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AN ESTIMATED DSGE MODEL FOR SWEDEN WITH A MONETARY REGIME CHANGE

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Abstract

Using Bayesian methods, we estimate a small open economy model for Sweden. We explicitly account for a monetary regime change from an exchange rate target zone to flexible exchange rates with explicit inflation targeting. In each of these regimes, we analyze the behavior of the monetary authority and the relative contribution to the business cycle of structural shocks in detail. Our results can be summarized as follows. Monetary policy is mainly concerned with stabilizing the exchange rate in the target zone and with price stability in the inflation targeting regime. Expectations of realignment and the risk premium are the main sources of volatility in the target zone period. In the inflation targeting period, monetary shocks are important sources of volatility in the short run, but in the long run, labor supply and preference shocks become relatively more important. Foreign shocks are much more destabilizing under the target zone than under inflation targeting.

Keywords: Bayesian estimation, DSGE models, target zone, inflation targeting, regime change

JEL: E5, C1, C3

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1 Introduction

In the period between the breakdown of the Bretton Woods system in 1973 and the more recent 2001 crisis in Argentina, we have witnessed the collapses of fixed exchange rate systems followed by severe recessions and considerable credibility costs. The experience in Finland, England and Sweden, among others, illustrates successful attempts of central banks at rebuilding credibility through the announcement of explicit inflation targets. The crash of the exchange rate system temporarily left monetary policy without an anchor. However, price stability soon became the new goal and inflation targeting the way for it to be achieved. After one decade of inflation targeting, it is time to evaluate the relations between different monetary policy systems and macroeconomic stabilization and assess the driving forces behind the business cycle under different regimes.

In this paper, we estimate a small open economy dynamic stochastic general equilibrium (DSGE) model on Swedish data with two specific goals in mind: estimating different monetary policy rules under target zone and inflation targeting regimes, and identifying which shocks drive the Swedish economy, which is a good example of a small open economy, under the two different monetary regimes. Thus, our work makes two main contributions to the existing literature. First, it estimates a small open economy model in a Bayesian framework explicitly dealing with monetary regime switches. A second contribution is the thorough analysis of differences in the behavior of the economy under the two regimes considered. It is quite important to analyze to what extent, in practice, policy was constrained in the target zone and under inflation targeting.

To analyze these questions, we estimate a stochastic business cycle model with physical capital, deviations from the law of one price (LOP) and Calvo price and wage setting, based on Kollmann (2001, 2002). As shown by Betts and Devereux (2000), pricing to market behavior by firms (PTM) increases nominal and real exchange rate volatility. Considering the empirical failure of the LOP, Kollmann (2001) assumes that intermediate goods firms can price discriminate between domestic and foreign markets and that prices are set in terms of the currencies of their customers. To capture the well documented inertia in consumption (e.g. King and Rebelo (2000)), we include external habit formation in the utility function. Moreover, we assume the existence of frictions in financial markets that create a wedge between the returns on domestic and foreign assets. As in Lindé, Nessén, and Söderström (2004), this risk premium is assumed to be a decreasing function of the country's net foreign asset position.

Price stability has only been the overall target of monetary policy in Sweden since January 1993, when the Riksbank announced an explicit inflation target of 2% (with ±1% bands). Previously, for almost 120 years[1], Sweden had maintained a fixed (or nearly fixed) exchange rate, which was abandoned on November 19 1992 after the Exchange Rate Mechanism (ERM) crisis.[2] To take the regime change into consideration, we study two different specifications for monetary policy. For the first part of the sample, the target zone period, we borrow part of the model in Svensson (1994). A linear managed float without an explicit band is used as an approximation to a non-linear exchange rate band model. In contrast to Svensson (1994), we describe monetary policy by an interest rate rule, whereby the monetary authority reacts to exchange rate deviations from central parity. For the second part of the sample, we follow Kollmann (2002) and describe monetary policy with a Taylor-type rule, where the policy variable is a function of current and past inflation and output, e.g. as in chapter 4 of Woodford (2003).

Eleven structural shocks complete the model specification: shocks to preferences, labor supply, productivity, monetary policy, risk premium, foreign output, foreign interest rate, foreign prices, wage and price markups and realignment expectations[3]. We limit the set

[1] In September 1931, Sweden abandoned the Gold standard and became the first country to adopt explicit price level targeting. The Swedish krona was left free to float until July 1933 when the Riksbank decided to enter the Sterling block, pegging the krona to the British pound. (cf. Berg and Jonung (1998))

[2] After the Bretton Woods collapse in 1973, Sweden participated in the so-called "snake" exchange rate mechanism. In 1977, the Riksbank announced a unilateral peg to a currency basket constructed using trading weights. In May 1991, the ECU became the official peg. Lindbeck, Molander, Persson, Petersson, Sandmo, Swedenborg, and Thygesen (1994), Lindberg, Soderlind, and Svensson (1993) and Lindberg and Soderlind (1994), and the official web page of Sveriges Riksbank are good references for a more detailed description of the exchange rate regimes adopted in Sweden in the last century.

[3] This last shock only plays a role in the fixed exchange rate regime period.

of variables used in the estimation to ten macroeconomic time series: foreign interest rate, foreign price index, foreign output, domestic output, domestic price, domestic interest rate, nominal exchange rate, real wages, hours worked and private consumption.

Following Smets and Wouters (2003), we estimate the model using the "strong econometric" interpretation of DSGE models, through the use of Bayesian methods. Numerical methods are used to find the mode of the posterior density. Then, we generate draws of the posterior employing Markov chain Monte Carlo (MCMC) methods. Finally, to investigate the differences between the relative contribution to the business cycle and the propagation of each of the eleven shocks under the two regimes, we compute variance decompositions and impulse response functions.

The estimated monetary policy rule highlights the strong focus of the Riksbank on exchange rate stabilization in the target zone regime. This restricts monetary independence (the ability to react to domestic shocks) and increases the exposure to foreign shocks. This is also clearly visible in the variance decomposition analysis, where realignment and risk premium shocks are the main sources of economic volatility. In contrast, under inflation targeting, the central bank is mainly concerned with price stabilization, which creates a stronger reaction to domestic shocks. Rather than risk premium and realignment expectations, it is monetary, labor supply and preference shocks that explain output, employment, and capital accumulation volatility in the inflation targeting regime. Moreover, real exchange rate variations are mostly explained by risk premium and realignment expectations shocks during the target zone regime and monetary shocks under inflation targeting. Finally, foreign shocks are not a significant source of volatility in the economy, but – as made clear by the impulse response analysis – the foreign sector is still very important for the propagation of shocks.

The rest of the paper is organized as follows. Section 2 presents the theoretical model. Section 3 briefly describes the data set, the estimation procedure and the priors. In Section 4, we analyze the results in terms of parameter estimates, impulse response functions and variance decomposition. Section 5 concludes.

2 The Model

We follow the model of Kollmann (2001) closely and assume a small open economy with a representative household, firms and a government. The single good produced by the country is assumed to be non tradable. A continuum of intermediate goods is traded. The final good market is perfectly competitive, while there is monopolistic competition in the intermediate goods market. Prices are assumed to be sticky in the buyer's currency. The household owns the domestic firms, holds domestic money and one-period domestic and foreign currency bonds and rents capital to firms. Overlapping wage contracts à la Calvo are assumed. Here, we modify the original model taking habit persistence into consideration, assuming the monetary authority to follow a Taylor rule and enriching the dynamics of the model with eleven structural shocks. Moreover, following Kollmann (2002), we model the risk premium on the return to foreign borrowing as a function of the level of net foreign assets. Now, we describe each sector of the economy in more detail.

2.1 Final goods production

A non-tradable final good is produced in a perfectly competitive market using the following technology:

$$Z_t = \left(\frac{Q_t^d}{\alpha^d}\right)^{\alpha^d} \left(\frac{Q_t^m}{1-\alpha^d}\right)^{1-\alpha^d}, \tag{2.1}$$

where

$$Q_t^i = \left[\int_0^1 q_t^i\left(s\right)^{\frac{1}{1+\nu_t}} ds\right]^{1+\nu_t}, \; i = d, m \tag{2.2}$$

are the domestic and the imported intermediate input quantity indices and $q_t^d\left(s\right)$ and $q_t^m\left(s\right)$ are the domestic and imported type "s" intermediate goods, respectively. As in Smets and Wouters (2003), ν_t is defined as $\nu + (1+\nu)\,\varepsilon_{\nu,t}$ and represents a time varying elasticity of the demand for the different varieties of goods; hence, a time varying price markup, which is the interpretation we shall use.

Cost minimization implies the following demand for inputs:

$$q_t^i(s) = Q_t^i \left(\frac{p_t^i(s)}{P_t^i}\right)^{-\frac{1+\nu_t}{\nu_t}}, \; i = d, m \tag{2.3}$$

$$Q_t^i = \alpha^i \frac{P_t Z_t}{P_t^i}, \tag{2.4}$$

and the price indices are given by:

$$P_t^i = \left[\int_0^1 p_t^i(s)^{-\frac{1}{\nu_t}} ds\right]^{-\nu_t}, \tag{2.5}$$

$$P_t = \left(P_t^d\right)^{\alpha_d} \left(P_t^m\right)^{1-\alpha_d}. \tag{2.6}$$

2.2 Intermediate goods production

In the intermediate goods market, a range of monopolistic competitive firms use the following technology:

$$y_t(s) = \theta_t K_t(s)^{\psi} L_t(s)^{1-\psi}, \tag{2.7}$$

with

$$L_t(s) = \left[\int_0^1 l_t(h;s)^{\frac{1}{1+\gamma_t}} dh\right]^{1+\gamma_t}, \tag{2.8}$$

where γ_t is defined as $\gamma + (1+\gamma)\varepsilon_{\gamma,t}$ and represents a time-varying elasticity of the demand for different varieties of labor; hence, a time varying wage markup.

Cost minimization implies

$$W_t = \left[\int_0^1 w_t(h)^{-\frac{1}{\gamma_t}} dh\right]^{-\gamma_t}, \tag{2.9}$$

where $w_t(h)$ denotes the nominal wage of worker h and W_t is the price index for labor inputs. The firm's production is sold to both the domestic and the foreign market:

$$y_t(s) = q_t^d(s) + q_t^x(s). \tag{2.10}$$

Export demand is assumed to be similar to the domestic demand function in that total foreign demand will be allocated to the different varieties according to the same elasticity:

$$Q_t^x = \left[\int_0^1 q_t^x(s)^{\frac{1}{1+\nu_t}} ds\right]^{1+\nu_t}. \tag{2.11}$$

Foreign demand is given by

$$Q_t^x = \left(\frac{P_t^x}{P_t^*}\right)^{-\eta} Y_t^*, \tag{2.12}$$

where Y_t^* is the foreign real GDP and P_t^* the foreign aggregate price level, here assumed to be exogenous series. The demand for each variety is therefore similar to domestic demand:

$$q_t^x(s) = Q_t^x \left(\frac{p_t^x(s)}{P_t^x}\right)^{-\frac{1+\nu_t}{\nu_t}}, \tag{2.13}$$

and the price index is:

$$P_t^x = \left[\int_0^1 p_t^x(s)^{-\frac{1}{\nu_t}} ds\right]^{-\nu_t}. \tag{2.14}$$

The profits from producing and importing are

$$\Pi_{t+\tau}^i\left(p_t^i\right) = \left(P_{t+\tau}^i\right)^{\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}} Q_{t+\tau}^i \left[\left(p_t^i\right)^{-\frac{1}{\nu_{t+\tau}}} - S_{t+\tau}^i \left(p_t^i\right)^{-\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}}\right], \text{ for } i = d, m, x,$$

where S_t^i is the marginal cost. Firms can price discriminate among the domestic and foreign markets and they set prices in the local currency. The firms' problem is given by

$$\begin{array}{ll} \max_{p_t^i} & \sum_{\tau=0}^{\infty} \alpha_p^\tau E_t\left[\rho_{t,t+\tau}\Pi_{t+\tau}^i\left(p_t^i\right)\right] \\ s.t. & \Pi_{t+\tau}^i\left(p_t^i\right) = \left(P_{t+\tau}^i\right)^{\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}} Q_{t+\tau}^i \left[\left(p_t^i\right)^{-\frac{1}{\nu_{t+\tau}}} - S_{t+\tau}^i \left(p_t^i\right)^{-\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}}\right], \end{array}$$

where

$$\rho_{t,t+\tau} = \beta^\tau \frac{\xi_{t+\tau} U_c(t+\tau)}{\xi_t U_c(t)} \frac{P_t}{P_{t+\tau}} \tag{2.15}$$

is the discount factor in domestic currency and $(1-\alpha_p)$ is the probability of being able to set the price at a given moment. Profit maximization yields the following optimal pricing rules:

$$0=\sum_{\tau=0}^{\infty}\alpha_p^{\tau}E_t\left[\rho_{t,t+\tau}\left(P_{t+\tau}^i\right)^{\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}}Q_{t+\tau}^i\left\{-\frac{1}{\nu_{t+\tau}}\left(p_t^i\right)^{-\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}}+\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}S_{t+\tau}\left(p_t^i\right)^{-\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}-1}\right\}\right], \tag{2.16}$$

for each market $i=d,m,x$.

Prices in each of these markets evolve as

$$\left(P_t^i\right)^{1-\nu}=\alpha_p\left(P_{t-1}^i\right)^{1-\nu}+(1-\alpha_p)\left(p_t^i\right)^{1-\nu},\ i=d,m,x. \tag{2.17}$$

2.3 The representative household

The representative household (HH) maximizes expected utility:[4]

$$\begin{array}{ll}\max & E_0\sum_{t=1}^{\infty}\beta^t\xi_t U\left(C_t,L_t\right)\\ s.t. & U\left(C_t,L_t\right)=\frac{1}{1-\sigma_c}\left(C_t-\upsilon\tilde{C}_{t-1}\right)^{1-\sigma_c}-\kappa_t L_t,\end{array}$$

where

$$L_t=\int_0^1 l_t\left(h\right)dh,$$

and $\tilde{C}_{t-1}$ represents past aggregate consumption, taken as exogenous by each individual household. In equilibrium, it must be the case that $\tilde{C}_t=C_t$. As in Smets and Wouters (2003), we introduce two preference shocks in the utility function: ξ_t, which affects the intertemporal elasticity of substitution and κ_t, a shock to labor disutility relative to the utility of consumption which later yields a shock to labor supply.

The household invests in capital:

$$K_{t+1}=(1-\delta)K_t+I_t-\phi\left(K_{t+1},K_t\right), \tag{2.18}$$

[4]Here, we assume a cashless limiting economy as in Woodford (2003).

where the convex adjustment costs are given by $\phi\left(K_{t+1}, K_t\right) = \frac{\Phi}{2}\frac{\left(K_{t+1}-K_t\right)^2}{K_t}$.

Frictions in financial markets create a wedge between the returns to domestic and foreign assets. As in Lindé et al. (2004), this risk premium is assumed to be a decreasing function of the country's net foreign asset position:

$$\Omega_t = \exp\left\{-\frac{\omega}{2\Upsilon}\frac{e_t B_t}{P_t} + \zeta_t\right\}, \tag{2.19}$$

where ζ_t is an exogenous shock and Υ is the steady state value of exports in units of domestic final goods $\left(\Upsilon = \frac{eP^x Q^x}{P}\right)$. This implies that households pay an increasing intermediation premium on their debt. Therefore**,** in a non stochastic steady state**, the** net foreign assets position is zero.[5]

The budget constraint is given by:

$$\begin{aligned} A_t + e_t B_t + P_t\left(C_t + I_t\right) &= T_t + \left(1 + i_{t-1}\right) A_{t-1} \\ &\quad + \left(1 + i_{t-1}^*\right)\Omega_{t-1} e_t B_{t-1} + R_t K_t \\ &\quad + \sum_{i=d,x,m}\int_0^1 \Pi_t^i(s)\, ds + \int_0^1\int_0^1 w_t(h)\, l_t(h;s)\, dh ds, \end{aligned}$$

where A_t and B_t are stocks of domestic and foreign assets at the end of period t and T_t is a monetary transfer from the monetary authorities. With probability $(1-\alpha_w)$, the HH is able to set the wage for type h labor, taking the average wage rate W_t as given and satisfying the demand for labor of each type:

$$\begin{aligned} l_t(h) &= \int_0^1 l_t(h;s)\, ds = \int_0^1 \psi^{-1}(1-\psi)\, w_t(h)^{-\frac{1+\gamma_t}{\gamma_t}} \left(W_t\right)^{\frac{1}{\gamma_t}} R_t K_t(s)\, ds \\ &= \psi^{-1}(1-\psi)\, w_t(h)^{-\frac{1+\gamma_t}{\gamma_t}} \left(W_t\right)^{\frac{1}{\gamma_t}} R_t K_t \end{aligned} \tag{2.20}$$

[5] The financial frictions generate a wedge between borrowing and lending to foreigners. This, together with the assumption that $\beta(1+i^*) = 1$, leads to an optimal choice of zero net foreign assets in a non-stochastic steady state.

simplified to

$$l_t(h) = \chi_t w_t(h)^{-\frac{1+\gamma_t}{\gamma_t}}. \tag{2.21}$$

The maximization problem is then

$$\begin{array}{ll} \max & E_0 \sum_{t=0}^{\infty} \beta^t \xi_t \left[\frac{\left(C_t - v\tilde{C}_{t-1}\right)^{1-\sigma_c}}{1-\sigma_c} - \kappa_t \int_0^1 \chi_t w_t(h)^{-\gamma} dh \right] \\ & T_t + (1+i_{t-1}) A_{t-1} + \left(1+i^*_{t-1}\right) \Omega_{t-1} e_t B_{t-1} + R_t K_t \\ s.t. & + \sum_{i=d,x,m} \int_0^1 \Pi^i_t(s)\, ds + \int_0^1 \chi_t w_t(h)^{-\frac{1}{\gamma_t}} dh \\ & = A_t + e_t B_t + P_t \left[C_t + K_{t+1} - (1-\delta) K_t + \phi(K_{t+1}, K_t)\right] \end{array}$$

which implies the following optimality conditions:

$$[C_t] \; : \; \xi_t U_{C,t} = \lambda_t P_t \tag{2.22a}$$

$$[A_t] \; : \; \lambda_t = (1+i_t)\, \beta E_t[\lambda_{t+1}] \tag{2.22b}$$

$$[B_t] \; : \; e_t \lambda_t = \beta (1+i^*_t)(\Omega_t + B_t \Omega_{B,t}) E_t[\lambda_{t+1} e_{t+1}] \tag{2.22c}$$

$$[K_{t+1}] \; : \; \lambda_t P_t \left(1+\phi_{1,t}\right) = \beta E_t \left\{ \lambda_{t+1} \left[R_{t+1} + P_{t+1} \left(1 - \delta - \phi_{2,t+1}\right)\right]\right\} \tag{2.22d}$$

$$[w_t(h)] \; : \; \begin{array}{l} 0 = \sum_{\tau=0}^{\infty} (\alpha_w \beta)^\tau E_t \left[\frac{1+\gamma_{t+\tau}}{\gamma_{t+\tau}} w_t(h)^{-\frac{1+\gamma_{t+\tau}}{\gamma_{t+\tau}} - 1} \kappa_{t+\tau} \xi_{t+\tau} \chi_{t+\tau} \right] \\ \qquad - \sum_{\tau=0}^{\infty} (\alpha_w \beta)^\tau E_t \left[\frac{1}{\gamma_{t+\tau}} w_t(h)^{-\frac{1+\gamma_{t+\tau}}{\gamma_{t+\tau}}} \lambda_{t+\tau} \chi_{t+\tau} \right] \end{array} \tag{2.22e}$$

and a wage index given by

$$(W_t)^{-\frac{1}{\gamma_t}} = \alpha_w (W_{t-1})^{-\frac{1}{\gamma_t}} + (1-\alpha_w)(w_t)^{-\frac{1}{\gamma_t}}. \tag{2.23}$$

2.4 Monetary authority

The model accounts for the monetary regime shift in Sweden after the 1992 crisis. The data set considered in this paper begins in 1980. Monetary policy between that year and the third quarter of 1992 is better described as a target zone regime. During this first part of the sample, we follow Svensson (1994) by explicitly modeling expectations of realignment and deviations from central parity. However, we depart from that paper by introducing an interest rate rule taking into account exchange rate deviations instead of deriving the optimal policy behavior.

After the ERM crisis of 1992, the Swedish authorities decided to let their currency float and enter a regime of explicit inflation targeting. In the floating regime, monetary policy is represented by a simple Taylor type rule with the interest rate responsive to inflation and output and interest rate smoothing.

2.4.1 Target zone

Following Svensson (1994), we write the exchange rate as $\hat{e}_t = \hat{e}_{c,t} + \hat{e}_{x,t}$, where $\hat{e}_{c,t}$ is the central parity exchange rate and $\hat{e}_{x,t}$ refers to the deviations of the exchange rate from central parity. It follows that expected realignments satisfy:

$$E_t \left[\hat{e}_{t+1} - \hat{e}_t\right] = E_t \left[\hat{e}_{c,t+1} - \hat{e}_{c,t}\right] + E_t \left[\hat{e}_{x,t+1} - \hat{e}_{x,t}\right]. \tag{2.24}$$

Realignment expectations have an endogenous component, here modeled as a linear response to the exchange rate deviations from central parity, and an exogenous component which follows an AR(1) process:

$$E_t \left[\hat{e}_{c,t+1} - \hat{e}_{c,t}\right] = g_t + \rho_x \hat{e}_{x,t} \tag{2.25}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_{g,t}. \tag{2.26}$$

Compared to a fully fixed exchange rate system, a target zone regime gives central banks more flexibility in the management of the exchange rate, thereby allowing monetary policy to be used for other purposes. Nevertheless, the central bank is constrained to use the policy instrument to also keep the exchange rate close to central parity and fight expectations of realignment. Therefore, we represent monetary policy by a modified Taylor rule taking into account the concern about exchange rate deviations from central parity:

$$\hat{\imath}_t = \rho_{m,TZ}\hat{\imath}_{t-1} + \left(1 - \rho_{m,TZ}\right)\left[\Gamma_{p,TZ}\left(\hat{P}_t - \hat{P}_{t-1}\right) + \Gamma_{y,TZ}\hat{Y}_t/4 + \frac{\Gamma_x}{(1-\rho_x)}\hat{e}_{x,t} + \varepsilon_{m,t}\right], \quad (2.27)$$

where $\hat{P}_t$ and $\hat{Y}_t$ are expressed as percentage deviations from steady state values, $\varepsilon_{i,t}$ is an i.i.d. shock to the rule, $\bar{\imath}_t$ is the target for the interest rate and $\hat{\imath}_t$ is defined by $\hat{\imath}_t \equiv \frac{i_t - i}{1+i_t}$. In this formula, the coefficient on the deviations from central parity has two terms to reflect the idea that there are two issues at stake in the interest rate response to $\hat{e}_{x,t}$: Γ_x is some measure of the importance of keeping the deviations from the central parity small; and $\frac{1}{1-\rho_x}$ conveys the idea that the stronger **is** the linkage between expectations of realignment and actual deviations from central parity, the more strongly should the central bank react to such deviations to curb the expectations of realignment.

Inserting (2.25) into (2.24) we get the expectations of depreciation:

$$E_t\left[\hat{e}_{t+1} - \hat{e}_t\right] = E_t\hat{e}_{x,t+1} + g_t - (1-\rho_x)\,\hat{e}_{x,t}; \quad (2.28)$$

an expression which will appear in the UIP relation for the target zone period.

2.4.2 Floating

In the floating period, the monetary authority is no longer constrained in its role of steering the economy. It is reasonable to expect that it might want to achieve greater interest rate smoothing, more aggressiveness in the reaction to the inflation and more responsiveness to output fluctuations. This will be part of the empirical question we are trying to address, namely to what extent the target zone limits central bank reactions to inflation and output changes as well as the degree of interest rate smoothing. At the same time, it has been empirically shown (e.g. Clarida, Galí, and Gertler (2001) and Lubik and Schorfheide (2003)) that the exchange rate does not play a quantitatively relevant role in setting monetary policy in the major industrialized countries. Hence, we model monetary policy through a standard log-linearized Taylor rule which does not depend on the exchange rate

$$\hat{\imath}_t = \rho_{m,FF}\hat{\imath}_{t-1} + \left(1 - \rho_{m,FF}\right)\left[\Gamma_{p,FF}\left(\hat{P}_t - \hat{P}_{t-1}\right) + \Gamma_{y,FF}\hat{Y}_t/4 + \varepsilon_{m,t}\right]. \tag{2.29}$$

Note that the two interest rate rules have coefficients that depend on the regime, precisely to allow for different coefficients on output, inflation and interest rate in the two regimes.

2.5 Equilibrium

The equilibrium in the domestic goods market requires that

$$Z_t = C_t + I_t, \tag{2.30}$$

$$K_t = \int_0^1 K_t(s)\,ds. \tag{2.31}$$

It is assumed that no foreigners hold domestic assets, so that in equilibrium:

$$A_t = 0. \tag{2.32}$$

Finally, in equilibrium, it is possible to recover the Balance of Payments equation from the budget constraint:

$$B_t = \left(1 + i^*_{t-1}\right)\Omega_{t-1}B_{t-1} + P^x_t Q^x_t - P^*_t Q^m_t. \tag{2.33}$$

There are eleven structural shocks in the economy: to preferences, productivity, Taylor rule (simply a white noise, $\varepsilon_{m,t}$), foreign prices, foreign demand, foreign interest rate, risk premium, labor supply, realignment expectations, price markup and wage markup. They follow stochastic processes given by:

$$z_t = (1 - \rho_z) + \rho_z z_{t-1} + \varepsilon_{z,t}, \tag{2.34}$$

for each shock z_t, except that the two markup shocks take the form

$$z_t = z + (1 + z)\,\varepsilon_{z,t}. \tag{2.35}$$

The model is solved and estimated in loglinear form around its deterministic steady state.[6][7]

3 Estimation

Following the seminal contribution of Obstfeld and Rogoff (1995),[8] researchers have, in recent years, created a workhorse model for open economy macroeconomic analysis. Key ingredients in this emerging literature are nominal rigidities, market imperfections and microfoundations, all embedded in a DSGE environment.[9]

Only more recently has the literature come to focus on empirically testing the implications of the new open economy macroeconomics. In between Ghironi (2000) and Adolfson, Lasén, Lindé, and Villani (2004), there are relatively few papers which test how reliable these models are on empirical grounds. One reason for this might be that this is a difficult task. Not until now have methods which make this feasible been developed and employed.

Ghironi (2000) uses both non-linear least squares and full maximum likelihood (ML) to estimate a two-country model with overlapping generations on Canadian and US data. Both Smets and Wouters (2002) and Lindé et al. (2004) estimate their models, on Euro and Swedish data respectively, minimizing the distance between empirical and model based impulse responses. Dib (2003), Ambler, Dib, and Rebei (2003) and Bergin (2003) adopt ML procedures to estimate small open economy models with nominal rigidities and different kinds of structural shocks.

The ML procedures can be understood as best practice, if feasible. The problem, though,

[6] The log-linearized equilibrium conditions are presented in Appendix A.

[7] We solve the model using the Matlab routine *gensys.m,* created by Christopher Sims.

[8] Actually, as pointed out by Sarno (2000), Svensson and van Wijnbergen (1989) deserves to be cited as a precursor of Obstfeld and Rogoff (1995).

[9] Both Lane (2001) and Sarno (2000) provide extensive surveys on this topic.

is that these models involve quite a large number of coefficients and highly non-linear likelihoods. Moreover, the data is not always perfect or available only for relatively short periods of time. Hence, it becomes crucial for the evaluation of these methods to measure how reliable the estimates are. This is where the increasingly popular approaches based on Bayesian Econometrics and MCMC methods can be of some help. These provide a way of simulating the entire likelihood, allowing for the measurement of different moments of the likelihood. This way, we can perform **a** proper inference of the likelihood. Furthermore, MCMC methods allow us to better evaluate how reliable are the modes provided by the maximization routines (because we can simulate draws of the different parameters and evaluate the likelihood value under the different draws) instead of the simple and ad-hoc procedure of starting the maximization routine with different guess values. Smets and Wouters (2003) have shown the advantages of using Bayesian techniques to estimate a DSGE closed economy model on Euro data. Adolfson et al. (2004) extend their work applying the same approach on an open economy model for the Euro area.

Following Smets and Wouters (2003), we estimate the model on Swedish data using the "strong econometric" interpretation of DSGE models. Rewriting the system in its state space form allows us to evaluate the likelihood function using the Kalman filter.[10] The model parameters are then estimated in a Bayesian framework. After forming the posterior density, we estimate its mode through numerical optimization methods. Then, we use an approximation around the posterior mode to generate a sample of MCMC draws to undertake a more extensive inference on the structural parameters, by characterizing the shape of the posterior distribution.

[10] More precisely, we proceed as follows. First, we set the state space form for the target zone period initializing the Kalman filter with mean zero and a diagonal covariance matrix with elements equal to 10. Then, we eliminate the last observation of the target zone subsample and the first of the free floating/inflation targeting to minimize the effects of breaks in the expectations in the theoretical model. We restart the Kalman filter for the second subsample with a mean equal to the values of the state variables of the last observation available for the target zone and a covariance matrix equal to the Mean Square Error (MSE) for those elements of that same observation, but multiplied by a factor of 1.5 squared to imply that there is some increase in uncertainty about the filter. For the iteration of the Kalman filter, we used the *kf.m* Matlab routine, created by Christopher Sims.

The following subsection describes our data. Subsection 3.2 describes the priors used and subsection 3.3 describes the MCMC methodology.

3.1 Data

Our data set contains quarterly data over the period 1980:1 - 2003:3. The data refers to Sweden and a foreign sector which is a composite of eight foreign countries among its major trading partners: Denmark, Finland,France, Germany, Italy, Japan, Netherlands, Norway, United Kingdom, and United States.[11] We limited the set of observables to the following ten series: foreign interest rate, foreign consumer price index (CPI), foreign output, domestic output, domestic CPI, domestic interest rate, nominal exchange rate, nominal wages, hours worked and consumption.

To construct foreign variables, we aggregate national variables according to the trade weights. In the nominal variables (CPI, interest rate and exchange rate), the US has double weight, in accordance with the actual basket which the Riksbank targeted in the first half of our sample. The argument explained in Franzén, Markowski, and Rosenberg (1980) is that most raw materials used to be priced in US dollars. Given that we have a general equilibrium model, we also use a double weight for prices and the interest rate, but not for real output (as the driving force behind the real demand for exports). We maintain the same weighting scheme through the second part of the sample to keep the model consistent.

All data series are logged and detrended using a linear trend. An exception is the interest rates, for which the gaps were defined as in the text, i.e. as the difference between the level and the trend divided by the gross interest rate value of the trend. The detrending process aims at making the theoretical model consistent with the data: in the theoretical model, we have deviations from steady state and thus, on the data side we should remove the major shifts, more associated with steady state changes, which are not explicitly modeled here. We start with the exchange rate process, i.e. the least standard one.

[11] Appendix B presents a more detailed description of the data set, including the data sources.

For the exchange rate, we must take into account that there are two regimes and the trend is therefore different. During a credible target zone, the trend should actually simply be a constant, except for revaluations and devaluations. In the case of the Swedish krona, Figure 1 reveals two devaluations, one in September 1981 and another in October 1982. After these devaluations and until 1992, the exchange rate was more or less constant and there was no clear trend of departure from central parity. We take central parity as the trend for this period. Therefore, the theoretical exchange rate deviations from steady state are empirically matched by the deviations from central parity. Central parity is also observable. However, we do not want to model the decision making process behind devaluations, so we consider the central parity variable to always be constant, despite the two devaluations actually observed. This is a simplification which could be considered in subsequent research. In the second quarter of 1991, central parity switched to be in terms of the ECU composite currency instead of the previous basket. This regime only lasted until the end of 1992. Since this is such a short time period and still a target zone regime, we simplify by assuming that the previous regime was still in place. This is another a simplification, but once more we consider this to be one first step in the analysis of the Swedish case. Therefore, we consider the target zone subsample to go through 1980:1 to 1992:4. For the free floating period, we compute a simple linear trend.

We computed a linear trend for the inflation rate in Sweden and the foreign inflation aggregate. For the price level, we used the inflation trend to accumulate recursively to the original price level in each period. For the interest rates, we subtracted the linear inflation trend and then subtracted the mean of the difference, which can be understood as the average real interest rate. Finally, for the wage rate, we computed real wages, a linear trend for this series and then compounded it with the linear trend for the price level of the economy.

3.2 Priors

In Bayesian estimation, priors fulfill two important purposes. The first is to incorporate information about some of the parameters of interest to narrow down the possible scope of search, thereby allowing for more precise estimation. In this sense, we are making a strict Bayesian updating on the previous available information. The modes can then be considered as reflecting previous calibrated or estimated values and the variances as reflecting our confidence in them. The second purpose of priors is to smooth the search and move it away from theoretically unacceptable parameter values that do not make any sense (like restricting the parameters to be positive). In setting the priors, we take these two purposes into account. The main properties of our prior distributions are presented in Table 1.

Technology, utility and price setting parameters are assumed to be Normal, Beta, whenever the parameter should vary in a range between zero and one, or Gamma, whenever parameters should be positive. Lindé (2003) calibrates the price elasticity of aggregate exports (η) for Sweden at 1, referring to the findings of Johansson (1998) who estimates this parameter at 1.3 for manufactured goods and at 0.7 for the services sectors. We use a prior distributed as a gamma with the mean at 1.12 and **a** standard error of 0.5 to imply that we are not very sure about this parameter. Apel, Friberg, and Hallsten (2001) provide a survey of Swedish firms according to which firms change their prices once a year. Therefore, for both the Calvo parameters α_p and α_w, we choose a beta distribution with the mode 0.75 and a standard error of 0.05, also similar to the priors in Smets and Wouters (2003). The prior for the risk aversion parameter is a Normal with mean 2, consistent with the calibrated value used by Kollmann (2001) and the value estimated by Lindé et al. (2004). In Smets and Wouters (2003), the prior for the habit persistence parameter (υ) is distributed as a beta with the mean 0.70, while Adolfson et al. (2004) have a prior with a lower mean, 0.65. We chose a beta with a mode 0.7 and the standard error 0.125. For the adjustments cost parameter Φ, we used a gamma with a mode of 15 according to the value used by Kollmann (2001). Lane and Milesi-Ferretti (2001) regress the interest rate differential on NFA/exports and estimate the financial frictions at 2.8. In our model, this would correspond to a ω of 0.0035, so this was used as the mode for our prior.

The priors for the monetary policy rule parameters are the same for the target zone and the free floating period. More precisely, we assume Γ_p and Γ_y to be distributed according to gammas with modes of 1.5 and 0.5. The prior for the interest rate smoothing parameter (ρ_m) is distributed as a beta with a mode of 0.8, while the Taylor rule parameter on the exchange rate (Γ_x) is a gamma with mode 2 and a standard error of 2. These parameters for Γ_x are to some extent based on the theoretical experiments and the empirical analysis by Svensson (1994). The mode for the coefficient for the endogenous part in the realignment expectations (ρ_x) is set at 0.35, based on Svensson's estimates of 1.4 for yearly data (but referred to as an upper limit).

All variances in the structural shocks are assumed to be distributed as inverted Gammas. Note, however, that for the observed shocks, the foreign variables, we ran simple AR processes to get an idea of the variance size and used it to calibrate the distributions as presented in tables. Finally, following Smets and Wouters (2003), we assume the autocorrelation coefficients of the shocks to follow a beta with a mean of 0.85 and a standard error of 0.1.

We chose to calibrate some parameters that are related to steady state levels and therefore difficult to pin down in our detrended data. More precisely, we set the discount factor, β, at 0.99 and the depreciation rate, δ, at 0.025. The fraction of the final goods expenditure that is made on domestic goods, α^d, is set to 0.7, so that the implied steady state imports GDP ratio is 30%. The technology parameter, ψ, is calibrated at 0.3, consistent with the value used in Lindé (2003) and Smets and Wouters (2003). As in Kollmann (2001), we refer to the estimates of Martins, Scarpetta, and Pilat (1996) to calibrate the steady state markup over marginal cost for intermediate good, ν, at 0.16; a value consistent with the estimate for the manufacturing sector in Sweden.

3.3 MCMC

A common problem in highly parametrized models is that it is usually impossible to directly infer the properties of the posterior. Thus, it is impossible to immediately characterize the estimates as well as any of their functions such as impulse response functions or variance decomposition. The obvious solution to this problem is to sample a given number of draws from the posterior and use these to characterize the desired statistics – this is the direct posterior simulation method as labeled in Gelman, Carlin, Stern, and Rubin (2004). In more complex models, however, direct simulation is no longer possible and it becomes necessary to employ iterative simulation algorithms. These start with a guess distribution for the posterior and through iterative jumping and an acceptance/rejection rule based on the true posterior, density converges into the true posterior distribution – this is the class of MCMC methods.

In this paper, we generate a sample of five parallel chains of 100,000 draws performing a Metropolis algorithm using a Normal as the jumping distribution. To initialize the MCMC procedure, we use importance resampling. First, we draw a sample of 1000 simulations from an approximate distribution based on a mixture of Normals with means equal to the posterior mode and variances equal to the inverse Hessian scaled, using four different factors. Then, we improve this approximation using importance resampling and using the results as starting points for the Metropolis algorithm. To ensure convergence, we twice updated the covariance matrix used for the jumping distribution. Each update was calculated after getting five different parallel chains of 100,000 draws, excluding the initial 10% and using every tenth draw. Both when using the Hessian and the updates of the covariance matrix, we multiplied them by a factor, as suggested in Gelman et al. (2004), to generate an acceptance ratio of about 23% for each chain. The results from the posterior estimation and MCMC draws are presented in table 1.

We monitored convergence by estimating the potential scale reduction ($\hat{R}$), and the effective number of independent draws for the group of five chains (mn_{eff}) as suggested in

Gelman et al. (2004). However, these statistics are mainly intended as a comparison of convergence across parallel chains, not within chains. To be more thorough, we followed the methods proposed in **Geweke (1999)** to compute the effective number of independent draws (n_{eff}) to monitor for within chain convergence. The aforementioned statistics are presented in Table 2. We complemented these tests with the separated partial means test also proposed in that paper as well as graphical analysis, which we are not presenting here but can provide upon request.

4 Results

How different is monetary policy under the two regimes? What is the relative importance of the different shocks in a small open economy under these two different monetary regimes? In this section, we present the results of our inference which try to answer these two questions. For this purpose, besides an analysis of the parameter estimates in the next subsection, we analyze the response of the main variables to the different structural shocks through an impulse response analysis in the following subsection and finally, the third subsection performs a variance decomposition analysis of the shocks. In the two latter parts, we only use 1000 draws and compute the 5th percentile, the 95th percentile and the median.

4.1 Parameter estimates

The results from the simulations, comparing prior with posterior moments, are reported in Table 1. The estimated monetary policy rules show interesting differences between the target zone and the inflation targeting period. It is noticeable that policy responded rather significantly to exchange rate deviations from central parity during the target zone period (a response of 90 annual basis points per percentage point of exchange rate deviation from central parity).[12] Another important result is that the policy coefficient on inflation is higher

[12] Γ_x has a mean of 3.58 and ρ_x a mean of 0.081 so that the coefficient on $e_{x,t}$ is 3.9, ignoring the interest rate smoothing. This is the relevant number if we want to compare the response of the interest rates to

under inflation targeting than under exchange rate targeting, as would be expected. Indeed, the mean of the coefficient is about 1.52 in the target zone and 2.2 in the inflation targeting period, thus quite significantly higher.

A third important component in the policy rules is the response to output. A priori, we would expect that in the target zone, under the pressure to pay more attention to the exchange rate, the monetary authority would not respond as aggressively to output variations as in an inflation targeting regime, assuming the latter to be a flexible inflation targeting regime. However, the results apparently show that while policy to some extent does react to output under the target zone period (mean of 0.54), it reacts very little in the period of inflation targeting (mean of 0.12). This seems to imply that during the inflation targeting period, the monetary authority is much more concerned with inflation stability than with the real economy. This finding is consistent with the Sveriges Riksbank Act, which states that the objective of monetary policy is to "maintain price stability" and suggests the attempt at rebuilding credibility and gaining the confidence of the general public. Another possible factor relevant for this analysis is that we are using output, not the output gap. It is possible that this distinction influences the estimates.

The remaining feature to be analyzed in the policy rules is the coefficient on interest rate smoothing. This is quite important because one minus this coefficient multiplies all the other coefficients and is thus relevant for the previous analysis. Regarding this coefficient, ρ_m, we can observe that its estimate is a typical one for the inflation targeting period (mean of 0.762), but that the estimate for the target zone period is higher (mean of 0.937). This implies that there is more interest rate smoothing during the target zone than during the inflation targeting period. One way of explaining this result is that the central bank preferred to keep the interest rate stable, unless there were changes in the exchange rate, to keep the

inflation, output and exchange rates. For the exact coefficient on $e_{x,t}$, we need to further multiply by $1-\rho_m$ which yields the coefficient of 0.226, but this number does not convey so much meaning in itself. Further, recall that this is the number for quarterly changes and therefore, 0.226 would be the effect on a quarterly interest rate not yet annualized. This implies that a 1% deviation in exchange rates from central parity would lead the annualized interest rates to move about 90 basis points, which is a significant impact.

target zone regime credible, thereby reacting less to domestic variables. Indeed, if we take into account the interest rate smoothing, the actual coefficient on inflation, $(1-\rho_m)\,\Gamma_p$, is 0.096 for the target zone period and 0.524 for the inflation targeting one so the gap between these two is actually larger than previously stated. The same calculation for the output coefficient, $(1-\rho_m)\,\Gamma_y$, yields 0.034 for the target zone period and 0.028 for the inflation targeting one; hence, the gap between the two is not as large as previously stated – but it is still clear that the inflation targeting regime is not too flexible towards output changes relative to inflation.

Another coefficient of significant interest is the sensitivity of the expected rate of re-alignment, ρ_x, which has a mean of 0.08 in our simulations. This is a lower value than in Svensson (1994), which presents values consistent with a quarterly coefficient around 0.3, but mentions that its estimate, obtained by ordinary least squares or instrumental variables, should be interpreted as an upper limit.

As for the other, regime independent, parameters, intertemporal elasticity of substitution, $1/\sigma_c$, is small and significantly less than one. This value, together with an estimated consumption habit parameter, υ, of 0.87 is higher than the estimates in Smets and Wouters (2003). The price elasticity of the foreign demand for the domestic good, η, is estimated at 1.96, thus considerably above the values estimated by Johansson (1998), but lower than the 3.0 obtained by Gottfries (2002). The estimated capital adjustment cost, Φ, has **a** mean 9.32, a value lower than that calibrated by Kollmann (2001), but more in line with the view according to which adjustment cost are economically relevant but modest in size.

The Calvo parameters, α_p and α_w, have the means 0.863 and 0.922, which imply that prices are changed slightly more often than every two years, while wages are set slightly less often than every three years. The level of wage rigidity is essentially the same as in Smets and Wouters (2004) for the Euro area in the period of 1983:1 to 2002:2, while the level of price rigidity is lower than their estimate for that same data set.

Finally, the shock processes are estimated to be quite persistent, except the technology and preference shocks, with estimated autocorrelation coefficients of 0.33 and 0.34.

4.2 Impulse response functions

In this subsection, we compare the reaction of some key variables of the Swedish economy to different shocks under the two regimes. These responses are shown in Figure 2 through Figure 12.[13] Our findings in this section can be summarized under five items. First, the responses to foreign shocks are generally stronger under the target zone regime than in the inflation targeting one. Second, domestic shocks seem to generate stronger responses of most variables in the inflation targeting regime. Third, foreign interest rate and risk premium shocks lead to stronger responses in the target zone period, precisely because monetary policy reacts to defend the exchange rate parity, channelling the shocks from the financial markets to the real economy with more strength. However, the response to a monetary shock is stronger in the inflation targeting regime and actually has very little real effects in the target zone regime (only the NFA seem to respond more significantly). Fourth, using the nominal interest rate, monetary policy reacts to most shocks in the inflation targeting period, except the risk premium and the foreign interest rate (it barely reacts to these), which are the only shocks leading to significant responses of the nominal interest rate in the target zone period (together with the expectations of realignment). This seems consistent with what we would expect in the two regimes: in the target zone regime, the authorities are essentially concerned with maintaining the exchange rate stability while under inflation targeting; they have the flexibility to react to the different shocks in the economy. Fifth, the external sector plays an important role in the economy. Exports account for about 30% of Sweden's GDP, and foreign demand seems to be rather price sensitive. Next, we analyze some of the responses in more detail.

An increase in the foreign interest rate (Figure 6) has a considerable effect on GDP, employment and capital accumulation in the target zone, but not under the inflation target-

[13] Responses are presented in percentage points. The shocks are set to one standard deviation. In the plots, we present the median and the bands are the 5th and 95th percentiles.

ing regime. On the other hand, the same shock induces a slightly larger real and nominal exchange rate depreciation under inflation targeting. This can be explained in the following way. In the inflation targeting regime, the interest rate does almost not react at all to the higher foreign interest rate. This leads to a depreciation in the short run, followed by a slight increase in exports and inflation, and therefore a slight increase in output and employment (barely noticeable). In the target zone period, the central bank instead wants to prevent a large depreciation, and thus substantially increases the domestic interest rate. This has contractionary effects, leading to lower output, employment, capital stock and real wages.

Similar differences arise for shocks to foreign demand (Figure 7) and foreign prices (Figure 5). In these two cases, the reason for the difference is not the same, however. Under the target zone, the exchange rate is essentially constant and therefore, these two shocks pass on to the economy at full force (notice the real depreciation in the case of the foreign price shock). In the case of flexible exchange rates and inflation targeting, the situation is different. Both higher foreign demand and higher foreign prices lead to a significant nominal and real appreciation of the Swedish krona, which significantly curtails the expansionary effects of the shocks. Furthermore, the nominal appreciation reduces inflation. To prevent a large fall in inflation, the monetary authority reduces the interest rate. The nominal appreciation in case of a foreign demand shock can be explained by the presence of pricing to market: as foreign demand expands, firms try to charge higher foreign prices without raising the domestic prices, which leads to the appreciation.

The risk premium shock (Figure 8) only plays a prominent role during the target zone period. The potential depreciation leads the authorities to push up the interest rate, which generates a contraction in the real economy. The same responses occur under a realignment expectations shock (Figure 10). In the inflation targeting period, only the inflation and the nominal and real exchange rates react to the risk premium shock.

The preference shock (Figure 2) to intertemporal substitution generates inflationary pressure. The Riksbank raises the interest rate much more during the inflation targeting regime than during the target zone regime.

A positive labor supply shock (Figure 9) changes the intratemporal substitution between labor and consumption. The shock produces the same qualitative effects on output, employment, capital accumulation and wages under both monetary regimes and this cost-push shock leads to stagflation if no action is taken. Indeed, this is what happens in the target zone period, so that there is a recession and inflation. In the inflation targeting period, the exchange rate is allowed to change and therefore, the necessary real exchange rate adjustment is more immediate. Instead of waiting for prices to slowly adjust, the exchange rate adjustment makes the exporters lose competitiveness much more quickly than in the target zone period, which forces the recession to take place sooner. As employment contracts, so does consumption. This strong short-run recession actually overruns the inflationary pressures in terms of domestic price index and inflation actually falls so that the interest rate is set at lower levels. Only as wages keep increasing and the real appreciation dissipates do the inflationary pressures occur more consistently, and the interest rate policy is eventually switched to a contractionary policy to curb inflation. Throughout the entire episode for the two regimes, capital stock falls significantly and very persistently.

A technology shock (Figure 3) generates qualitatively similar responses in output, employment, capital stock and inflation but once more, the magnitudes are not the same with much stronger responses in the inflation targeting regime. This is due to the fact that monetary policy reacts to the conditions closing the deflationary gap (in both low inflation and output – recall that potential output temporarily increases as productivity increases).

A monetary shock (Figure 4) is worth mentioning only in that it generates a stronger response in the flexible exchange rate period; as exchange rates are free to float and react, exports are more responsive (precisely because export prices change more) as does output and the remaining economy.

Finally, both markup shocks (Figures 11 and 12) are cost push shocks which lead to a stronger reaction of the central bank during the inflation targeting regime.

4.3 Variance decomposition

One of the main purposes of this paper is to establish the relative importance of the different shocks in the Swedish economy during the two periods. To achieve this, we perform a variance decomposition analysis, the results of which we present in Tables 3 through 8.[14]

The variance decomposition of output highlights the striking differences between the two regimes. During the target zone period, most of the output variability is explained by the shock to realignment expectations and, in the short run, by the risk premium shock. On a one-quarter and one-year horizon, these two shocks account for roughly 90% of the volatility of real output (with the expectations of realignment accounting for about 80%). On a five-year horizon, the expectations of realignment reduce their importance to 72% and the risk premium to only 4.6%. Of the remaining shocks, preference shocks and price markup seem to have some impact (about 3.5% and 2%, respectively) in the short run but in the long run, labor supply shocks are the most important shock after the realignment expectations, accounting for 17%.

By contrast, in the inflation targeting period, the risk premium is negligible as a source of output fluctuations. To find the main culprits of real business cycles in Sweden in this later period of flexible exchange rates and inflation targeting, we need to split the analysis into a short and a long run analysis. In the short run, monetary policy shocks and price markup shocks are the most important ones (36.5% and 28.7% in a one quarter horizon), while at a longer horizon, the most important shocks are related to labor supply (48.2%) and preferences (38.8%). This shows the usual effect of long-run money neutrality, but not short-run money non neutrality. One interesting fact is that technological shocks are never too important relative to other shocks, accounting for 9.1% of the real business cycle on a one-year horizon but only 4.6% on a one-quarter and 2.9% on a five-year horizon. At odds with the RBC paradigm, this result corroborates the findings of Gali (1999, 2004) according to which technology shocks are not a significant source of fluctuations in employment and

[14] Each element of the table presents the median followed by the 5th and 95th percentiles in parenthesis.

GDP for both the US and the Euro area.

The variance decomposition for the capital stock reveals that in the target zone period, the expectations of realignment and risk premium are even more important (above 95%), even in the long run. This is due to the strong responses of interest rates to those shocks, with subsequent repercussions on the cost of capital. For the inflation targeting period, the risk premium is once more negligible and the main factor of instability for capital is the preference shock with 47.1% on a quarterly basis, 66.7% on a yearly basis and 87.6% on a five-year basis. Secondary factors of instability for capital are monetary and price markup shocks in the short run, and labor supply shocks in the long run.

For the remaining productive factor, labor, the story is similar but now the influence of the expectations of realignment and risk premium is weakened as compared to the other two cases. Their combined effect is the strongest not on impact but on a yearly basis, when it roughly reaches about 84%. In the very short run, the technology shock is also an important driving force (12.8%) while in the long run, labor supply shocks assume a significant role (21%). During the inflation targeting period at a quarterly horizon, monetary shocks and price markup shocks are once more very important, but the first most important shock is now the technological one with a contribution of 28.5%. In the long run, the most important shocks for labor volatility are preference shocks (23.3%) and, mainly, labor supply shocks (60.6%).

These results are perfectly consistent with the impulse response analysis performed above. As highlighted by our estimated interest rate rules, during the target zone period, the Riksbank reacted aggressively to deviations of the exchange rate from central parity. A positive shock to the risk premium translates into a depreciation of the exchange rate to which the central bank reacts more strongly under the target zone period. This implies a larger and persistent decline in output, employment and capital accumulation.

The price markup shock explains most of the inflation variation under both monetary regimes in the short and medium horizons. In the five-year horizon, this is also true only under the target zone period, while in the inflation targeting period inflation volatility is mainly explained by preference shocks (45%) and once more, the price markup shock (39%).

Regarding the wage markup, it is interesting to note that in the target zone regime, the wage markup plays a major role only in the short run (78.1%), while the expectations of realignment makes a larger contribution at longer horizons (88.6% at a yearly horizon and 52.5% at a five-year horizon). Another shock with significant impact on wage volatility in the long run is the labor supply shock (36.5%). During the inflation targeting regime, the wage markup is once more the most important source of wage volatility only in the very short run (92.8% at a quarterly horizon, but only about 8% at a five-year horizon). The other sources of long-run wage volatility in the inflation targeting regime were preference shocks (63%) and labor supply shocks (24%).

Nominal exchange rate variability is entirely driven by the risk premium, realignment expectations and monetary shocks during the target zone, where monetary shocks play a residual role of about 8%. During inflation targeting, monetary shocks are the most important source of exchange rate instability at all time horizons with weights above 40% in the short run and 32.5% in the long run. In the short run, the second most important source of exchange rate instability is the risk premium shocks accounting for 26.7% but in the long run, their role is reduced to 10%. In the long run, two other volatility sources are more important: labor supply shocks, with 20.2%, and preference shocks, with 18.5%. Real exchange rate volatility is also mainly determined by realignment expectations in the target zone period and risk premium shocks with monetary shocks assuming a more residual role. In the inflation targeting period, monetary shocks are once more the main determinant, accounting for about 40% of the volatility in the short run and 35% in the long run. Other important determinants of the real exchange rate are risk premium, whose weight is higher in the short run (26.2% at a one-quarter horizon) and much smaller in the long run (12.5%). It should also be mentioned that, mainly in the long run, preference shocks and labor supply shocks are also very important sources of real exchange rate volatility in the inflation targeting period with weights of 13.6% and 26.3%, respectively.

Finally, foreign shocks do not seem to make any significant contributions to economic volatility in Sweden, in any regime or at any time horizon. This seems awkward, given that the Swedish economy is so open. Recalling the results from the impulse responses, however, we realize that the foreign sector does indeed play a very significant role in the economy. But it is not a source of the shocks, but rather as a propagation mechanism that the foreign sector is important. Foreign shocks may also have been small **as** compared to domestic shocks, at least in this sample.

5 Conclusions

In this paper, we estimate a small economy model on Swedish data using Bayesian techniques. An important novel innovation of the paper is to account for the monetary policy regime shift, occurring in 1992 after the speculative attack against the Swedish krona, and the consequent switch from a target zone regime to explicit inflation targeting. We explore the behavior of the Swedish economy across those two regimes, and its main sources of volatility.

One first finding is that in the inflation targeting period, monetary policy reacts to most shocks, except the risk premium and foreign interest rate (it barely reacts to these); on the contrary, these are the only shocks leading to significant responses of the nominal interest rate in the target zone period (together with the expectations of realignment). This seems consistent with a priori expectations: in the target zone, the authorities are essentially concerned with maintaining exchange rate stability, while under inflation targeting, they have the flexibility to react to different shocks. This interpretation is confirmed by the estimated coefficients of the interest rate rules. The policy rule in the target zone is highly responsive to the exchange rate. However, the inflation targeting regime does not seem too flexible, given that the coefficient on output in the policy rule is rather small.

Responses of variables to foreign shocks are generally stronger under exchange rate targeting than under inflation targeting, while domestic shocks seem to generate stronger responses in the inflation targeting regime. The foreign interest rate and risk premium shocks lead to stronger responses in the target zone period (precisely because monetary policy reacts to defend the exchange rate central parity, channelling the shocks from the financial markets to the real economy with more strength).

In terms of the contribution to the volatility of the economy, preference and labor supply shocks are two important sources in the long run, whereas monetary shocks are important in the short run, especially under inflation targeting. In the target zone period, the expectations of realignment and risk premium assume the predominant roles in generating economic volatility. One interesting fact is that technologic shock seems to account for very little of the overall variance, questioning the literature that uses technological shocks as the main source of real business cycles.

Finally, foreign shocks do not appear to be an important source of volatility in the economic variables in Sweden in any regime or time horizon. But the foreign sector is still very significant in the economy as must be the case when exports account for about 30% of the GDP. Rather than a source of the shocks, the foreign sector plays its role in the propagation of other shocks throughout the economy.

Overall, our results seem quite satisfactory with a few exceptions. The estimated degree of price and wage rigidity is too high and the response of output after a monetary policy shock is not as hump shaped as in many other empirical studies. We explicitly choose not to model the reasons behind changes in central parity and we only focus on the expectations of realignment. Following Svensson (1994), the endogenous part of this expectation is simply a function of deviation of the exchange of central parity. We leave the possibility of a deeper analysis of both endogenous and exogenous components of such expectations to future research. Furthermore, the policy rule in the inflation targeting regime is modeled as a Taylor rule. This is just a first approximation, given that trying to derive optimal policy would burden the estimation process.

Given the high number of parameters and the limited amount of data, we have chosen to only vary parameters of the Taylor rules across the two subsamples. It would be interesting to evaluate the variation of other parameters across the two regimes to search for empirical evidence for the "Lucas critique". For example, it would be interesting to allow for a different degree of exchange rate pass-through or a different volatility in the risk premium shocks under the two different exchange rate regimes.

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A Log-linearized equations

In this section we present all log-linearized expressions, using the notation of $\hat{X}_t = \ln(X_t/X)$.

$$\hat{Z}_t = \alpha_d \hat{Q}_t^d + (1-\alpha_d)\hat{Q}_t^m \tag{A.1}$$

$$\hat{Q}_t^d = \hat{P}_t + \hat{Z}_t - \hat{P}_t^d \tag{A.2}$$

$$\hat{Q}_t^m = \hat{P}_t + \hat{Z}_t - \hat{P}_t^m \tag{A.3}$$

$$\hat{Q}_t^x = -\eta\left(\hat{P}_t^x - \hat{P}_t^*\right) + \hat{Y}_t^* \tag{A.4}$$

$$\hat{Y}_t = \frac{\alpha_d(1+\nu)}{\alpha_d(1+\nu)+(1-\alpha_d)}\hat{Q}_t^d + \frac{1-\alpha_d}{\alpha_d(1+\nu)+(1-\alpha_d)}\hat{Q}_t^x \tag{A.5}$$

$$\hat{Y}_t = \hat{\theta}_t + \hat{K}_t + (1-\psi)\left(\hat{R}_t - \hat{W}_t\right) \tag{A.6}$$

$$\widehat{L}_t = \widehat{R}_t + \widehat{K}_t - \widehat{W}_t \tag{A.7}$$

$$\hat{P}_t = \alpha_d \hat{P}_t^d + (1-\alpha_d)\hat{P}_t^m \tag{A.8}$$

$$\begin{aligned}\left(1+\alpha_p^2\beta\right)\hat{P}_t^d &= \alpha_p \hat{P}_{t-1}^d + \alpha_p\beta E_t \hat{P}_{t+1}^d \\ &\quad + (1-\alpha_p)(1-\alpha_p\beta)\left[-\hat{\theta}_t + \psi\hat{R}_t + (1-\psi)\hat{W}_t + \hat{\nu}_t\right]\end{aligned} \tag{A.9}$$

$$\begin{aligned}\left(1+\alpha_p^2\beta\right)\hat{P}_t^x &= \alpha_p \hat{P}_{t-1}^x + \alpha_p\beta E_t \hat{P}_{t+1}^x \\ &\quad + (1-\alpha_p)(1-\alpha_p\beta)\left[-\hat{\theta}_t + \psi\hat{R}_t + (1-\psi)\hat{W}_t - \hat{e}_t + \hat{\nu}_t\right]\end{aligned} \tag{A.10}$$

$$\left(1+\alpha_p^2\beta\right)\hat{P}_t^m = \alpha_p \hat{P}_{t-1}^m + (1-\alpha_p)(1-\alpha_p\beta)\left[\hat{e}_t + \hat{P}_t^* + \hat{\nu}_t\right] + \alpha_p\beta E_t \hat{P}_{t+1}^m \tag{A.11}$$

$$\begin{aligned}\left(1+\alpha_w^2\beta\right)\hat{W}_t &= \alpha_w \hat{W}_{t-1} + \alpha_w\beta E_t \hat{W}_{t+1} + (1-\alpha_w)(1-\alpha_w\beta) \\ &\quad \left[\hat{\gamma}_t + \hat{\kappa}_t + \hat{P}_t + \sigma_c(1-\upsilon)^{-1}\left(\hat{C}_t - \upsilon\hat{C}_{t-1}\right)\right]\end{aligned} \tag{A.12}$$

$$0 = \hat{\imath}_t + E_t\hat{\xi}_{t+1} - \hat{\xi}_t - \left(E_t\hat{P}_{t+1} - \hat{P}_t\right) - \frac{\sigma_c}{(1-\upsilon)}\left[E_t\hat{C}_{t+1} - (1+\upsilon)\hat{C}_t + \upsilon\hat{C}_{t-1}\right] \tag{A.13}$$

$$\begin{aligned}\hat{\imath}_t &= \left(E_t\hat{P}_{t+1} - \hat{P}_t\right) + [1-\beta(1-\delta)]\left(E_t\hat{R}_{t+1} - E_t\hat{P}_{t+1}\right) + \Phi\beta E_t\hat{K}_{t+2} \\ &\quad -\Phi(1+\beta)\hat{K}_{t+1} + \Phi\hat{K}_t\end{aligned} \tag{A.14}$$

$$\hat{B}_t = \beta^{-1}\hat{B}_{t-1} + \hat{P}_t^x + \hat{Q}_t^x - \hat{P}_t^* - \hat{Q}_t^m \tag{A.15}$$

$$\hat{Z}_t = \left(1 - \delta \frac{K}{Z}\right) \hat{C}_t + \frac{K}{Z} \left[\hat{K}_{t+1} - (1-\delta)\hat{K}_t\right] \tag{A.16}$$

$$\hat{\imath}_t = \hat{\imath}^*_t + E_t \hat{e}_{t+1} - \hat{e}_t - \omega \hat{B}_t + \zeta_t \text{ (Free Floating)} \tag{A.17}$$

$$\hat{\imath}_t = \hat{\imath}^*_t + g_t + E_t \hat{e}_{t+1} + (\rho_x - 1)\hat{e}_t - \omega \hat{B}_t + \zeta_t \text{ (Target Zone)} \tag{A.18}$$

$$\begin{aligned} \hat{\imath}_t \;=\; & \left(E_t \hat{P}_{t+1} - \hat{P}_t\right) + \left[1 - \beta(1-\delta)\right]\left(E_t \hat{R}_{t+1} - E_t \hat{P}_{t+1}\right) + \Phi \beta E_t \hat{K}_{t+2} \\ & -\Phi(1+\beta)\hat{K}_{t+1} + \Phi \hat{K}_t \end{aligned} \tag{A.19}$$

$$\hat{\imath}_t = \rho_{m,FF} \hat{\imath}_{t-1} + \left(1 - \rho_{m,FF}\right)\left[\Gamma_{p,FF}\left(\hat{P}_t - \hat{P}_{t-1}\right) + \Gamma_{y,FF} \hat{Y}_t/4 + \varepsilon_{m,t}\right] \text{(Free floating)} \tag{A.20}$$

$$\hat{\imath}_t = \rho_{m,TZ} \hat{\imath}_{t-1} + \left(1 - \rho_{m,TZ}\right)\left[\Gamma_{p,TZ}\left(\hat{P}_t - \hat{P}_{t-1}\right) + \Gamma_{y,TZ} \hat{Y}_t/4 + \frac{\Gamma_x}{(1-\rho_x)} \hat{e}_{x,t} + \varepsilon_{m,t}\right] \text{(Target Zone)} \tag{A.21}$$

$$\hat{\xi}_t = \rho_\xi \hat{\xi}_{t-1} + \varepsilon_{\xi,t} \tag{A.22}$$

$$\hat{\theta}_t = \rho_\theta \hat{\theta}_{t-1} + \varepsilon_{\theta,t} \tag{A.23}$$

$$\hat{P}^*_t = \rho_p \hat{P}^*_{t-1} + \varepsilon_{p,t} \tag{A.24}$$

$$\hat{Y}^*_t = \rho_y \hat{Y}^*_{t-1} + \varepsilon_{y,t} \tag{A.25}$$

$$\hat{\imath}^*_t = \rho_i \hat{\imath}^*_{t-1} + \varepsilon_{i,t} \tag{A.26}$$

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \varepsilon_{\zeta,t} \tag{A.27}$$

$$\hat{\kappa}_t = \rho_\kappa \hat{\kappa}_{t-1} + \varepsilon_{\kappa,t} \tag{A.28}$$

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \varepsilon_{g,t} \tag{A.29}$$

$$\widehat{\nu}_t = \varepsilon_{\nu,t} \tag{A.30}$$

$$\widehat{\gamma}_t = \varepsilon_{\gamma,t} \tag{A.31}$$

B Data

The series were collected through the DRI-Webstract from the IMF International Financial Statistics database.

For the interest rate, we used the series L60C, which refers to the treasury bills rate or the equivalent. Due to the lack of that series for Norway, Japan and Finland, we use the money market rate, series L60B. For Denmark, we used the series of 3 month treasury bills from the Danish MONA data bank. For Sweden, the series L60B is discontinued from 2002 onwards and thus, we decided to use the series L60A which corresponds to the Repo rate used in the open market operations.

For the exchange rates, we used the series LAE, which represents the end of period nominal exchange rate of each national currency per USD.

For the price levels, we used L64, referring to the Consumer Price Index (CPI).

We collected data for the nominal GDP through series L99B, which was not seasonally adjusted for Sweden, Norway and Finland and seasonally adjusted (SA) for all the remaining countries. For converting this into real GDP, we collected series for the GDP deflator with a base year in 1995, series L99BI (once more SA for all except those three countries). Then, we generated the series of real GDP. For the series that were not seasonally adjusted, we used the X12 filter incorporated in the Eviews econometric package (using additive method – the multiplicative method was tried and essentially yielded the same results). While plotting the series for the nominal GDP series for Great Britain and France, we also noticed some seasonality at the end of the sample which might be due to some problem in the data; hence, we decided to **also** run the X12 filter on these series. Note that for the deflator of Norway, there was not much evidence of seasonal adjustment but nevertheless, we used the filter to keep it consistent across series. For Denmark, the IMF/IFS data was incomplete and therefore we used the real GDP from the Danish MONA data bank (also with a deflator base in 1995). The series was originally in annualized terms (multiplied by 4), which we reversed.

For the wage in Sweden, we used a hourly wages series created by Kent Friberg for the Sveriges Riksbank (for more information about this series, we refer to Friberg (2003)). The series was seasonally adjusted using the same method as for the other variables already mentioned.

The exchange rate is defined as the number of Swedish kronor per foreign currency.

The trade weights were obtained from two different sources. For the first part of the sample, we have exact weights provided in Lindberg and Soderlind (1994) and for the second part, we got the weights from the Swedish National Institute of Economic Research. The methodologies are slightly different but hopefully similar enough for us to be able to apply the weights at the same time since they are the only ones available. All weights are computed yearly in April. For the first part of the sample, Lindberg and Soderlind (1994) mention that the weights take effect in the second quarter of each year; hence, we keep the same periodicity over the entire sample. Given that we do not have the weights for the last year, 2002, we will use the weights of 2001 for that year.

C Tables and Figures

Figure 1: Swedish krona

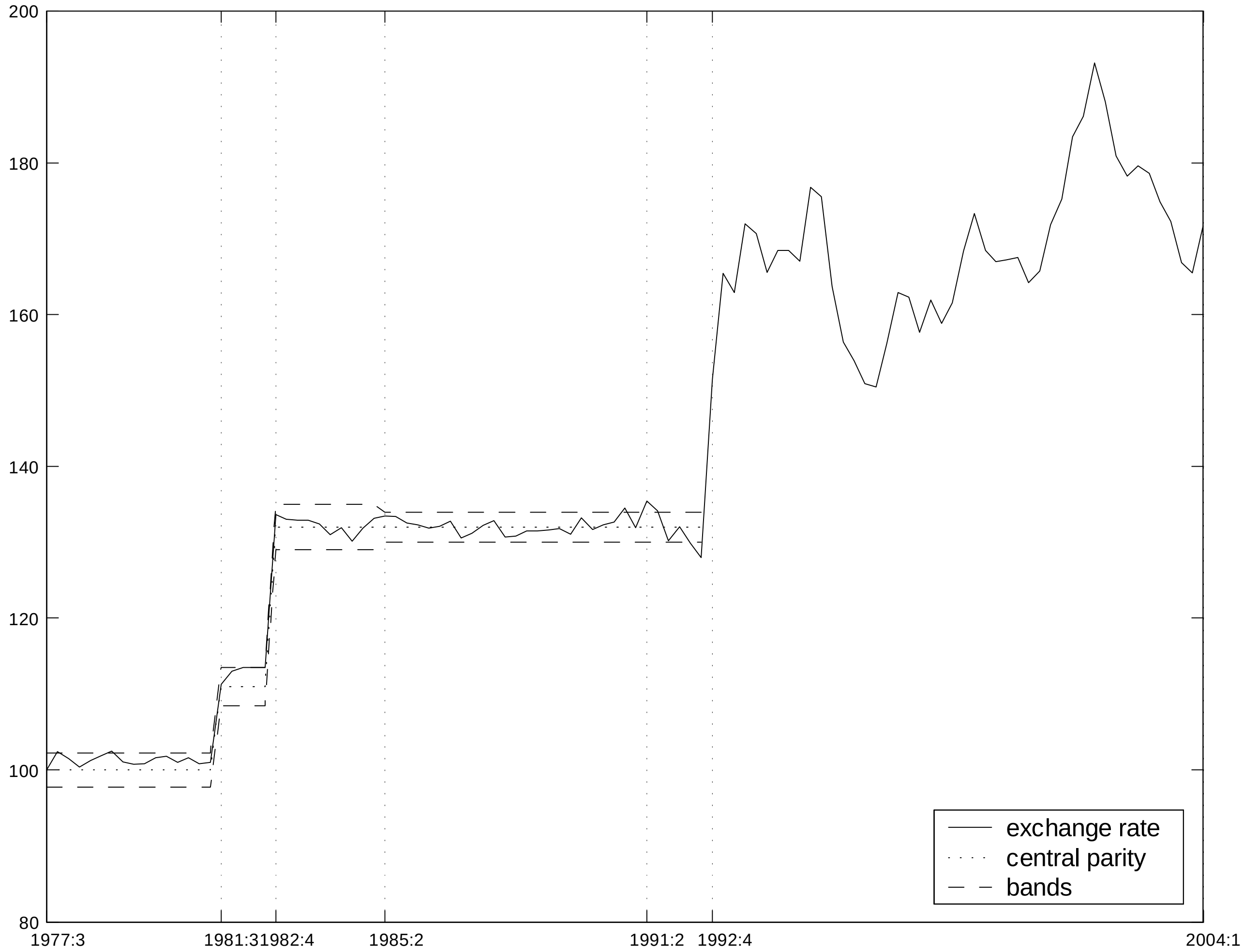

Table 1: Parameter Estimates

	Prior						Posterior					
	Dist.	Mean	SE	2.5%	Median	97.5%	Mode	Mean	SE	2.5%	Median	97.5%
η	gamma	1.1227	0.5	0.367	1.049	2.294	1.9708	1.9637	0.2097	1.5757	1.955	2.3998
α_p	beta	0.7434	0.05	0.64	0.746	0.835	0.8633	0.863	0.0101	0.843	0.8632	0.8823
α_w	beta	0.7434	0.05	0.64	0.746	0.835	0.918	0.9215	0.0136	0.8921	0.9225	0.9452
σ_c	normal	2	0.4	1.216	2	2.784	1.9684	2.0618	0.3595	1.3683	2.0594	2.773
Φ	gamma	24.2702	15	4.275	21.26	61.277	8.9347	9.3234	1.6991	6.4184	9.1713	13.0467
υ	beta	0.7	0.1	0.488	0.707	0.874	0.8795	0.8689	0.031	0.8009	0.8718	0.9214
ω	gamma	0.0038	0.001	0.002	0.004	0.006	0.0037	0.004	0.001	0.0023	0.0039	0.0061
$\Gamma_{p,TZ}$	gamma	1.5406	0.25	1.09	1.527	2.068	1.4711	1.5247	0.2418	1.0912	1.5115	2.0351
$\Gamma_{p,FF}$	gamma	1.5406	0.25	1.09	1.527	2.068	2.1169	2.2009	0.197	1.8469	2.1893	2.6213
$\Gamma_{y,TZ}$	gamma	0.6035	0.25	0.217	0.569	1.183	0.4513	0.5407	0.2231	0.196	0.5108	1.0658
$\Gamma_{y,FF}$	gamma	0.6035	0.25	0.217	0.569	1.183	0.0971	0.1189	0.0465	0.0447	0.1134	0.2243
Γ_x	gamma	3.2361	2	0.57	2.835	8.17	2.9984	3.5776	1.412	1.6432	3.3168	7.0137
$\rho_{m,TZ}$	beta	0.8028	0.1	0.574	0.817	0.955	0.937	0.937	0.0233	0.8831	0.9404	0.9724
$\rho_{m,FF}$	beta	0.8028	0.1	0.574	0.817	0.955	0.7667	0.7615	0.0419	0.6694	0.7647	0.8337
ρ_x	beta	0.2353	0.1	0.073	0.225	0.457	0.0638	0.081	0.0394	0.0226	0.075	0.172

Table 1: Parameter Estimates (continued)

	Prior						Posterior					
	Dist.	Mean	SE	2.5%	Median	97.5%	Mode	Mean	SE	2.5%	Median	97.5%
ρ_ξ	beta	0.85	0.1	0.608	0.87	0.983	0.3285	0.3382	0.0645	0.2174	0.3366	0.469
ρ_θ	beta	0.85	0.1	0.608	0.87	0.983	0.298	0.3262	0.0987	0.1535	0.3195	0.5326
ρ_p	beta	0.85	0.1	0.608	0.87	0.983	0.9924	0.9913	0.0028	0.9846	0.9918	0.9955
ρ_y	beta	0.85	0.1	0.608	0.87	0.983	0.8581	0.8537	0.0351	0.7815	0.8549	0.919
ρ_i	beta	0.85	0.1	0.608	0.87	0.983	0.921	0.9166	0.0298	0.8552	0.9179	0.9709
ρ_ζ	beta	0.85	0.1	0.608	0.87	0.983	0.7217	0.7091	0.048	0.6076	0.712	0.795
ρ_κ	beta	0.85	0.1	0.608	0.87	0.983	0.981	0.9789	0.0111	0.9539	0.9801	0.9963
ρ_g	beta	0.85	0.1	0.608	0.87	0.983	0.9758	0.9725	0.0127	0.9444	0.9736	0.9938
σ_ξ	i-gamma	0.1	0.1	0.028	0.075	0.323	0.3098	0.3155	0.0736	0.2001	0.3056	0.4892
σ_θ	i-gamma	0.1	0.1	0.028	0.075	0.323	0.0188	0.0193	0.0016	0.0165	0.0192	0.0226
σ_m	i-gamma	0.1	0.1	0.028	0.075	0.323	0.0052	0.0055	0.0006	0.0044	0.0054	0.0068
σ_p	i-gamma	0.005	0.1	0.001	0.003	0.021	0.0046	0.0047	0.0004	0.004	0.0046	0.0054
σ_y	i-gamma	0.005	0.1	0.001	0.003	0.021	0.0053	0.0053	0.0004	0.0046	0.0053	0.0062
σ_i	i-gamma	0.005	0.1	0.001	0.003	0.021	0.001	0.001	0.0001	0.0009	0.001	0.0012
σ_ζ	i-gamma	0.1	0.1	0.028	0.075	0.323	0.0181	0.0196	0.0025	0.0153	0.0194	0.0249
σ_κ	i-gamma	0.1	0.1	0.028	0.075	0.323	0.0485	0.0566	0.0112	0.0385	0.0552	0.0825
σ_ν	i-gamma	0.1	0.1	0.028	0.075	0.323	0.338	0.3479	0.0513	0.2609	0.343	0.463
σ_γ	i-gamma	0.1	0.1	0.028	0.075	0.323	1.3906	1.6525	0.5182	0.8771	1.571	2.8828
σ_g	i-gamma	0.1	0.1	0.028	0.075	0.323	0.0102	0.0111	0.0018	0.0081	0.0109	0.015

Table 2: Convergence

	$\hat{R}$	mn_{eff}	$n_{eff}(1)$	$n_{eff}(2)$	$n_{eff}(3)$	$n_{eff}(4)$	$n_{eff}(5)$
η	1.0008	2878	502	576	578	512	479
α_p	1.0006	3756	467	472	541	466	673
α_w	1.0013	1795	429	379	442	239	382
σ_c	1.0023	1067	434	668	370	510	604
Φ	1.0023	1084	483	454	561	522	708
υ	1.0007	3475	317	258	407	333	585
ω	1.0004	5439	516	635	431	476	706
$\Gamma_{p,TZ}$	1.0006	3654	520	530	898	822	453
$\Gamma_{p,FF}$	1.0003	7290	552	364	579	697	614
$\Gamma_{y,TZ}$	1.0006	3856	631	624	715	498	478
$\Gamma_{y,FF}$	1.0021	1137	505	332	897	528	617
Γ_x	1.0026	961	334	328	285	218	316
$\rho_{m,TZ}$	1.0025	978	314	413	320	277	330
$\rho_{m,FF}$	1.0006	3851	716	475	415	401	489
ρ_x	1.002	1241	452	525	592	559	506
ρ_ξ	1.001	2334	682	486	446	410	555
ρ_θ	1.0006	3869	480	440	624	625	350
ρ_p	1.0017	1432	282	192	367	299	431
ρ_y	1.0001	14910	585	396	483	488	678
ρ_i	1.0008	2938	478	438	817	449	461
ρ_ζ	1.0005	4276	498	467	448	536	340
ρ_κ	1.0004	5206	619	379	503	535	666
ρ_g	1.0003	7365	613	678	568	648	598
σ_ξ	1.0016	1523	297	329	532	229	373
σ_θ	1.0013	1889	545	403	919	375	402
σ_m	1.0007	3529	580	512	874	679	648
σ_p	1.0007	3262	428	540	443	570	710
σ_y	1.0017	1424	606	610	492	392	559
σ_i	1.0012	1931	702	506	739	468	718
σ_ζ	1.0002	9355	389	469	394	756	387
σ_κ	1.0001	13308	526	346	290	308	678
σ_ν	1.0013	1891	410	643	504	393	531
σ_γ	1.0006	3634	344	269	441	242	403
σ_g	1.0004	6046	372	492	558	454	490

Figure 2: Responses to a preference shock

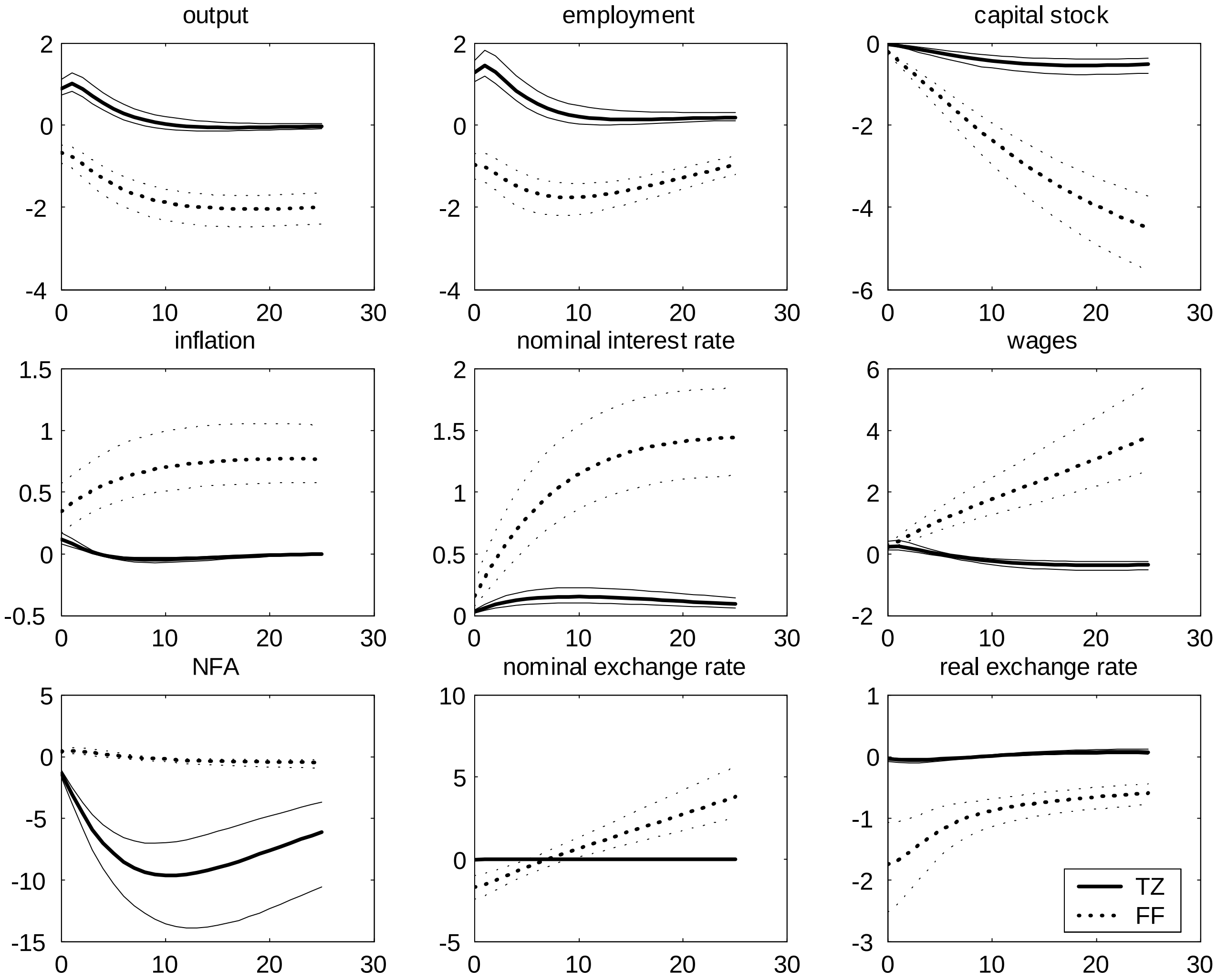

Figure 3: Responses to a technology shock

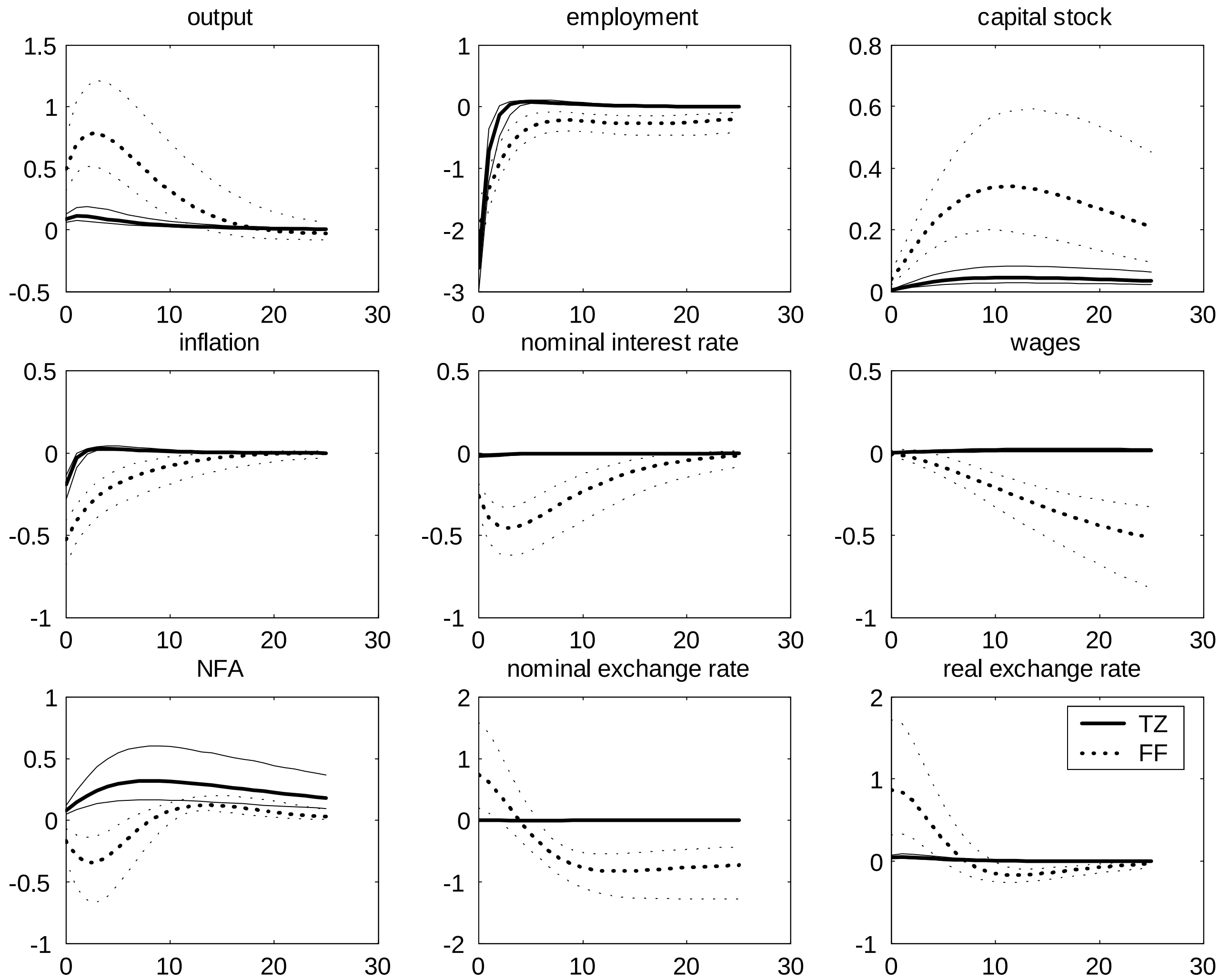

Figure 4: Responses to a monetary shock

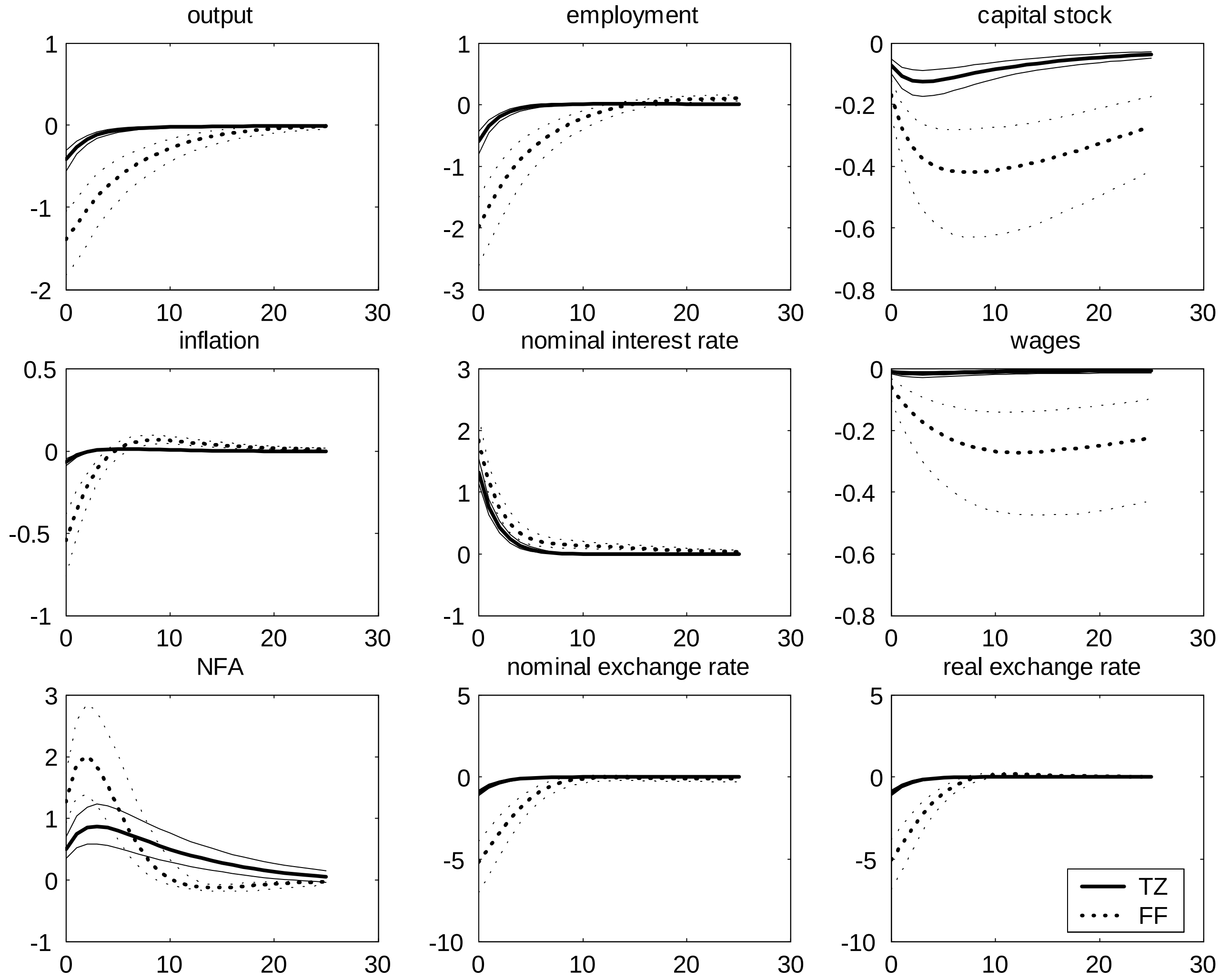

Figure 5: Responses to a foreign price shock

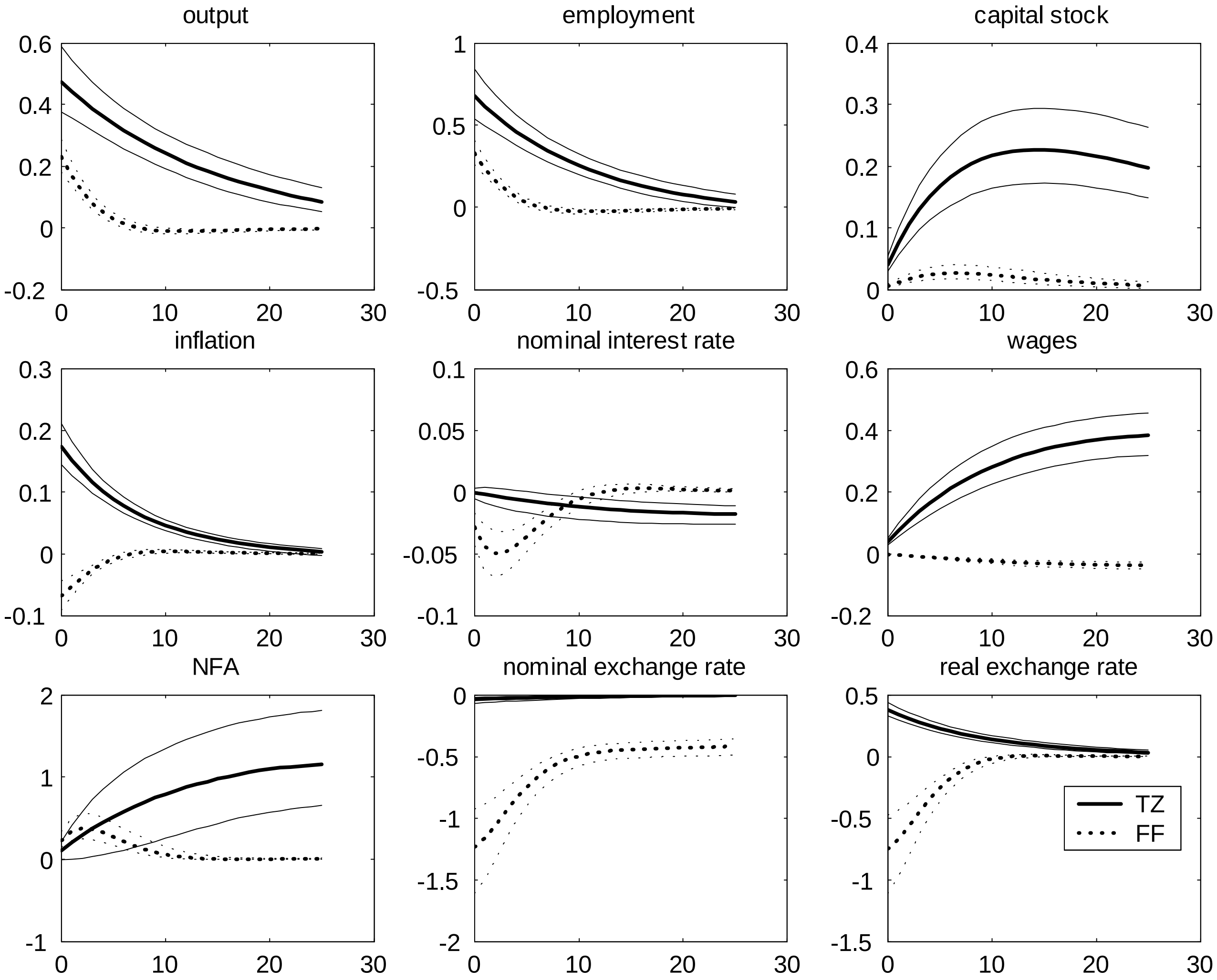

Figure 6: Responses to a foreign interest rate shock

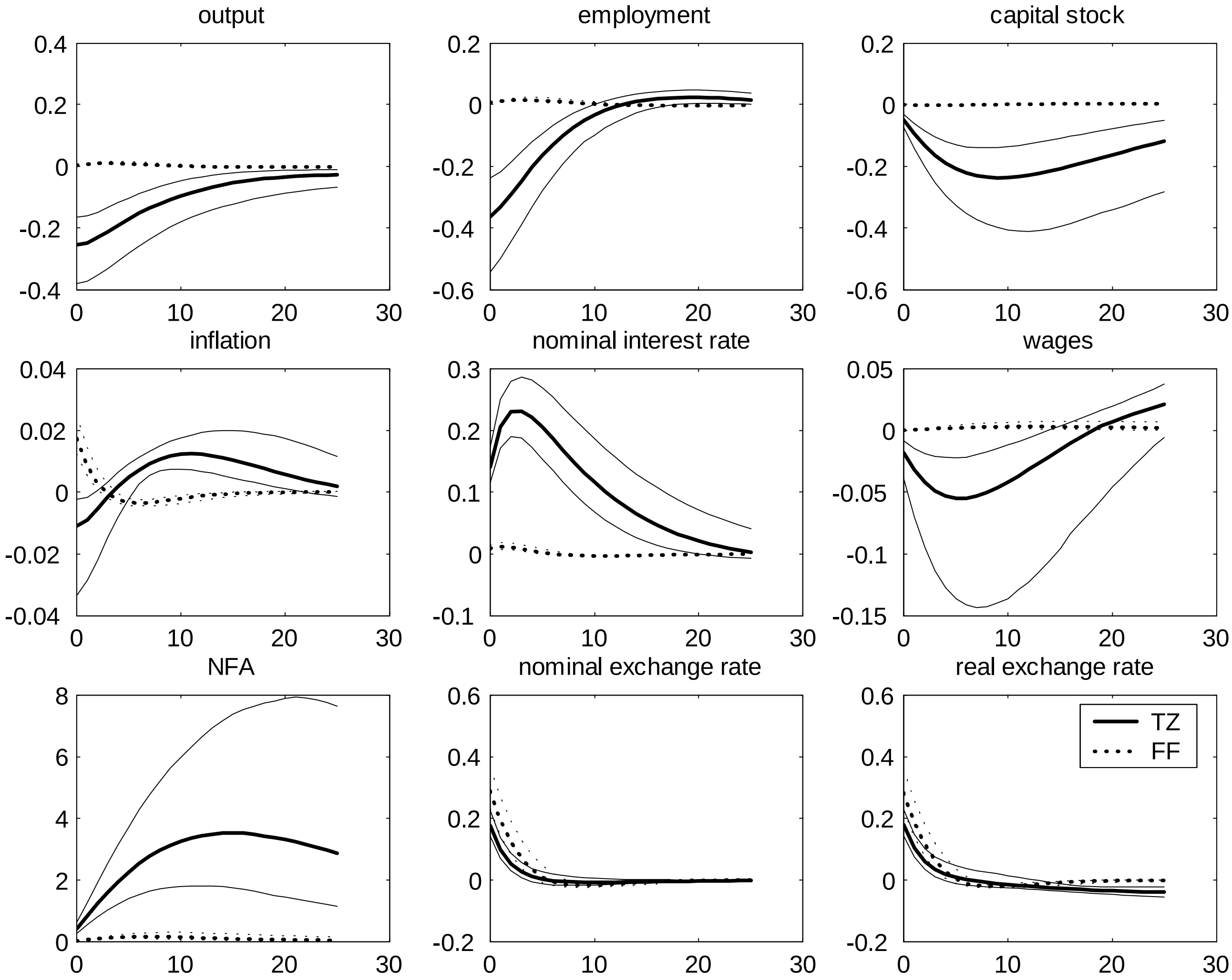

Figure 7: Responses to a foreign output shock

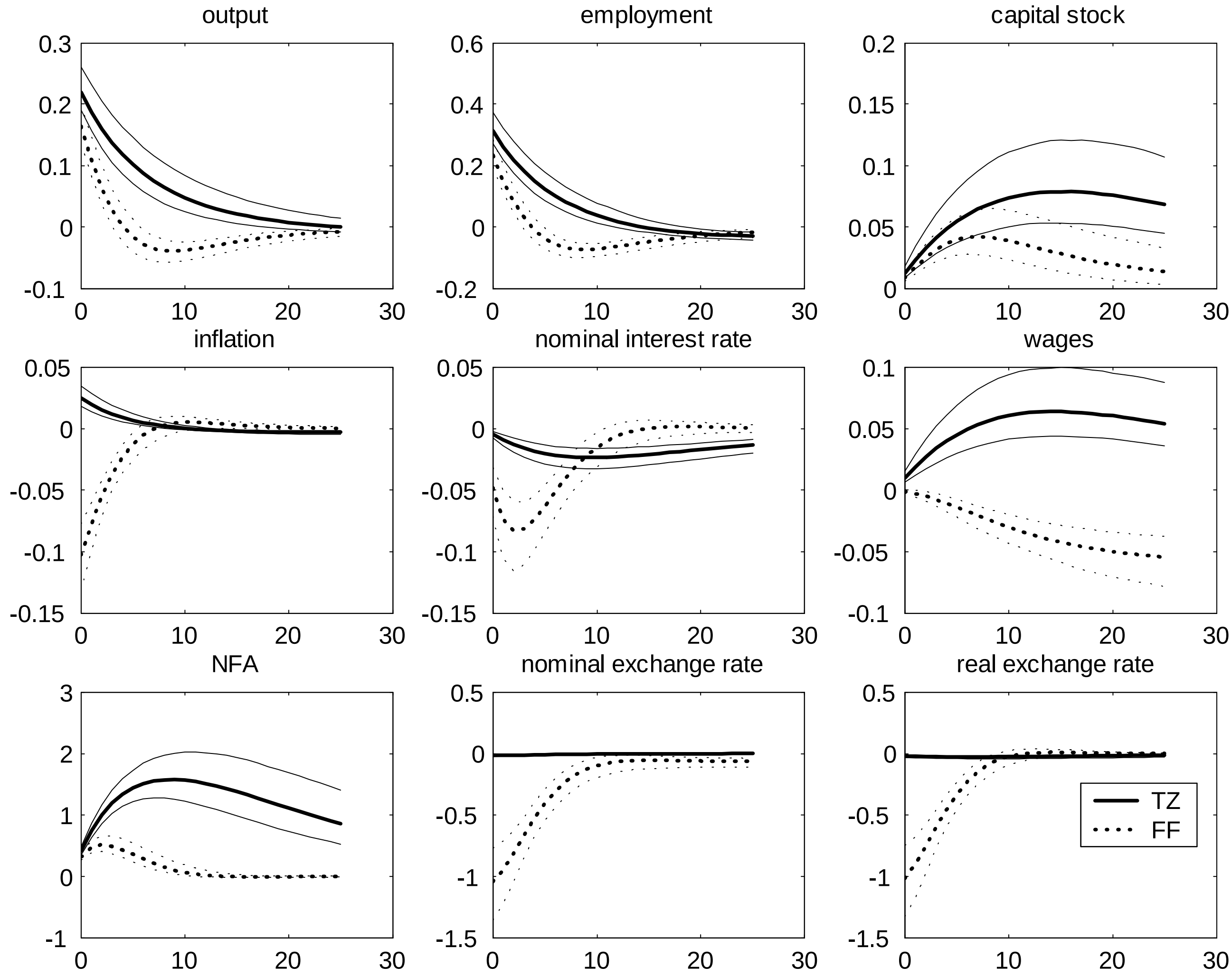

Figure 8: Responses to a risk premium shock

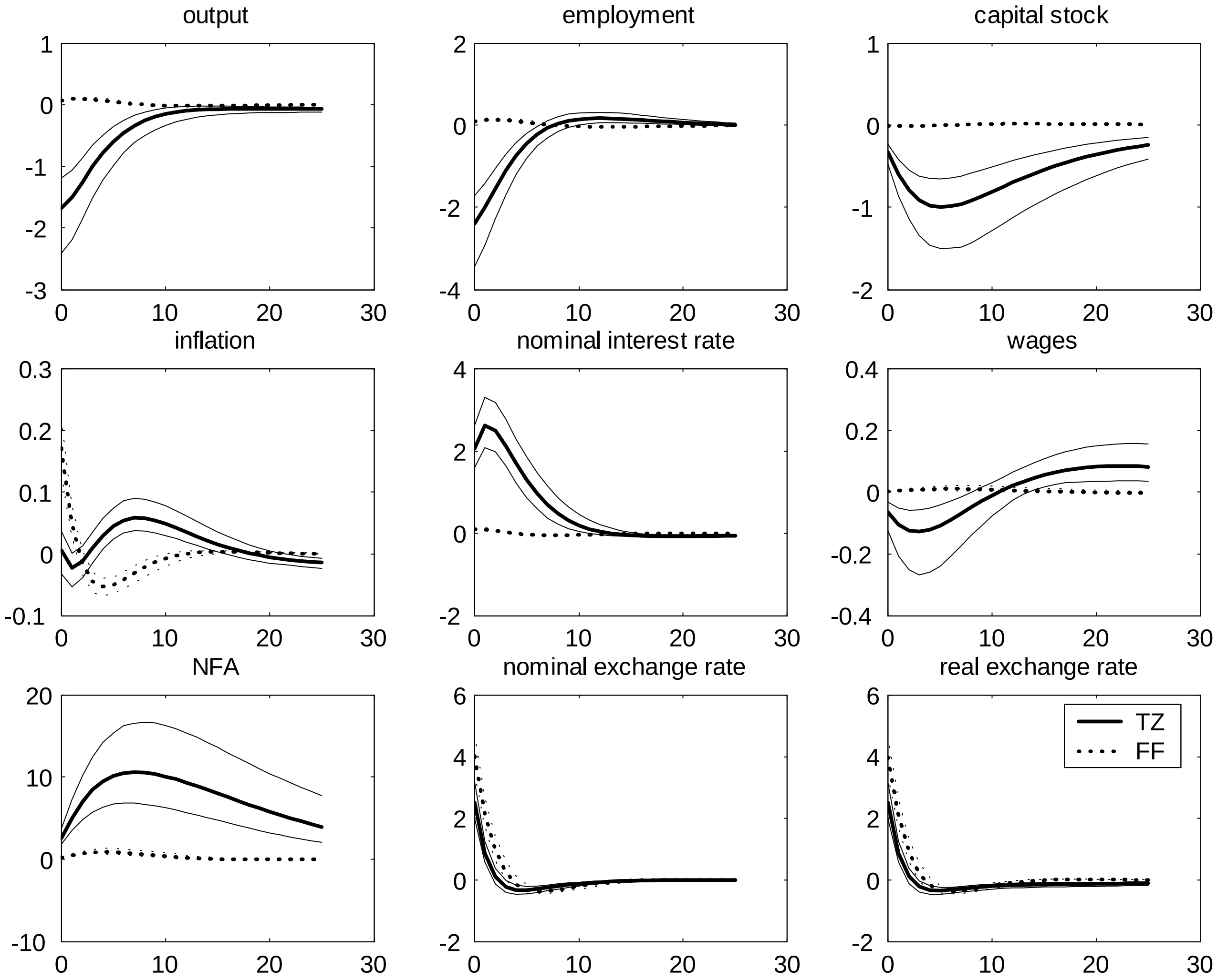

Figure 9: Responses to a labor supply shock

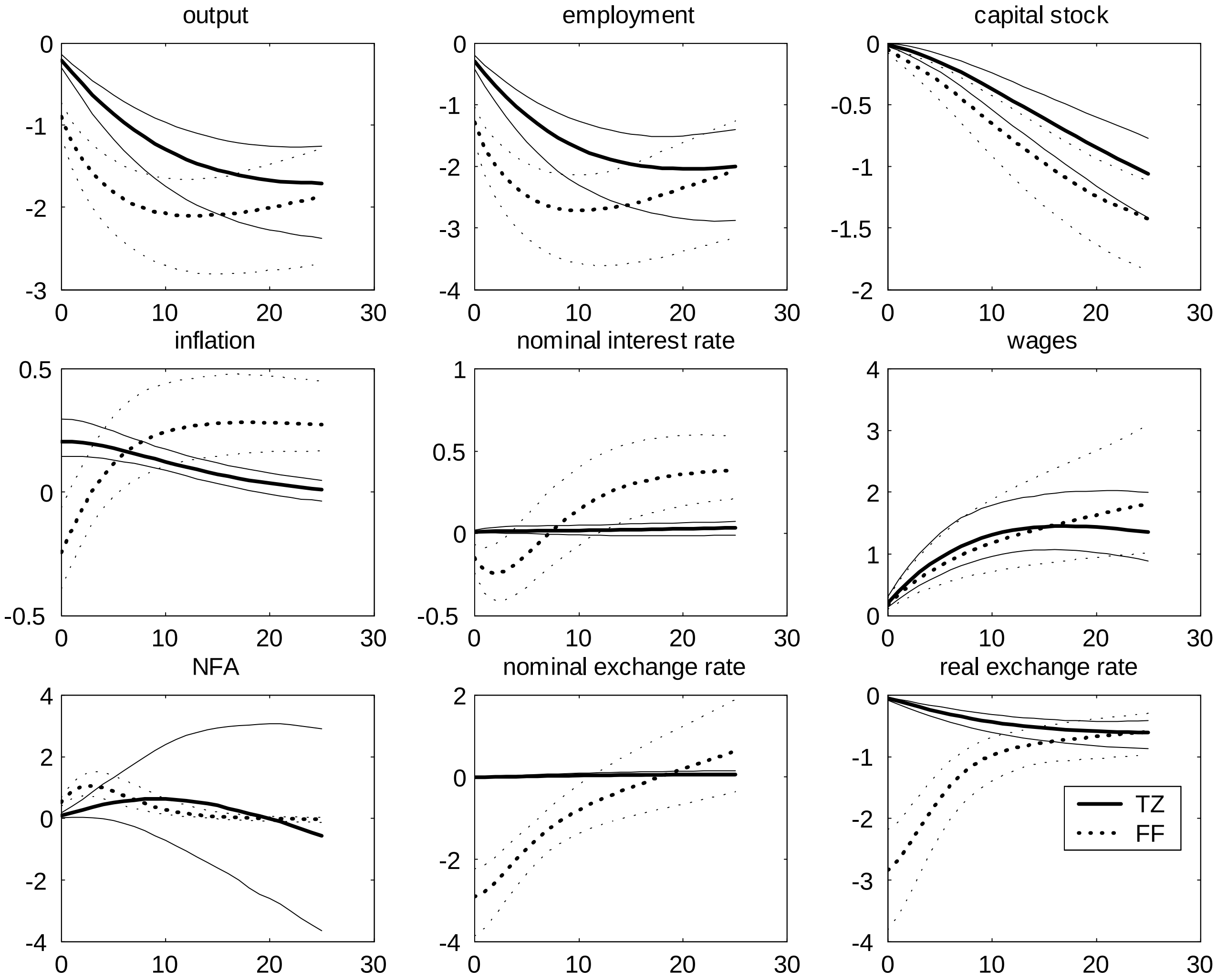

Figure 10: Responses to a realignment expectations shock

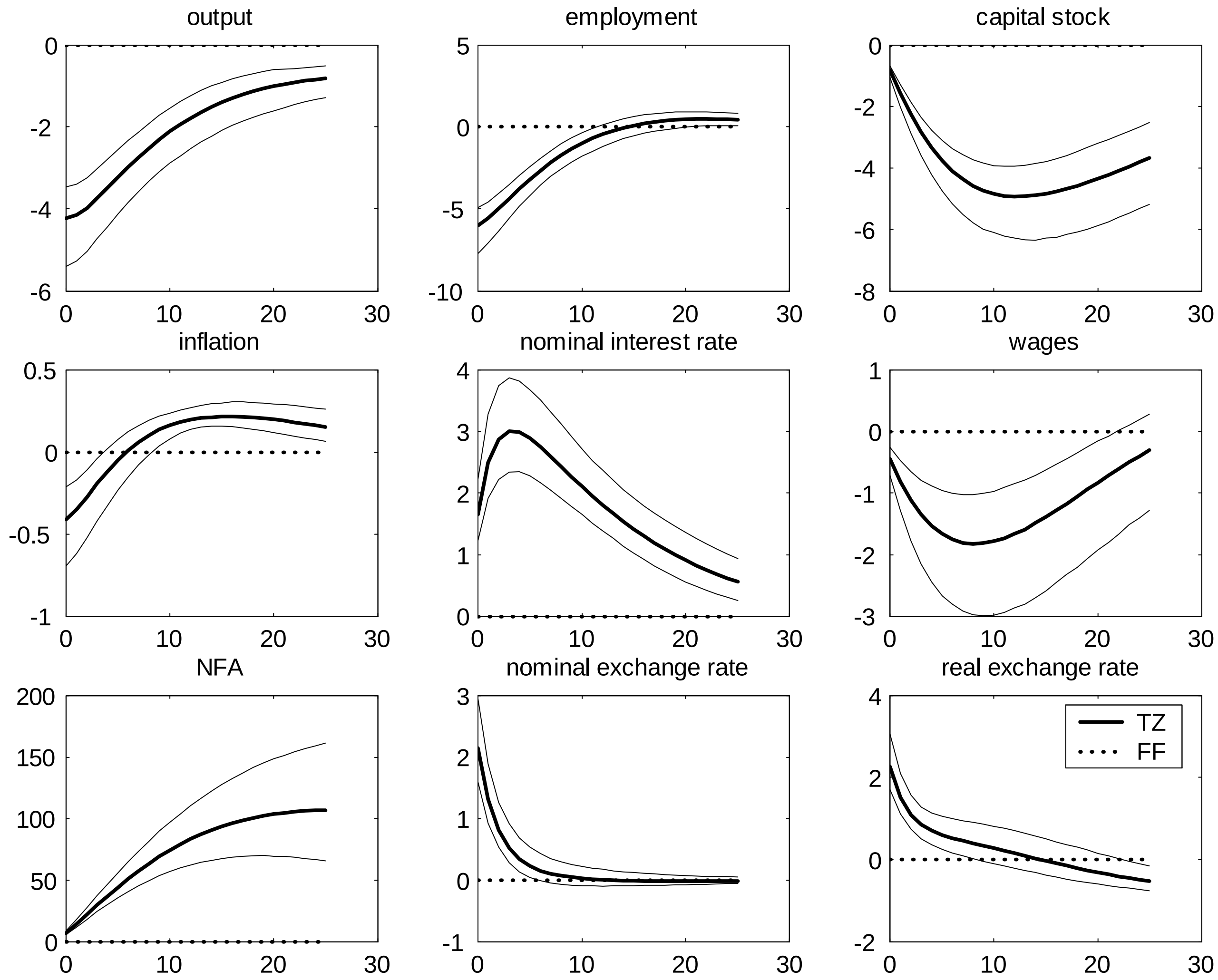

Figure 11: Responses to a price markup shock

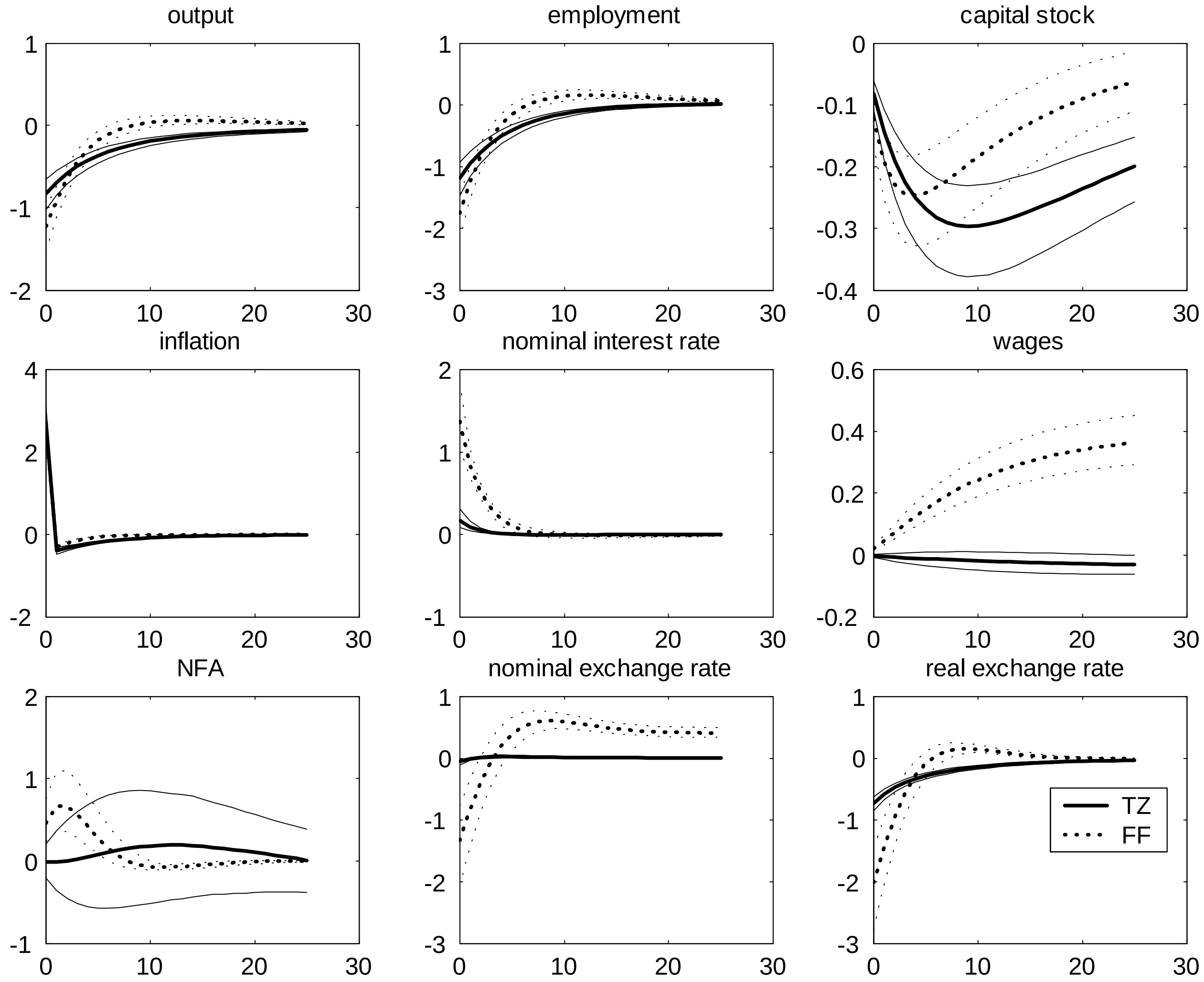

Figure 12: Responses to a wage markup shock

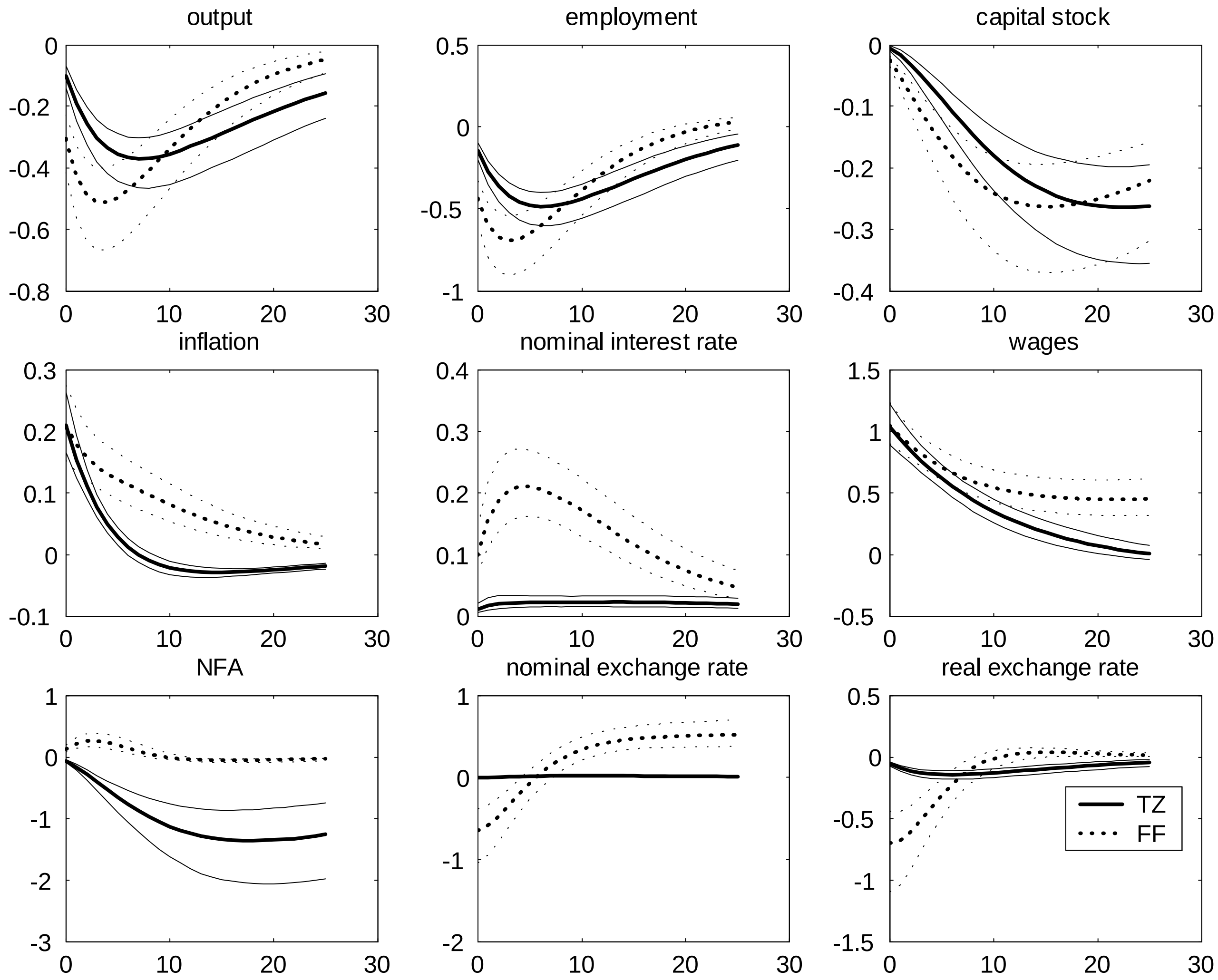

Table 3: variance decomposition for the target zone period, 1 quarter ahead

	ϵ_ξ	ϵ_θ	ϵ_m	ϵ_p	ϵ_y	ϵ_i	ϵ_ζ	ϵ_κ	ϵ_ν	ϵ_γ	ϵ_g
Y	0.0344	0.0003	0.0073	0.0096	0.0021	0.0027	0.123	0.0018	0.0295	0.0004	0.7836
	[0.019,0.059]	[0,0.001]	[0.004,0.013]	[0.006,0.016]	[0.001,0.003]	[0.001,0.006]	[0.071,0.203]	[0.001,0.004]	[0.018,0.046]	[0,0.001]	[0.699,0.851]
L	0.0301	0.1277	0.0064	0.0083	0.0018	0.0024	0.1068	0.0016	0.0256	0.0004	0.6796
	[0.018,0.051]	[0.078,0.191]	[0.004,0.011]	[0.005,0.013]	[0.001,0.003]	[0.001,0.005]	[0.062,0.179]	[0.001,0.004]	[0.016,0.039]	[0,0.001]	[0.592,0.762]
K	0.001	0	0.0064	0.002	0.0002	0.0029	0.1325	0.0003	0.0082	0	0.8461
	[0,0.003]	[0,0]	[0.003,0.011]	[0.001,0.003]	[0,0]	[0.001,0.007]	[0.076,0.217]	[0,0.001]	[0.005,0.014]	[0,0]	[0.758,0.906]
π	0.0018	0.0049	0.0006	0.004	0.0001	0	0	0.0056	0.9533	0.0058	0.0224
	[0.001,0.004]	[0.002,0.01]	[0,0.001]	[0.003,0.006]	[0,0]	[0,0]	[0,0]	[0.003,0.012]	[0.907,0.975]	[0.004,0.01]	[0.006,0.063]
i	0.0001	0	0.1959	0	0	0.0022	0.4828	0	0.0031	0	0.3087
	[0,0]	[0,0]	[0.132,0.287]	[0,0]	[0,0]	[0.002,0.003]	[0.378,0.578]	[0,0]	[0.001,0.01]	[0,0]	[0.215,0.421]
W	0.0364	0	0.0001	0.0011	0.0001	0.0002	0.003	0.0305	0	0.781	0.1396
	[0.013,0.089]	[0,0]	[0,0]	[0.001,0.002]	[0,0]	[0,0.001]	[0.001,0.009]	[0.015,0.06]	[0,0]	[0.61,0.892]	[0.058,0.271]
B	0.034	0.0001	0.0043	0.0002	0.003	0.0027	0.1184	0.0001	0.0001	0.0001	0.8337
	[0.019,0.058]	[0,0]	[0.002,0.008]	[0,0.001]	[0.002,0.005]	[0.001,0.007]	[0.068,0.199]	[0,0.001]	[0,0.001]	[0,0]	[0.75,0.89]
e	0	0	0.0785	0.0001	0	0.0026	0.5237	0	0.0003	0	0.3879
	[0,0]	[0,0]	[0.049,0.125]	[0,0]	[0,0]	[0.002,0.004]	[0.412,0.629]	[0,0]	[0,0.001]	[0,0]	[0.282,0.514]
q	0.0001	0.0002	0.0691	0.0111	0	0.0025	0.4772	0.0002	0.0403	0.0002	0.3903
	[0,0.001]	[0,0]	[0.044,0.106]	[0.006,0.018]	[0,0]	[0.002,0.004]	[0.375,0.579]	[0,0.001]	[0.025,0.065]	[0,0]	[0.287,0.514]

Table 4: variance decomposition for the target zone period, 4 quarters ahead

	ϵ_ξ	ϵ_θ	ϵ_m	ϵ_p	ϵ_y	ϵ_i	ϵ_ζ	ϵ_κ	ϵ_ν	ϵ_γ	ϵ_g
Y	0.0363	0.0005	0.003	0.0091	0.0015	0.0026	0.0872	0.0143	0.02	0.0033	0.8159
	[0.019,0.065]	[0,0.002]	[0.002,0.005]	[0.005,0.015]	[0.001,0.002]	[0.001,0.006]	[0.046,0.152]	[0.007,0.029]	[0.012,0.032]	[0.002,0.006]	[0.74,0.875]
L	0.0441	0.0448	0.0031	0.0096	0.0016	0.0025	0.0834	0.0157	0.021	0.0036	0.7605
	[0.024,0.078]	[0.027,0.071]	[0.002,0.006]	[0.006,0.016]	[0.001,0.003]	[0.001,0.006]	[0.045,0.146]	[0.008,0.031]	[0.013,0.033]	[0.002,0.006]	[0.681,0.829]
K	0.0025	0.0001	0.002	0.0018	0.0002	0.0028	0.0914	0.0009	0.0056	0.0003	0.8911
	[0.001,0.006]	[0,0]	[0.001,0.004]	[0.001,0.003]	[0,0]	[0.001,0.007]	[0.048,0.16]	[0,0.002]	[0.003,0.01]	[0,0.001]	[0.818,0.937]
π	0.0026	0.0046	0.0006	0.0109	0.0002	0	0.0003	0.0229	0.8938	0.0104	0.0493
	[0.001,0.006]	[0.002,0.01]	[0,0.001]	[0.008,0.016]	[0,0]	[0,0]	[0,0.001]	[0.011,0.047]	[0.787,0.944]	[0.006,0.016]	[0.011,0.151]
i	0.0006	0	0.0407	0	0	0.0034	0.395	0	0.0006	0	0.5574
	[0,0.001]	[0,0]	[0.025,0.064]	[0,0]	[0,0]	[0.002,0.006]	[0.29,0.518]	[0,0]	[0,0.002]	[0,0]	[0.432,0.67]
W	0.0126	0	0.0001	0.0052	0.0003	0.0006	0.005	0.1382	0	0.308	0.5127
	[0.004,0.033]	[0,0]	[0,0]	[0.003,0.009]	[0,0.001]	[0,0.003]	[0.001,0.015]	[0.069,0.25]	[0,0]	[0.165,0.51]	[0.282,0.715]
B	0.0352	0.0001	0.0009	0.0001	0.0014	0.0025	0.0715	0.0001	0.0001	0.0002	0.8855
	[0.019,0.06]	[0,0]	[0,0.002]	[0,0.001]	[0.001,0.002]	[0.001,0.007]	[0.036,0.131]	[0,0.001]	[0,0]	[0,0]	[0.82,0.928]
e	0	0	0.0861	0.0003	0.0001	0.0027	0.4457	0	0.0003	0	0.4581
	[0,0]	[0,0]	[0.051,0.138]	[0,0.001]	[0,0]	[0.002,0.004]	[0.329,0.555]	[0,0]	[0,0.001]	[0,0]	[0.34,0.596]
q	0.0007	0.0005	0.0634	0.024	0.0002	0.0023	0.348	0.0065	0.065	0.003	0.4759
	[0,0.002]	[0,0.001]	[0.039,0.098]	[0.013,0.04]	[0,0]	[0.001,0.004]	[0.252,0.448]	[0.003,0.014]	[0.039,0.106]	[0.002,0.006]	[0.354,0.614]

Table 5: variance decomposition for the target zone period, 20 quarters ahead

	ϵ_ξ	ϵ_θ	ϵ_m	ϵ_p	ϵ_y	ϵ_i	ϵ_ζ	ϵ_κ	ϵ_ν	ϵ_γ	ϵ_g
Y	0.0193	0.0004	0.0015	0.0084	0.0009	0.002	0.0463	0.1667	0.0125	0.0096	0.7215
	[0.011,0.033]	[0,0.001]	[0.001,0.003]	[0.005,0.014]	[0,0.002]	[0.001,0.006]	[0.023,0.09]	[0.09,0.284]	[0.007,0.021]	[0.006,0.016]	[0.598,0.823]
L	0.0337	0.0287	0.002	0.0098	0.0012	0.0019	0.0555	0.2108	0.0154	0.0111	0.6166
	[0.019,0.06]	[0.018,0.045]	[0.001,0.004]	[0.006,0.016]	[0.001,0.002]	[0.001,0.005]	[0.029,0.105]	[0.118,0.339]	[0.009,0.025]	[0.007,0.019]	[0.484,0.732]
K	0.0086	0.0001	0.0004	0.002	0.0002	0.0021	0.0278	0.0116	0.0035	0.0017	0.9372
	[0.004,0.021]	[0,0]	[0,0.001]	[0.001,0.004]	[0,0.001]	[0.001,0.007]	[0.012,0.06]	[0.005,0.027]	[0.002,0.007]	[0.001,0.003]	[0.896,0.965]
π	0.0043	0.0043	0.0006	0.0132	0.0002	0.0002	0.0026	0.0416	0.8156	0.0102	0.0997
	[0.002,0.009]	[0.002,0.009]	[0,0.001]	[0.009,0.019]	[0,0]	[0,0.001]	[0.001,0.006]	[0.023,0.078]	[0.697,0.884]	[0.006,0.016]	[0.049,0.209]
i	0.0028	0	0.0204	0	0.0001	0.0033	0.226	0.0001	0.0003	0.0001	0.7448
	[0.001,0.007]	[0,0]	[0.013,0.033]	[0,0]	[0,0]	[0.002,0.006]	[0.146,0.331]	[0,0]	[0,0.001]	[0,0]	[0.636,0.831]
W	0.0167	0	0	0.0182	0.0007	0.0003	0.0016	0.3653	0.0001	0.0651	0.5251
	[0.007,0.036]	[0,0]	[0,0]	[0.009,0.035]	[0,0.002]	[0,0.003]	[0,0.005]	[0.16,0.617]	[0,0.001]	[0.03,0.13]	[0.237,0.776]
B	0.0123	0	0.0001	0.0001	0.0003	0.0015	0.0129	0.0001	0	0.0002	0.9706
	[0.006,0.025]	[0,0]	[0,0]	[0,0]	[0,0.001]	[0,0.007]	[0.005,0.032]	[0,0.001]	[0,0]	[0,0]	[0.946,0.984]
e	0.0002	0	0.0833	0.0005	0.0001	0.0027	0.4518	0.0016	0.0005	0.0002	0.4513
	[0,0.001]	[0,0]	[0.049,0.133]	[0,0.001]	[0,0]	[0.002,0.004]	[0.329,0.563]	[0,0.009]	[0,0.002]	[0,0.001]	[0.333,0.594]
q	0.0019	0.0004	0.0455	0.027	0.0005	0.002	0.2752	0.1342	0.0596	0.0094	0.4252
	[0.001,0.004]	[0,0.001]	[0.028,0.069]	[0.015,0.043]	[0,0.001]	[0.001,0.003]	[0.184,0.374]	[0.067,0.248]	[0.037,0.092]	[0.005,0.018]	[0.289,0.587]

Table 6: variance decomposition for the inflation targeting period, 1 quarter ahead

	ϵ_ξ	ϵ_θ	ϵ_m	ϵ_p	ϵ_y	ϵ_i	ϵ_ζ	ϵ_κ	ϵ_ν	ϵ_γ
Y	0.0865	0.0456	0.3648	0.0101	0.0052	0	0.0008	0.1553	0.2866	0.0178
	[0.041,0.156]	[0.019,0.106]	[0.261,0.5]	[0.007,0.015]	[0.003,0.008]	[0,0]	[0,0.002]	[0.093,0.241]	[0.215,0.371]	[0.009,0.034]
L	0.0646	0.2845	0.2752	0.0075	0.0038	0	0.0006	0.1149	0.2129	0.0133
	[0.031,0.117]	[0.178,0.409]	[0.179,0.395]	[0.005,0.011]	[0.002,0.006]	[0,0]	[0,0.001]	[0.075,0.17]	[0.149,0.299]	[0.007,0.026]
K	0.4713	0.0157	0.3046	0.0004	0.0008	0	0.0002	0.0295	0.1549	0.0063
	[0.322,0.617]	[0.005,0.039]	[0.193,0.45]	[0,0.001]	[0,0.002]	[0,0]	[0,0.001]	[0.01,0.063]	[0.103,0.24]	[0.003,0.013]
π	0.0143	0.0333	0.0358	0.0006	0.0012	0	0.0036	0.0073	0.8933	0.0053
	[0.003,0.038]	[0.021,0.052]	[0.017,0.071]	[0,0.001]	[0.001,0.002]	[0,0]	[0.002,0.006]	[0.001,0.019]	[0.847,0.927]	[0.003,0.009]
i	0.0046	0.0124	0.6227	0.0001	0.0004	0	0.0015	0.0042	0.3496	0.0018
	[0.001,0.012]	[0.007,0.021]	[0.483,0.75]	[0,0]	[0,0.001]	[0,0]	[0.001,0.003]	[0.001,0.01]	[0.228,0.484]	[0.001,0.003]
W	0.0382	0	0.0029	0	0	0	0	0.0268	0.0004	0.9279
	[0.019,0.077]	[0,0]	[0.001,0.009]	[0,0]	[0,0]	[0,0]	[0,0]	[0.011,0.064]	[0,0.001]	[0.868,0.964]
B	0.067	0.0105	0.619	0.0214	0.0392	0.0002	0.0218	0.1053	0.0832	0.0066
	[0.026,0.145]	[0.002,0.039]	[0.494,0.735]	[0.008,0.042]	[0.023,0.068]	[0,0]	[0.011,0.042]	[0.058,0.172]	[0.025,0.184]	[0.003,0.016]
e	0.0464	0.0087	0.4389	0.0247	0.0172	0.0013	0.2666	0.1375	0.0286	0.0066
	[0.015,0.097]	[0.001,0.039]	[0.31,0.582]	[0.014,0.04]	[0.011,0.028]	[0.001,0.003]	[0.178,0.373]	[0.087,0.212]	[0.01,0.061]	[0.002,0.017]
q	0.0513	0.0121	0.417	0.0092	0.0164	0.0013	0.2623	0.1318	0.0659	0.0079
	[0.018,0.104]	[0.002,0.047]	[0.293,0.562]	[0.004,0.018]	[0.01,0.026]	[0.001,0.002]	[0.176,0.364]	[0.083,0.206]	[0.035,0.112]	[0.003,0.019]

Table 7: variance decomposition for the inflation targeting period, 4 quarters ahead

	ϵ_ξ	ϵ_θ	ϵ_m	ϵ_p	ϵ_y	ϵ_i	ϵ_ζ	ϵ_κ	ϵ_ν	ϵ_γ
Y	0.1486	0.0914	0.2402	0.0047	0.002	0	0.0013	0.3125	0.1354	0.0351
	[0.07,0.248]	[0.039,0.194]	[0.148,0.375]	[0.003,0.007]	[0.001,0.003]	[0,0]	[0.001,0.002]	[0.203,0.448]	[0.095,0.188]	[0.02,0.063]
L	0.116	0.1624	0.2236	0.0047	0.002	0	0.0014	0.3051	0.1286	0.0336
	[0.052,0.205]	[0.092,0.247]	[0.133,0.351]	[0.003,0.007]	[0.001,0.004]	[0,0]	[0.001,0.003]	[0.211,0.417]	[0.087,0.184]	[0.018,0.063]
K	0.6665	0.0285	0.1675	0.0005	0.001	0	0.0001	0.0364	0.0755	0.0103
	[0.525,0.779]	[0.011,0.065]	[0.095,0.293]	[0,0.001]	[0,0.002]	[0,0]	[0,0]	[0.013,0.079]	[0.048,0.123]	[0.006,0.02]
π	0.0791	0.0631	0.0489	0.0009	0.0021	0	0.0035	0.0094	0.7664	0.0124
	[0.03,0.166]	[0.038,0.102]	[0.023,0.101]	[0,0.002]	[0.001,0.003]	[0,0]	[0.002,0.006]	[0.003,0.03]	[0.68,0.835]	[0.007,0.021]
i	0.0628	0.06	0.537	0.0007	0.002	0	0.0022	0.0178	0.2886	0.0106
	[0.024,0.136]	[0.033,0.1]	[0.413,0.672]	[0,0.001]	[0.001,0.004]	[0,0]	[0.001,0.005]	[0.002,0.047]	[0.192,0.403]	[0.006,0.018]
W	0.2035	0.0005	0.0114	0	0	0	0	0.1341	0.0032	0.6297
	[0.116,0.34]	[0,0.002]	[0.003,0.032]	[0,0]	[0,0]	[0,0]	[0,0]	[0.061,0.264]	[0.002,0.006]	[0.464,0.78]
B	0.0341	0.0152	0.5663	0.0211	0.0377	0.0012	0.0768	0.1444	0.0654	0.0094
	[0.008,0.086]	[0.002,0.056]	[0.432,0.696]	[0.009,0.04]	[0.023,0.061]	[0.001,0.002]	[0.036,0.149]	[0.083,0.231]	[0.021,0.147]	[0.004,0.021]
e	0.056	0.0082	0.461	0.0358	0.0222	0.001	0.1622	0.2018	0.0191	0.0076
	[0.015,0.119]	[0.001,0.043]	[0.318,0.618]	[0.02,0.058]	[0.014,0.035]	[0.001,0.002]	[0.103,0.243]	[0.128,0.304]	[0.006,0.045]	[0.002,0.021]
q	0.0787	0.0177	0.424	0.0114	0.0203	0.001	0.1606	0.1921	0.0544	0.0115
	[0.028,0.156]	[0.002,0.068]	[0.29,0.582]	[0.005,0.022]	[0.013,0.032]	[0.001,0.002]	[0.103,0.235]	[0.122,0.293]	[0.027,0.096]	[0.005,0.027]

Table 8: variance decomposition for the inflation targeting period, 20 quarters ahead

	ϵ_ξ	ϵ_θ	ϵ_m	ϵ_p	ϵ_y	ϵ_i	ϵ_ζ	ϵ_κ	ϵ_ν	ϵ_γ
Y	0.3875	0.0288	0.0462	0.0007	0.0004	0	0.0003	0.4817	0.0205	0.0164
	[0.262,0.528]	[0.01,0.085]	[0.024,0.088]	[0,0.001]	[0,0.001]	[0,0]	[0,0.001]	[0.341,0.635]	[0.013,0.033]	[0.009,0.031]
L	0.2329	0.0415	0.0588	0.0011	0.0007	0	0.0004	0.6058	0.0294	0.0194
	[0.135,0.36]	[0.023,0.066]	[0.03,0.108]	[0.001,0.002]	[0,0.001]	[0,0]	[0,0.001]	[0.466,0.739]	[0.018,0.047]	[0.01,0.037]
K	0.876	0.0117	0.0203	0.0001	0.0002	0	0	0.0732	0.0048	0.0065
	[0.81,0.923]	[0.004,0.035]	[0.01,0.044]	[0,0]	[0,0]	[0,0]	[0,0]	[0.038,0.132]	[0.002,0.009]	[0.003,0.013]
π	0.4545	0.0415	0.0272	0.0005	0.0011	0	0.0022	0.053	0.3923	0.0117
	[0.315,0.596]	[0.022,0.077]	[0.011,0.06]	[0,0.001]	[0.001,0.002]	[0,0]	[0.001,0.004]	[0.025,0.127]	[0.263,0.535]	[0.007,0.019]
i	0.6366	0.0465	0.1684	0.0003	0.001	0	0.001	0.0321	0.085	0.0142
	[0.501,0.757]	[0.02,0.096]	[0.102,0.259]	[0,0.001]	[0,0.002]	[0,0]	[0,0.002]	[0.016,0.076]	[0.048,0.149]	[0.008,0.026]
W	0.6319	0.0109	0.01	0.0001	0.0002	0	0	0.2412	0.0099	0.0779
	[0.467,0.778]	[0.004,0.025]	[0.002,0.035]	[0,0]	[0,0]	[0,0]	[0,0]	[0.115,0.413]	[0.005,0.02]	[0.042,0.147]
B	0.0607	0.0163	0.4512	0.0198	0.0343	0.007	0.1526	0.1662	0.0464	0.0095
	[0.03,0.123]	[0.004,0.059]	[0.306,0.602]	[0.009,0.037]	[0.022,0.054]	[0.003,0.021]	[0.071,0.278]	[0.098,0.265]	[0.014,0.11]	[0.004,0.022]
e	0.1845	0.043	0.3247	0.0438	0.0171	0.0006	0.103	0.2019	0.0312	0.016
	[0.087,0.367]	[0.017,0.103]	[0.184,0.49]	[0.028,0.065]	[0.011,0.027]	[0,0.001]	[0.069,0.147]	[0.124,0.31]	[0.019,0.054]	[0.008,0.032]
q	0.1357	0.0165	0.3481	0.0101	0.0179	0.0008	0.1249	0.2625	0.0436	0.0109
	[0.065,0.232]	[0.003,0.063]	[0.217,0.51]	[0.004,0.02]	[0.011,0.028]	[0,0.001]	[0.084,0.179]	[0.167,0.378]	[0.022,0.076]	[0.005,0.025]

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