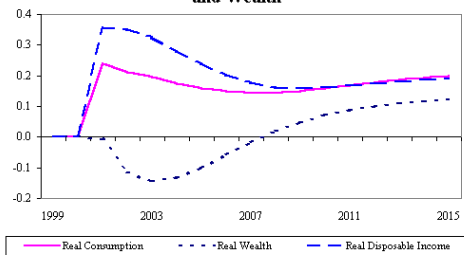
**Real, Potential GDP, and Unemployment**



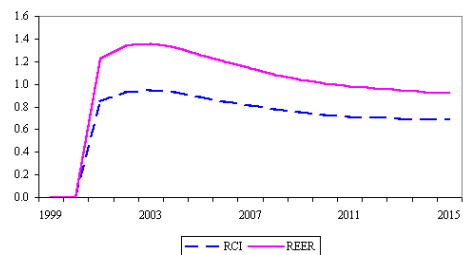
**Interest Rates**



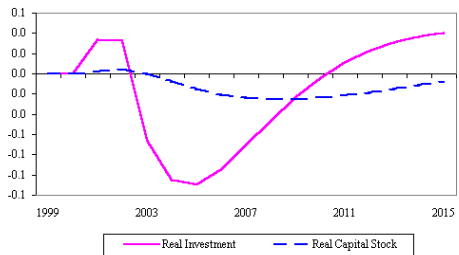
**Consumption, Disposable Income, and Wealth**



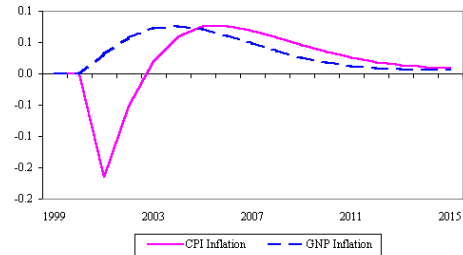
**Real Eff. Exchange Rate and Real Comp. Index**



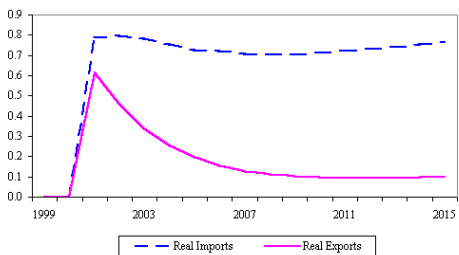
**Investment and Capital Stock**



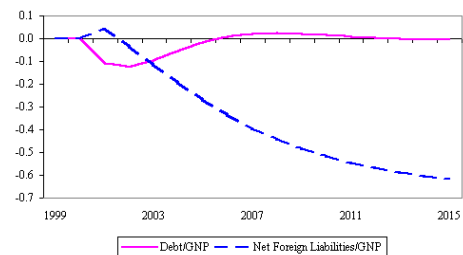
**CPI and GNP Inflation**



**Exports and Imports**



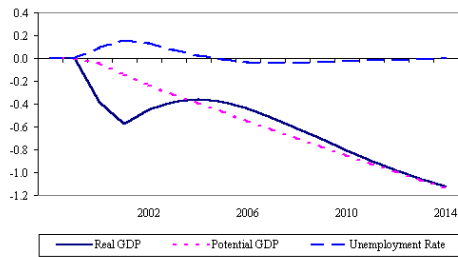
**Debt and Net Foreign Liabilities**



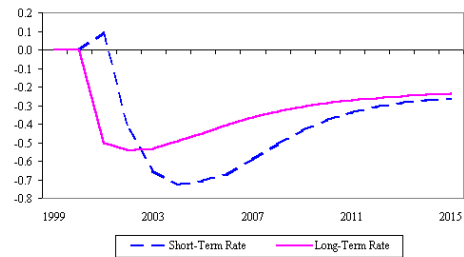
# EURO Area

## A 1 Percentage Point Permanent Increase in the Equity Premium

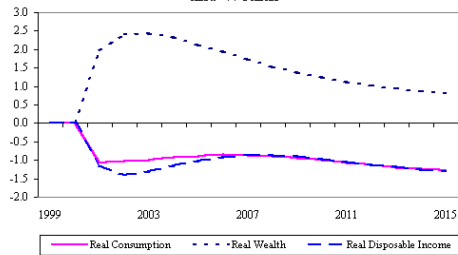
**Real, Potential GDP, and Unemployment**



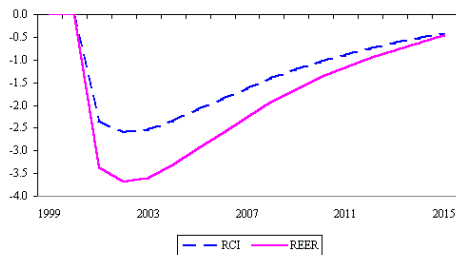
**Interest Rates**



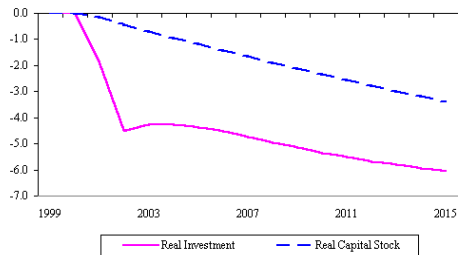
**Consumption, Disposable Income, and Wealth**



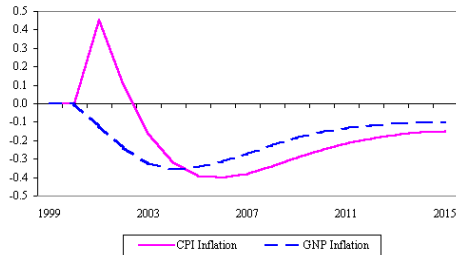
**Real Eff. Exchange Rate and Real Comp. Index**



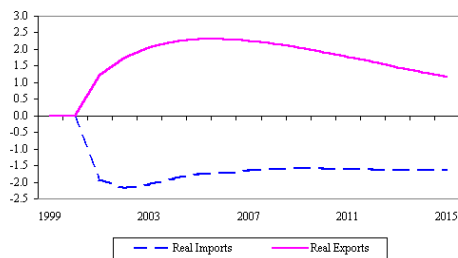
**Investment and Capital Stock**



**CPI and GNP Inflation**



**Exports and Imports**



**Debt and Net Foreign Liabilities**

