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Business Cycles**

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Monetary Regime Change and Business Cycles*

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Abstract

This paper proposes a simple method to structurally estimate a model over a period of time containing a regime shift. It then evaluates to which degree it is relevant to explicitly acknowledge the break in the estimation procedure. We apply our method on Swedish data, and estimate a DSGE model explicitly taking into account the monetary regime change in 1993, from exchange rate targeting to inflation targeting. We show that ignoring the break in the estimation leads to spurious estimates of model parameters including parameters in both policy and non-policy economic relations. Accounting for the regime change suggests that monetary policy reacted strongly to exchange rate movements in the first regime, and mostly to inflation in the second. The sources of business cycle fluctuations and their transmission mechanism are significantly affected by the exchange rate regime. (JEL: C1, C5, E5, F4)

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

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1 Introduction

After the breakdown of the Bretton-Woods system, several countries searched for a new nominal anchor for their monetary policy. Many small open economies initially opted for some form of managed exchange-rate regimes but, over time, most proved to be incapable of resisting the pressures of international capital markets. As those regimes proved to be ineffective, central banks around the world searched for a new framework to conduct monetary policy. Inflation targeting eventually became the new regime of choice, initially adopted by New Zealand and quickly followed by others, such as Canada, United Kingdom and Sweden.

From a methodological point of view, dealing with regime breaks is not a trivial task. In this paper, we propose a simple method to estimate a model over a period of time containing a regime shift. We then evaluate to which degree it is important to explicitly acknowledge the break in the estimation procedure. In our analysis, we focus on those cases where the timing of the shift is known by the econometrician. Thus, we are not engaging in an exercise in which we are searching for the structural break.

We apply our method to Sweden, a good example of a small open economy that went through such a monetary policy regime change. Sweden adopted an exchange rate target zone in 1977, setting a central parity for the Swedish krona against a basket of currencies, and only allowing small deviations from that parity. After the dramatic and unsuccessful attempt to defend the currency at the end of 1992, the Swedish authorities decided to abandon that exchange rate regime. Shortly thereafter, in January of 1993, Sveriges Riksbank (the central bank of Sweden) announced the adoption of an inflation targeting regime.¹

We start by estimating a DSGE open economy model assuming that all the parameters

¹After the Bretton Woods collapse in 1973, Sweden participated in the so-called “snake” exchange rate mechanism. In 1977, the Riksbank announced a unilateral target zone to a currency basket constructed using trading weights. In May 1991, the ECU became the official target. [Lindbeck et al. \(1994\)](#), [Lindberg et al. \(1993\)](#), [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.

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are constant in the two sub-periods, except for the monetary policy related ones.² This allows us to estimate two separate policy rules, one for each regime, i.e., the target zone (TZ) period and the inflation targeting (IT) period. We then compare the propagation of shocks in the two periods through impulse response analysis, and then analyze whether the regime change implies a different decomposition of business cycle volatility. Our results suggest that the influence of different shocks is regime dependent to a substantial degree. We also find that monetary policy reacted strongly to exchange rate movements during the target zone regime while it focused mainly on inflation stabilization during the inflation targeting period. The difference between the two regimes is sharper in response to shocks that originate abroad — foreign shocks hit the economy harder during the TZ period than during the IT period because the exchange rate’s role as a shock absorber was more restricted. We thus conclude that it is important to account for the regime change in the estimated DSGE in order to properly capture the information in the data.

We then investigate the extent to which ignoring the regime change can lead to spurious results. Therefore we reestimate the model ignoring the policy break and compare the results to our benchmark estimation. We find that in this case we risk capturing business cycle properties that are averaged across the two periods. This misspecification will affect not only the parameters of the policy rule but also the posterior distribution of the parameters associated with structural economic relations unrelated to the policy regime. This means that we estimate a policy characterization that is not correct for either period and further contaminates the estimation of the policy-independent parameters. In particular, the misspecification affects the parameters associated with the demand side of the economy and, therefore, the whole internal propagation mechanism of the model.

In order to shed further light on the implications of the two monetary regimes on the

²As explained at some length in the model section, besides the parameters in the Taylor rule we also allow the risk premium shock in the UIP condition to be regime-dependent.

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business cycles of a small open economy, we also conduct a counterfactual experiment. We evaluate how the inflation targeting monetary policy rule would have performed in response to the shock innovations from the target zone historical sample. In this exercise we find that Sweden would have had significantly higher levels of output, hours and consumption, at the expense of a more depreciated currency (in both nominal and real terms), higher inflation and more macroeconomic volatility.

The model considered is close to [Kollmann \(2001\)](#), and to describe monetary policy during the Target zone period we follow [Svensson \(1994\)](#) and assume a linear managed float without an explicit band as an approximation to a non-linear exchange rate band model.

Structural estimation of small open economy models has been the subject of extensive research in the recent past.³ Unlike the previous literature, this paper considers the effects of monetary regime change on the dynamics of a small open economy. In this way, the paper contributes to the literature on time-varying DSGE models, e.g., [Fernández-Villaverde and Rubio-Ramírez \(2007\)](#) and [Justiniano and Primiceri \(2008\)](#). However, in contrast to those papers, we model a specific change of monetary policy regimes at a given well known date, rather than allowing specific parameters to change over time in a random fashion. In a way, we follow [Lubik and Schorfheide \(2004\)](#) who estimate a model with regime breaks dividing the data in two samples. Unlike [Lubik and Schorfheide \(2004\)](#) we assume that only certain parameters can change with the regime and estimate the two regimes jointly. This allows us to establish a “computational bridge” between sub-samples to avoid losing information on parameters that are unrelated to the regime change. [Belaygorod and Dueker \(2009\)](#) also assume constant “deep parameters” across regimes. However, they use a change-point approach to allow the data to provide estimates of the regime change dates. Differently from them, in our case the econometrician does not draw any inference about the timing of

³See [Smets and Wouters \(2003\)](#), [Adolfson et al. \(2007\)](#), [Justiniano and Preston \(2010a\)](#), [Justiniano and Preston \(2010b\)](#), and [Lubik and Schorfheide \(2007\)](#), among many others.

the switch. In a way, the approach in [Belaygorod and Dueker \(2009\)](#) is more general than ours because it allows for uncertainty about the date of the regime change. In the case of an explicitly announced change in regime, like ours, this is less crucial. On the one hand, with an announcement there could still be some uncertainty about when the new regime was implemented in practice. On the other hand, this is not likely to alter much the estimation given that it would affect at most one or two quarters before or after the announcement date.⁴

To deal with regime shifts also means to take a stand on agents' beliefs about the policy change. A recent strand of literature has focused on explicitly modeling those expectations. [Davig and Leeper \(2007\)](#) discusses the role of Markov regime-switching policy rules in a DSGE model and its effects on business cycle dynamics. [Bianchi \(2012\)](#) shows that agents' expectations about switches in the reaction function of the Fed were crucial in explaining the Great Inflation.⁵ In the present paper, we take an alternative approach and assume that the shift in the policy regime was not anticipated — much like [Lubik and Schorfheide \(2004\)](#) and [Belaygorod and Dueker \(2009\)](#). However, it seems reasonable that in reality at least some agents doubted the stability of the target zone regime and expected some other regime before its actual collapse. Thus, to the extent that economic agents do form expectations about the regime change in reality, our proposed method is just an approximation to the true underlying non-linear regime change specification. Although our approach is admittedly simplistic, it has the great computational advantage of allowing for regime breaks within the log-linear framework with only a relatively minor departure in terms of how to generate the posterior function, while keeping the same estimation methods.

Moreover, in the specific case of Sweden, the assumption that the regime was unexpected

⁴In the estimation section and the appendix, we discuss how we attempt to mitigate this issue. Robustness estimations suggest that our main results are not affected by it.

⁵[Eo \(2008\)](#) also accounts for regime switches.

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does not seem too unrealistic. There is narrative evidence coming from old newspapers,⁶ and press releases of the government,⁷ suggesting that it was difficult to envision the conduct of monetary policy with a free floating krona, after 20 years of quasi-fixed exchange rates. Moreover, neither the government or the opposition wanted to be remembered in Swedish economic history as those pushing for a new devaluation.⁸ At the time, Sweden had a clear interest in starting its upcoming membership in the European Union with a strong currency. But perhaps the most convincing evidence that the switch to a floating regime was indeed unexpected is the significant number of the small companies holding loans in German marks that went bust after the crisis, unable to sustain the prohibitive costs of a weak Krona.⁹

Independent work by [Adolfson et al. \(2008\)](#) also considers the change in monetary policy due to the adoption of inflation targeting in Sweden. However, their paper only considers the impact of regime change on the stability of the interest rate rule parameters. Instead, we focus on the overall monetary policy regime, model explicitly the exchange rate targeting regime and evaluate the role of devaluation expectations during the target zone.

The rest of the paper is organized as follows. Section 2 presents the theoretical model. Section 3 describes the estimation procedure and presents the results from the estimation with the regime change in terms of parameter estimates, impulse response functions and

⁶“The history of the krona’s fall starts in 1982, when Sweden devaluates the currency for the seventh time in a 10 years period. The Social Democrats and the Conservative and Liberal parties promise it is the last time. the fixed rate becomes increasingly important in the speeches of politicians and of the Riksbank...” Dagens Nyheter, “DN Special: The Swedish Krona didn’t have a chance,” 1 November 1996. (*DN Special: Kronan hade inte skuggan av en chans*). ”

⁷In september 1992, after increasing the repo rate to 500%, Bengt Dennis, the Riksbank governor at the time, stated: “The sky is the limit,” to convey the message that there was no upper limit for further increases of interest rates in defense of the currency. In december 1992, two weeks after the speculative attack, during a speech at the parliament the finance minister Anne Wibble said “We will slowly go back to a fixed exchange rate regime.”

⁸“The Socialdemocrats did not want to appear as those promoting a new devaluation. And the government of Bildt had a political interest to not be tainted by history. This made both the opposition and the government having an hard time thinking about a new devaluation” Bengt Dennis (Riksbank Governor 1982-93), Dagens Nyheter, ”Dennis defends the defense”, 14 April 2002 (*”Dennis försvarar svaret”*)

⁹Also big companies like SAS and Volvo, as well as the cities of Göteborg and Örebro made large losses on their loans in foreign currencies. (Source: *”DN Special: Kronan hade inteskuggan av en chans”*)

variance decomposition. In section 4 we present the results from reestimating the model ignoring the break. Section 5 describes a counterfactual exercise in which we apply the shock innovations extracted from the target zone historical sample to the estimated system under inflation targeting. Section 6 presents our conclusions.

2 The Model

The model follows closely Kollmann (2001) with a small open economy with a representative household, firms and a government. A single non-tradable final good is produced by the domestic country, as well as a continuum of intermediate tradable goods. The final-goods 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 one-period domestic and foreign currency bonds and rents capital to firms. Overlapping wage contracts *a la* Calvo are assumed. The monetary authority follows a Taylor-type interest rate rule in both monetary policy regimes. The remainder of this section describes each sector of the economy in more detail.¹⁰

2.1 Final Goods Production

The non-tradable final good, Z_t , is produced in a perfectly competitive market using domestically produced (Q^d) and imported (Q^m) intermediate goods according to the following technology:

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

where

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

¹⁰In the interest of keeping the presentation of the model short, we only show in the text the agents' optimization problems, leaving the full list of equations (already log-linearized) to the technical appendix.

are the domestic and the imported intermediate input quantity indices, $q_t^d(s)$ and $q_t^m(s)$ the domestic and imported type “ s ” intermediate goods and ν_t a shock to the demand elasticity (which translates to a time varying price markup shock).¹¹

2.2 Intermediate Goods Production

In the intermediate goods market, a continuum of monopolistic competitive firms combines labor (L) and capital (K) according to the following technology:

$$y_t(s) = \theta_t K_t(s)^\psi L_t(s)^{1-\psi}, \quad (2.3)$$

with

$$L_t(s) = \left[\int_0^1 l_t(h; s)^{\frac{1}{1+\gamma_t}} dh \right]^{1+\gamma_t}, \quad (2.4)$$

where γ_t is a time varying wage markup.

Cost minimization implies

$$W_t = \left[\int_0^1 w_t(h)^{-\frac{1}{\gamma_t}} dh \right]^{-\gamma_t}, \quad (2.5)$$

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 at both domestic and foreign markets:

$$y_t(s) = q_t^d(s) + q_t^x(s). \quad (2.6)$$

Export demand is assumed to have the following form,

$$Q_t^x = \left(\frac{P_t^x}{P_t^*} \right)^{-\eta} Y_t^*, \quad (2.7)$$

¹¹We further assume that $\alpha^m + \alpha^d = 1$.

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where Y_t^* is foreign real GDP and P_t^* the foreign aggregate price level. Total foreign demand is allocated to the different varieties according to:

$$Q_t^x = \left[\int_0^1 q_t^x(s)^{\frac{1}{1+\nu_t}} ds \right]^{1+\nu_t}. \quad (2.8)$$

The profits from producing and importing are

$$\Pi_{t+\tau}^i(p_t^i) = (P_{t+\tau}^i)^{\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}} Q_{t+\tau}^i \left[(p_t^i)^{-\frac{1}{\nu_{t+\tau}}} - S_{t+\tau}^i (p_t^i)^{-\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}} \right], \text{ for } i = d, m, x, \quad (2.9)$$

where S_t^i is the marginal cost. Firms can price discriminate among the domestic and foreign markets and set prices in the currency of the buyer. The firms' profit maximization problem is therefore:

$$\begin{aligned} \max_{p_t^i} \quad & \sum_{\tau=0}^{\infty} \alpha_p^\tau E_t [\rho_{t,t+\tau} \Pi_{t+\tau}^i(p_t^i)] \\ \text{s.t.} \quad & \Pi_{t+\tau}^i(p_t^i) = (P_{t+\tau}^i)^{\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}} Q_{t+\tau}^i \left[(p_t^i)^{-\frac{1}{\nu_{t+\tau}}} - S_{t+\tau}^i (p_t^i)^{-\frac{1+\nu_{t+\tau}}{\nu_{t+\tau}}} \right], \end{aligned} \quad (2.10)$$

where

$$\rho_{t,t+\tau} = \beta^\tau \frac{\xi_{t+\tau} U_c(t+\tau)}{\xi_t U_c(t)} \frac{P_t}{P_{t+\tau}} \quad (2.11)$$

is the discount factor in domestic currency and $(1 - \alpha_p)$ is the probability of being able to set the price in a given period, as implied by the representative household problem described in the following subsection.

2.3 The Representative Household

The representative household (HH) maximizes expected utility:¹²

$$\begin{aligned} \max \quad & E_0 \sum_{t=1}^{\infty} \beta^t \xi_t U(C_t, L_t) \\ \text{s.t.} \quad & U(C_t, L_t) = \frac{1}{1-\sigma_c} \left(C_t - v\tilde{C}_{t-1} \right)^{1-\sigma_c} - \kappa_t \int_0^1 \frac{l_t(h)^{1+\sigma_l}}{1+\sigma_l} dh, \end{aligned} \quad (2.12)$$

where $l_t(h)$ represents the quantity of labor of type h supplied and \tilde{C}_{t-1} past aggregate consumption, taken as exogenous by each individual household. Two preference shocks enter in the utility function: ξ_t , which affects the intertemporal elasticity of substitution and κ_t , a shock to the disutility of labor relative to the utility of consumption.

The household invests in capital, which has the following law of motion:

$$K_{t+1} = (1 - \delta) K_t + I_t - \frac{\Phi (K_{t+1} - K_t)^2}{2 K_t}. \quad (2.13)$$

Frictions in financial markets create a wedge between the returns to domestic and foreign assets. As in [Schmitt-Grohe and Uribe \(2001\)](#), this risk premium is assumed to be a decreasing function of the country's net foreign asset position:

$$\Omega_t = \exp \left\{ -\frac{\omega}{2\Upsilon} \frac{e_t B_t}{P_t} + \zeta_t \right\}, \quad (2.14)$$

where ζ_t is an exogenous shock, and Υ is the steady state value of exports in units of domestic final goods, $\Upsilon \equiv eP^x Q^x / P$.

¹²We assume a cashless limit economy as in [Woodford \(2003\)](#).

The budget constraint is:

$$\begin{aligned}
 A_t + e_t B_t + P_t (C_t + I_t) &= (1 + i_{t-1}) A_{t-1} \\
 &+ (1 + i_{t-1}^*) \Omega_{t-1} e_t B_{t-1} + R_t K_t \\
 &+ \sum_{i=d,x,m} \int_0^1 \Pi_t^i(s) ds + \int_0^1 \int_0^1 w_t(h) l_t(h; s) dh ds,
 \end{aligned} \tag{2.15}$$

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

$$l_t(h) = \frac{1 - \psi}{\psi} W_t^{\frac{1}{\gamma_t}} R_t K_t w_t(h)^{-\frac{1+\gamma_t}{\gamma_t}}. \tag{2.16}$$

2.4 Monetary Authority

The model accounts for the monetary policy 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 best 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.

After the exchange rate crisis in 1992, the Riksbank decided to let the krona float and enter a regime of explicit inflation targeting. In the inflation targeting regime, monetary policy is represented by a simple Taylor-type rule in which the interest rate responds to inflation and output.

2.4.1 Target Zone Regime

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:

$$E_t [\hat{e}_{t+1} - \hat{e}_t] = E_t [\hat{e}_{c,t+1} - \hat{e}_{c,t}] + E_t [\hat{e}_{x,t+1} - \hat{e}_{x,t}]. \quad (2.17)$$

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:

$$E_t [\hat{e}_{c,t+1} - \hat{e}_{c,t}] = g_t + \rho_x \hat{e}_{x,t} \quad (2.18)$$

$$g_t = \rho_g g_{t-1} + \varepsilon_{g,t}. \quad (2.19)$$

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 using 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 reaction to exchange rate deviations from the central parity:

$$\hat{i}_t = \rho_{m,TZ} \hat{i}_{t-1} + (1 - \rho_{m,TZ}) \left[\Gamma_{p,TZ} \hat{\pi}_t + \Gamma_{y,TZ} \hat{Y}_t / 4 + \Gamma_{x,TZ} \hat{e}_{x,t} \right] + \varepsilon_{m,TZ,t}, \quad (2.20)$$

where $\hat{\pi}_t$ and \hat{Y}_t are expressed as percentage deviations from steady state values, $\varepsilon_{m,t}$ is an i.i.d. shock which captures the non-systematic component of monetary policy, and \hat{i}_t is defined by $\hat{i}_t \equiv (i_t - \bar{i}) / (1 + \bar{i})$, with \bar{i} the steady state level of the interest rate. Inserting

(2.18) into (2.17), we get an expression for the expectations of depreciation:

$$E_t [\hat{e}_{t+1} - \hat{e}_t] = E_t \hat{e}_{x,t+1} + g_t - (1 - \rho_x) \hat{e}_{x,t}. \quad (2.21)$$

With some algebra, it is possible to rewrite the uncovered interest rate parity relation for the target zone period as:

$$\hat{i}_t = \hat{i}_t^* + E_t \hat{e}_{t+1} + (\rho_x - 1) \hat{e}_t - \omega \hat{B}_t + \zeta_{t,TZ}, \quad (2.22)$$

where we define

$$\zeta_{t,TZ} \equiv g_t + \zeta_t \quad (2.23)$$

to highlight the fact that the exogenous component of the expectation of realignment, g , appears only in the target zone period. For identification reasons, we choose to estimate the sum $g + \zeta$, and rename it simply as $\zeta_{t,TZ}$. Thus, in what follows, the “risk premium shock” encompasses both a pure “expectations of devaluation” and a “risk premium” component when referring to the target zone regime. To make it clear, for the inflation targeting regime we define similarly

$$\zeta_{t,IT} \equiv \zeta_t, \quad (2.24)$$

and we allow $\zeta_{t,TZ}$ and $\zeta_{t,IT}$ to follow different stochastic processes (allowing for different autocorrelation and volatility).

2.4.2 Inflation Targeting Regime

In the inflation targeting period, with the exchange rate freely floating, the monetary authority’s actions while steering the economy are no longer constrained. Hence, we model

monetary policy through a standard log-linearized Taylor rule as:¹³

$$\hat{i}_t = \rho_{m,IT} \hat{i}_{t-1} + (1 - \rho_{m,IT}) \left[\Gamma_{p,IT} \hat{\pi}_t + \Gamma_{y,IT} \hat{Y}_t / 4 \right] + \varepsilon_{m,IT,t}. \quad (2.25)$$

Note that the coefficients in the two Taylor rules, in equation (2.20) and (2.25), are regime-dependent; hence we allow for different responses of the monetary authority to inflation, output, exchange rate and interest rate in the two regimes. Moreover, the variance of the monetary policy shock is allowed to vary across the two subsamples. The uncovered interest parity relation, too, is regime dependent. When the exchange rate is free to float, the UIP reads:

$$\hat{i}_t = \hat{i}_t^* + E_t \hat{e}_{t+1} - \hat{e}_t - \omega \hat{B}_t + \zeta_{t,IT}. \quad (2.26)$$

2.5 Foreign Sector

For simplicity, we treat the foreign sector as exogenous and assume that foreign output, inflation and interest rate follow a log-linear VAR model with one lag:

$$A_0 \begin{bmatrix} \hat{Y}_t^* \\ \hat{\pi}_t^* \\ \hat{i}_t^* \end{bmatrix} = A_1 \begin{bmatrix} \hat{Y}_{t-1}^* \\ \hat{\pi}_{t-1}^* \\ \hat{i}_{t-1}^* \end{bmatrix} + \begin{bmatrix} \varepsilon_{y,t}^* \\ \varepsilon_{p,t}^* \\ \varepsilon_{i,t}^* \end{bmatrix}. \quad (2.27)$$

¹³According to the results in [Lubik and Schorfheide \(2007\)](#), the Bank of Canada and the Bank of England include the nominal exchange rate in their policy rules while the central banks of Australia and New Zealand do not. We conduct a similar exercise on Swedish data and find that the data strongly prefer a version of the model with no response on the exchange rate. See [Section 3](#) for more details.

2.6 Equilibrium and Shock structure

The equilibrium in the domestic goods market requires that

$$Z_t = C_t + I_t, \tag{2.28}$$

$$K_t = \int_0^1 K_t(s) ds. \tag{2.29}$$

It is assumed that no foreigners hold domestic assets, so that in equilibrium $A_t = 0$. The Balance of Payments equation from is given by:

$$B_t = (1 + i_{t-1}^*) \Omega_{t-1} B_{t-1} + P_t^x Q_t^x - P_t^* Q_t^m. \tag{2.30}$$

There are seven structural shocks in the economy: shocks to preferences, productivity, the risk premium, labor supply, the Taylor rule, the price markup and the wage markup. The first four follow stochastic processes given by:

$$z_t = (1 - \rho_z) + \rho_z z_{t-1} + \varepsilon_{z,t}, \tag{2.31}$$

while the two markup shocks, the monetary shock and the foreign shocks — shocks to foreign inflation, output and interest rate — are all i.i.d.

3 Estimation With Regime Change

We estimate the model using Bayesian techniques such as those described in [An and Schorfheide \(2007\)](#). The key innovation that we make relative to those methods is in the incorporation of the regime change into the estimation. As in [Lubik and Schorfheide \(2004\)](#) we break the sample into two subsamples. However, instead of considering two completely

separate estimations (one for each sample), we estimate the two samples jointly. The reason for this is that, as described in the previous section, the only two economic relations that change with the regime are the monetary policy rule and UIP, while all other relations are exactly the same in the two regimes. Furthermore, to the extent that these are structural economic relations, we assume that the parameters determining these relations are also constant across regimes. Under these assumptions doing two separate estimations would imply a significant loss of information that we want to avoid. The next subsection describes how we account for the regime change in the estimation. We then describe the data, priors and present the estimations results.

3.1 Accounting for the Regime Change in the Estimation

Here we give a simple overview of our method to incorporate the regime change in the estimation, and refer the reader to the technical appendix for a more thorough and rigorous description.

In order to accommodate the regime change we set Θ as the vector with all the parameters (including those for both regimes) and set a prior for them. Each regime has its own rational expectations equilibrium (REE), given by

$$z_t = G_1^j(\Theta)z_{t-1} + G_2^j(\Theta)\epsilon_t, \text{ for } j = TZ, IT, \quad (3.1)$$

where z_t is a vector with all state space variables and $\{G_1^j, G_2^j\}_{j=TZ,IT}$ are matrices which depend on the vector of parameters Θ . The observation equations are identical across regimes. Thus, we compute two separate equilibria for the same model with only two regime-dependent equations changed — the Taylor rule and the UIP condition — and we reconnect the two REE via the likelihood function as described below.

We compute the likelihood function recursively, as proposed in [Hamilton \(1994\)](#), except

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that we break the sample in two components, so that the posterior function can be expressed as follows:

$$p(\Theta) \propto \prod_{t=T_0^{TZ}}^{T_1^{TZ}} p_N(x_t | \mu_t(\Theta), \Sigma_t(\Theta)) \times \prod_{t=T_0^{IT}}^{T_1^{IT}} p_N(x_t | \mu_t(\Theta), \Sigma_t(\Theta)) \times q(\Theta), \quad (3.2)$$

where the first term is the likelihood function for the target zone, and $\{\mu_t(\Theta), \Sigma_t(\Theta)\}$ are given from a Kalman filter recursion based on the target zone REE solution matrices presented in (3.1), with $j = TZ$, and the first sub-sample; the second term is the likelihood function for the inflation targeting period, and $\{\mu_t(\Theta), \Sigma_t(\Theta)\}$ now depend on the inflation target REE solution matrices presented in (3.1), with $j = IT$, and that regime's sub-sample; and the third term is the prior probability density function.

One issue to tackle in this computation is how to set the initial state prior for each regime. We assume that the TZ sample starts with the first observation in the sample, and set a prior on the initial state to have mean zero and an identity covariance matrix. We also omit the last observation of the target zone sub-sample and the first of the inflation targeting to minimize the effects of breaks in expectations in the theoretical model. Another reason to omit these observations is that there was substantial instability in the economy at the time of the regime change, with interest rate as high as 500 basis points and sharp movements in several variables. We consider that there is more noise than information in these movements and as such is preferable to omit them. For the initial state of the target zone regime we set a prior with mean equal to the last state of the previous regime and a covariance matrix proportional to the covariance matrix of that state. The factor of proportionality is set to $(1.5)^2$, corresponding to increased uncertainty due to the regime change, crisis periods and omission of observations.

Once we have the posterior function, all the usual Bayesian estimation methods described

in An and Schorfheide (2007) apply.¹⁴

3.2 Data

The data used for the estimation corresponds to ten variables in the model: foreign interest rate, foreign consumer price index (CPI), foreign output, domestic output, domestic CPI, domestic interest rate, nominal exchange rate, real wages, hours worked and consumption. Our data set contains quarterly data over the period 1980q1 - 2008q4. 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. To construct foreign variables, we aggregate national variables according to their trade weights. All series were seasonally adjusted and detrended using a linear trend prior to estimation.¹⁵ A more detailed description of the data can be found in the technical appendix.

3.3 Priors

The main properties of our prior distributions are presented in Table 1. Technology, utility and price setting parameters are assumed to be Normal, Beta, Gamma or Inverse Gamma depending on the supports and the uncertainty surrounding the parameters. For the price elasticity of aggregate exports (η) we refer to the findings of Johansson (1998) who estimates this parameter at 1.3 for manufactured goods and 0.7 for the services sectors and use a prior distributed as an inverted gamma with mean 1.5. Apel et al. (2005) provide a survey of Swedish firms according to which firms change their prices once a year. However, using macro data, both Smets and Wouters (2003) and Adolfson et al. (2007) estimate a higher degree of price rigidity for the Euro area. Therefore, for both Calvo parameters α_p

¹⁴Please see the technical appendix for additional details.

¹⁵Interest rate and exchange rate series were not seasonally adjusted.

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and α_w , we choose a beta distribution with a mean of 0.76. The prior for the risk aversion parameter is a Normal with mean 2, while the prior for the habit persistence parameter (ν) is distributed as a beta with a mean of 0.7. As for the other utility parameter, the inverse elasticity of labor supply (σ_l), we chose a normal with mean 1. For the adjustments cost parameter Φ , we use a gamma with a mean of 10 and a standard deviation of 5 to encompass the values used in [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 mean for our prior.

We consider identical priors for the monetary policy rule parameters for both periods. More precisely, we assume Γ_p and Γ_y to be distributed according to gammas with means of 2 and 0.5, respectively. The prior for the interest rate smoothing parameter (ρ_m) is distributed as a beta with a mean of 0.8. The Taylor rule parameter on the exchange rate (Γ_e) is a truncated normal with a mean of 1.6 and the mean for the coefficient for the endogenous part in the realignment expectations (ρ_x) is set at 0.24. These last two parameters are to some extent based on the theoretical experiments and empirical analysis by [Svensson \(1994\)](#).

For the foreign sector VAR, we take a conservative stand and set our priors as if foreign inflation, output and interest rates follow three independent AR(1) processes. We choose a mean of 0.75 for the autoregressive coefficients and a mean of zero for all the other cross-parameters.

The parameters controlling the standard deviation of innovation for all of the shocks have inverted Gamma priors, with a normalized mean and loose variance. We assume the autocorrelation coefficients of the shocks to follow a beta with a mean of 0.725 and a standard deviation of 0.15.

We choose to calibrate some parameters that are related to steady state levels. 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 calibrated to

match the implied steady state imports GDP ratio in the two subsamples. The technology parameter, ψ , is calibrated at 0.3. We refer to the estimates of [Martins et al. \(1996\)](#) to calibrate the steady state markup over marginal cost for intermediate good, ν , at 0.16, a value in line with the estimate for the manufacturing sector in Sweden.

3.4 Parameter Posteriors

The first question that we ask in this paper is whether there are significant differences in monetary policy under the target zone and inflation targeting regimes. In order to answer that we start by analyzing the posterior of the parameters, with a special focus on those related to the regime change. [Table 1](#) displays a comparison of prior with posterior moments. The first two panels show parameters that are constant across regimes while the lower two panels show the parameters associated with each regime.¹⁶ The first four columns refer to the prior, while the following three columns summarize the 5th percentile, the median and the 95th percentile for the marginal posterior of each parameter in the case of regime change. The last three columns refer to the similar estimation in which we assume that there is no regime change, which will be discussed in the following section.

The estimated monetary policy rules show interesting differences between the target zone and the inflation targeting regimes. Consistent with *a priori* expectations, in the target zone the central bank reacted strongly to exchange rate deviations from central parity while under inflation targeting monetary policy focused mainly on inflation stabilization. According to our results, monetary policy responded aggressively to exchange rate movements during the target zone period. During the target zone regime $\Gamma_{e,TZ}$ has a posterior median of 1.3 – taking into account the interest rate smoothing parameter, our estimate implies that a 1% deviation of the exchange rate from central parity would lead, *ceteris paribus*, to a 92 basis

¹⁶We jointly estimate the DSGE and the foreign VAR parameters. The estimates for the VAR coefficients are available upon request.

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point increase in the policy rate. In contrast, in the inflation targeting regime the data strongly prefer a model with no response to the exchange rate. More precisely, if we allow for a response on the nominal exchange rate during the inflation targeting period, we find that marginal data density of the benchmark model ($\Gamma_{e,IT} = 0$) is 11.8 larger on a log scale.

The estimated response of monetary policy to inflation is somewhat stronger during the inflation targeting regime (median of 2.08) than during the target zone period (median of 1.74). Interestingly, policy reacted to some extent to output during the target zone period (median of 0.69), but almost not at all in the period of inflation targeting (median of 0.01). Thus, according to our estimation, during the inflation targeting period, monetary policy is more focused on responding to inflation than responding to movements in the real economy.

As expected, we estimate a lower value for the interest rate smoothing coefficient during the target zone regime (median of 0.82) than during the inflation targeting period (median of 0.89). The non-systematic component in the Taylor rule ($\varepsilon_{m,t}$) is 3 times more volatile during the target zone period than during the inflation targeting period. These results are consistent with the findings in [Adolfson et al. \(2008\)](#), and suggest that monetary policy has become more predictable and systematic after the introduction of the inflation targeting regime. Another coefficient of significant interest is the sensitivity of the expected rate of realignment, ρ_x , with a posterior median of 0.37, a value close to the estimates in [Svensson \(1994\)](#). The combined shock to realignment expectations and risk premium shock in the target zone is both less persistent and less volatile than the risk premium shock in the inflation targeting regime.

As for other, regime independent parameters, shown in the top two panels, our posterior moments are in the ballpark of previous studies.

3.5 Transmission and Sources of Business Cycle Fluctuations

The two estimated monetary policy regimes affect the transmission of different shocks, as measured by the response of some key macro variables. Not surprisingly given that result, the policy regimes also lead to different decompositions of the sources of business cycle fluctuations, in terms of the contribution of each shock to the volatility of each variable. The results illustrate the importance of correctly formulating the monetary policy regime.

The international transmission mechanism is significantly affected by the choice of exchange rate regime. In particular, the difference in the economic dynamics under the two regimes is sharper in the case of shocks that originate abroad. Foreign shocks play a more important role in the target zone regime than in the inflation targeting regime since the exchange rate acts as a shock absorber in the latter. As highlighted in our results in Section 4 (discussed below), it is therefore crucial to account for the regime change in our estimated DSGE to properly analyze the business cycle dynamics of a small open economy like Sweden. We analyze some of the responses in more detail below. Figures 1 through 3 present impulse response functions to different shocks.¹⁷ The figures show the responses under both the TZ and IT regimes (the third response will be discussed in the following section).

The risk premium shocks (Figure 1) have very different effects during the two regimes. The comparison between the two is particularly interesting since, as explained above, in our estimation for the target zone period the risk premium shock also incorporates a realignment expectations component. During the target zone period, the depreciation generated by an increase in the risk premium (or expectations of depreciation) leads the monetary authorities to increase the interest rate, thus generating a contraction in the real economy. In contrast, under inflation targeting, the monetary policy tightening that follows a risk premium shock is

¹⁷Responses are presented in percentage points. The shocks are set to one standard deviation. In the plots, we present the median response. For the sake of exposition, we present only 3 shocks. All the other impulse response functions are available upon request.

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more muted. As a consequence, there is a larger real and nominal exchange rate depreciation. This leads to an increase in output, employment and inflation. Therefore, the two regimes imply responses that are both qualitatively and quantitatively different.

A technology shock (Figure 2) generates similar qualitative responses in the two regimes. However, in the inflation targeting period, the domestic currency is allowed to depreciate more, leading to higher interest rates and slightly lower output as compared to the target zone period. In the inflation targeting period, the real exchange rate adjustment is more sizable and immediate.

A monetary shock (Figure 3) is worth mentioning only in that it generates a much stronger response in the inflation targeting period. Even though the size of the shock during this period is about half the one during the target zone period, output response is almost twice as strong. The reason for this is that such a monetary shock destabilizes the exchange rate and, thus, needs to be undone in a target zone regime soon after. In the inflation targeting regime, because exchange rates are free to float and react, exports are more responsive (precisely because export prices change more), as are output and the remaining economy.

To analyze to what extent differences in policy regimes affect the sources of business cycle fluctuations, we also perform a variance decomposition for output, inflation, interest rate, and nominal and real exchange rates. Tables 2 through 4 present the decomposition of the variance of selected variables as implied by individual shocks, as a ratio of total variance for those variables.¹⁸ The top two panels show those relative contributions for the TZ and IT regimes, while the third panel will be discussed in the following section.

Labor supply shocks are the most significant source of output fluctuations in both regimes and for all of the time horizons considered. Our results are in line with [Smets and Wouters \(2003\)](#), who find that labor supply shocks are one of the main sources of output variation

¹⁸Each element of the table presents the median contribution, where 1 corresponds to 100%.

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for the Euro area.¹⁹

In the short run (as measured at one quarter ahead), preferences shocks are the second most important source of output fluctuations in both periods. However, they are more relevant during the inflation targeting regime, accounting for about 9% of the volatility of real output during the target zone regime and for about 19% during the second regime.

The risk premium and realignment expectation shocks are both important in explaining nominal and real exchange rate volatilities in the short and medium run, in both the target zone and inflation targeting regimes (recall that in the former, the risk premium also includes shocks to realignment expectations), but are more relevant in the second regime. To be precise, at the four-quarter horizon, risk premium shocks account for about 50% of nominal and real exchange rate volatility during the inflation targeting regime, while during the target zone period risk premium shocks (including shocks to the expectation of realignment) explain up to 19% and 15%, respectively. During the target zone regime, these shocks also play an important role in explaining interest rates fluctuations accounting for more than 20% of interest rates volatility in the short and medium run, while their role during the inflation targeting regime is only limited (1% and 3%, respectively).

Interestingly, monetary shocks account for a significant part of the real exchange rate fluctuations during the target zone (almost 48% at 1 quarter ahead, 38% at 4 quarters ahead and 9% at 20 quarters ahead), but have only a limited role during the inflation targeting period (always less than 6%). Price markup shocks explain most of the inflation variation under both monetary regimes at all horizons.

Finally, it is worth noting that, consistent with previous DSGE studies,²⁰ foreign shocks have only a limited contribution to business cycle fluctuations at every horizon in both regimes. However, their importance is somewhat higher during the target zone period. For

¹⁹Labor supply shocks may capture unmodelled labor market features or shifts in per capita hours of work due, for example, to demographic changes or fiscal reforms.

²⁰See, e.g., Justiniano and Preston (2010a).

example, in the short run their role in explaining output fluctuations is as much as 6 times larger in the target zone period than in the inflation targeting period.

4 Estimation Without Regime Change

The previous section discussed the differences between the two monetary policy regimes. This section analyzes how important it is to properly account for the monetary policy regime change in the estimation. To do this, we re-estimate the model over the exact same data, but without the policy regime change from one subperiod to the other, so that in both periods we assume that the regime can be described with the same interest rate rule — which we assume to have the same form as in (2.25), the IT rule. Notice that this also implies no realignment expectations shocks and therefore the risk premium term has the same properties in the two subperiods.

The main goal of this analysis is to evaluate the extent to which ignoring the regime break can lead to spurious results in the estimation of the model.

4.1 Spurious Parameter Posteriors

First of all, it is important to note that the fit of the model without policy shift (NRC) deteriorates compared to the case where we explicitly acknowledge the policy break (RC). As shown in the last row of Table 1, the difference in the log marginal likelihood between the two cases is 3.7 points, thus suggesting strong evidence in favor of the model with the regime change.²¹

As concerned the parameters estimates, *ex ante*, we should expect that the NRC estimation would yield parameter posteriors for the policy rule that would be a mixture of the

²¹Kass and Raftery (1995) suggests that a difference in marginal likelihood in natural logs between 3 and 5 should be considered strong evidence in favor of the model with the higher marginal likelihood.

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posterior for the two regimes in the baseline estimation (the two lower groups of parameters in Table 1). Furthermore, if the misspecification is not significant then it should not affect the structural parameters that are constant across regimes (the two top panels in Table 1).

Let us begin with the parameters that are regime-dependent, shown in the bottom two panels in the table. Using the median of the posterior distributions, we can write the policy rules as:

$$TZ : \hat{i}_t = 0.82\hat{i}_{t-1} + 0.18 \left[1.74\hat{\Pi}_t + 0.69\frac{\hat{Y}_t}{4} + 1.30\hat{e}_{x,t} \right] + 0.0059\varepsilon_{m,TZ,t} \quad (4.1)$$

$$IT : \hat{i}_t = 0.89\hat{i}_{t-1} + 0.11 \left[2.08\hat{\Pi}_t + 0.01\frac{\hat{Y}_t}{4} \right] + 0.0018\varepsilon_{m,IT,t} \quad (4.2)$$

$$NRC : \hat{i}_t = 0.83\hat{i}_{t-1} + 0.17 \left[1.58\hat{\Pi}_t + 0.005\frac{\hat{Y}_t}{4} \right] + 0.0026\varepsilon_{m,t} \quad (4.3)$$

where TZ refers to the target zone policy rule in the baseline estimation, IT to the inflation targeting rule in the baseline estimation, and NRC to the policy rule estimated without taking into account the break.

When estimating the NRC rule, we test for a response on the exchange rate. As in the IT period, in the NRC case the data strongly prefers the model with no response to the exchange rate. More precisely, we find that marginal data density of the benchmark model ($\Gamma_e = 0$) is 2.5 larger on a log scale. Thus, ignoring the regime change would imply, *ceteris paribus*, a policy response to the exchange rate similar to the inflation targeting rule. Similarly, the response to output is negligible in both the IT period and the NRC estimation, while it is fairly strong in the TZ period. This means that if we focus on the current policy response function there is no significant bias on these two coefficients if we omit the regime change in the estimation.

In contrast, the response to inflation in the NRC is lower compared to both IT and TZ. Moreover, ignoring the regime change in the estimation yields a volatility of the monetary

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policy shock that is somewhat in between (0.0026) the IT and TZ estimates, which is not a total surprise — a similar result applies to the persistency of the interest rate level.

The characteristics of the risk premium shock are very different across regimes, much like the monetary policy shock. It is thus not surprising that the volatility of these two shocks in the NRC estimation is in between that of the two separate periods in the baseline estimation.

Turning to the parameters considered to be constant across regimes in both estimations (upper two panels in Table 1), we find that both prices and wages have estimated degrees of rigidity that are similar across the two estimations. This element is important because nominal rigidities are key for the role of monetary policy and finding that they are not sensitive to the inclusion of the monetary regime break is an indication that the model is somewhat robust to the monetary regime specification, at least in this respect. However, when we compare the price-elasticity of foreign demand, η , across the two estimations, the posterior median is very different (1.69 in the benchmark estimation, compared to 2.46 in the NRC case), which suggests that exports are more sensitive to changes in relative prices in the NRC case. This is obviously important for the estimation of a small (very) open economy model, as is the case for Sweden.

Two other structural parameters that do not show robustness across estimations with and without regime change are the households' preference parameters: the intertemporal elasticity of substitution, σ_c^{-1} , and the habit formation parameter, v . This implies that the sensitivity of consumption to the interest rate, $(1 - v)\sigma_c^{-1}$ is substantially higher in the NRC estimation than in the baseline estimation (0.29 versus 0.02, so about one order of magnitude). It is true that nominal rigidities affect how much impact the monetary policy can have on the economy and they are stable across estimation assumptions, but the sensitivity of demand to the real interest rate is crucial for the evaluation of how the demand responds to monetary policy, and this is at the heart of the transmission mechanism. Our results show that the transmission mechanism is influenced by whether we acknowledge

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the regime shift in the estimation or not. In particular the results suggest that the policy rate has to move about ten times more when we acknowledge the regime change in order to achieve the same impact in household expenditure, compared to the assumption of no regime change.

The differences relate to the parameters of the preference shock. In the NRC estimation this shock is both less persistent and less volatile. In terms of volatility it is one order of magnitude smaller, much like the sensitivity of consumption to the real interest rate. From the Euler equation,

$$E_t \hat{C}_{t+1} - (1 + v) \hat{C}_t + v \hat{C}_{t-1} = \sigma_c^{-1} (1 - v) (\hat{i}_t - E_t \hat{\pi}_{t+1}) + \sigma_c^{-1} (1 - v) \left(E_t \hat{\xi}_{t+1} - \hat{\xi}_t \right), \quad (4.4)$$

it is clear that if we interpret $\hat{\xi}_t$ as capturing shocks to consumption, its size is then influenced by the estimate for $\sigma_c^{-1} (1 - v)$. Hence, if in the NRC we get $\sigma_c^{-1} (1 - v)$ to be higher by a factor of 10, it is not surprising that the standard deviation of $\hat{\xi}_t$ is lower by a factor of 10, which keeps the response of consumption to that shock roughly similar. Hence this change is not surprising once we establish the difference in the sensitivity of consumption to the real interest rate.

Another parameter of interest for a small open economy is the degree of sensitivity of the interest rate to the level of debt, ω . If we acknowledge the regime change this parameter is 0.001, while if we ignore the regime change we get a posterior median of 0.004, which implies a much higher sensitivity of the country risk-premium to the net indebtedness of the country. This might be induced in the estimation by the need of the model to generate country risk premium during the target zone period that is no longer accounted for by the risk of realignment expectations. When we estimate the model taking into account the policy break, devaluation expectations appear to depend on the current exchange rate deviation from the central parity. Because the NRC estimation does not account for that

when generating the UIP relation it forces the risk premium to depend more strongly on the international indebtedness of the country.

The labor supply elasticity parameter, σ_l , and the investment adjustment cost, Φ , are both smaller in the NRC case, compared to the benchmark, but neither of them by much. If we consider that habits and investment adjustment costs are two important channels of endogenous persistency then we conclude that ignoring the monetary policy regime change in the estimation leads to less endogenous persistency in terms of the real side of the economy. Regarding the parameters of the exogenous processes, they are mostly similar across the two estimations with the exception of the preferences shock, which was discussed previously.

The results discussed in this section are important for two reasons. First, they show that an estimation of the policy rule that ignores the fact that there was a monetary policy regime change will result in a policy characterization that is not correct for either period. This is especially relevant if we want to use the estimation results to undertake forecasting exercises. Second, ignoring the regime change in the estimation does affect the posterior distribution of the parameters that are supposed to be structural and independent of the policy regime, which will make the whole estimation unreliable. In particular this affects the parameters associated with the demand side (the ones associated with the so-called “IS curve”, which relates how the demand curve responds to the interest rate). If we want to conduct policy simulations based on such “structural” parameters then we may get biased simulations.

4.2 Spurious Business Cycle Properties

The omission of the monetary policy regime break and the biased estimation results documented in the previous subsection significantly affect the estimation of the dynamic responses and sources of business cycle volatility. The results are shown in Figures 1 through 3, and Tables 2 through 4.

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The dynamic responses of output, inflation and employment after a productivity (Figure 2) or monetary shock (Figure 3) clearly illustrate this point. Even though the responses of these variables are similar during the IT and the TZ periods, the NRC estimation delivers very different results. After a technology shock, output and employment are more responsive on impact and display more persistency in the NRC estimation than compared to either the IT or TZ regimes. The estimated higher price-elasticity of foreign demand in the NRC case makes export more sensitive to relative prices changes. As export prices decrease, the resulting surge in exports busts the real side of the economy. After a monetary shock, output, employment and inflation decrease much more substantially in the NRC estimation than in the IT or TZ cases. Again, in the NRC estimation exports are more responsive after a monetary policy tightening. Even though the increase in export prices is comparable in the IT and NRC cases, exports decrease more in the latter.

The variance decomposition analysis also shows interesting results but mainly with respect to the secondary contributions to business cycle volatility. At the one-quarter-ahead horizon, the NRC estimation closely reproduces the IT regime results in terms of the biggest contribution for all the variables. However, when it comes to the second biggest contributions to business cycle volatility we find some differences. For example the technology shock, θ_t , explains up to 8% of output volatility in both monetary regimes, while in the NRC estimation it contributes 14%. Moreover, the monetary policy shock has a residual contribution to the volatility of output in both the TZ and IT periods but in the NRC regime it explains up to 12% of output fluctuations — clearly the misspecification of the policy regime induces a bias in the variance decomposition in the very short run.

At the 4-quarter-ahead horizon, we find similar results as for the 1-quarter-ahead case, in terms of the biggest contribution and the fact that the secondary contributions are biased in the NRC. For example, the productivity shock accounts for about 11% of the volatility of output in the two regimes but the NRC estimation assigns it 21%. Similarly, at the

longer horizon (20 quarters ahead) technology shocks play a bigger role in explaining output volatility in the NRC than in the IT and TZ regimes.

5 A Counterfactual Experiment

To further highlight the differences and implications of the two monetary regimes under study for the business cycle of a small open economy, in this section we perform a counterfactual experiment. Namely, we extract the shock innovations from the target zone historical sample and then apply them to the equations in the inflation targeting regime. This analysis allows us to consider how different the evolution of the economy would have been if the policy regime were the one estimated for the inflation target regime. The results are shown in Table 5 and in Figure 4.²²

Our main conclusion is that applying the IT policy regime to the innovations in the shocks hitting Sweden during the target zone period results in higher levels of output, capital, hours and consumption, at the expense of a more depreciated currency (in both nominal and real terms). Moreover, inflation would be on average higher while the nominal interest rate would be lower under the IT policy.

On the other hand, the volatility of most variables would be higher. Notice, however, that the increase in volatility of output and inflation are fairly small, especially in comparison to the increased level of output. It is up for discussion which of these is more important from a normative standpoint and greatly depends on the loss function of the policymakers.

²²The numbers in both the table and figure are shown in percentage deviations from trend.

6 Conclusion

The main contribution of this paper is to propose a tractable way to deal with regime breaks in the structural estimation of linearized DSGE models.

We apply our proposed method to Sweden, an example of a small open economy that went through a regime break. In the estimation procedure, we explicitly account for the well documented monetary policy regime shift that occurred after the speculative attack against the Swedish krona in 1992 and the subsequent switch from a target zone regime to explicit inflation targeting. We analyze the economy behavior across those two regimes and quantify to what extent ignoring the regime shift in the estimation can produce spurious results.

Our main finding is that it is important to account for the regime change in the estimated DSGE to properly capture the information in the data. If we had estimated the model over the entire sample without accounting for this, we would have acquired business cycle properties that are averaged across the two periods and obtained spurious results for both the policy rule and the policy-independent parameters of the model.

It can be argued that, based on these results, we should attempt to develop a model that is more robust to the policy specification. However, it is not obvious *ex-ante* how one can do that in a systematic way without incurring the risk of simple data/model-mining. With our paper we suggest that a first step is to make sure that the policy regime is properly characterized.

Our method is applicable to all those cases in which there is a well documented regime change and there is no need to search for when it happened, like in Sweden, where both monetary policy regimes were well advertised. Importantly, there is a significant number of small open economies in which monetary and exchange rate regimes have been announced and changed during the last thirty years, thus compromising the estimation of models for these economies.

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Table 1: Parameter posteriors in the baseline estimation.

	Dist	Prior			Posterior: RC			Posterior: NRC		
		5%	Median	95%	5%	Median	95%	5%	Median	95%
η	IG2	1.081	1.463	2.046	1.460	1.687	1.958	2.112	2.457	2.875
α_p	B	0.583	0.775	0.910	0.833	0.856	0.878	0.821	0.840	0.858
α_w	B	0.583	0.775	0.910	0.909	0.934	0.955	0.881	0.906	0.929
σ_c	G	0.683	1.836	3.877	0.524	1.720	4.050	0.216	0.336	0.574
σ_l	G	0.342	0.918	1.938	0.300	0.850	1.892	0.171	0.544	1.414
Φ	G	3.416	9.180	19.384	14.012	18.659	24.943	10.043	13.207	17.564
v	B	0.524	0.707	0.853	0.948	0.974	0.988	0.862	0.903	0.936
100ω	G	0.203	0.341	0.529	0.065	0.121	0.205	0.229	0.371	0.556
σ_y	IG1	0.333	0.687	2.473	0.461	0.512	0.573	0.460	0.511	0.574
σ_p	IG1	0.333	0.687	2.473	0.255	0.285	0.321	0.250	0.278	0.312
σ_i	IG1	0.333	0.687	2.473	0.103	0.114	0.128	0.103	0.115	0.129
ρ_ξ	B	0.447	0.745	0.935	0.183	0.310	0.452	0.144	0.253	0.379
ρ_θ	B	0.447	0.745	0.935	0.982	0.993	0.998	0.990	0.996	0.999
ρ_κ	B	0.447	0.745	0.935	0.992	0.998	0.999	0.993	0.998	0.999
σ_ξ	IG1	0.333	0.687	2.473	2.505	9.027	25.845	0.323	0.481	0.877
σ_θ	IG1	0.333	0.687	2.473	1.209	1.344	1.509	1.213	1.348	1.511
σ_κ	IG1	0.333	0.687	2.473	0.162	0.205	0.268	0.158	0.199	0.259
σ_ν	IG1	0.333	0.687	2.473	0.653	0.736	0.836	0.549	0.617	0.697
σ_γ	IG1	0.333	0.687	2.473	0.790	0.897	1.025	0.795	0.899	1.025
$\Gamma_{p,TZ}$	G	1.607	1.990	2.428	1.408	1.739	2.117	—	—	—
$\Gamma_{y,TZ}$	G	0.171	0.459	0.969	0.450	0.685	1.036	—	—	—
$\Gamma_{e,TZ}$	TN	0.125	1.349	3.920	0.817	1.299	2.055	—	—	—
$\rho_{m,TZ}$	B	0.713	0.803	0.877	0.764	0.823	0.871	—	—	—
$\sigma_{m,TZ}$	IG1	0.333	0.687	2.473	0.449	0.585	0.803	—	—	—
ρ_x	G	0.102	0.226	0.425	0.273	0.370	0.491	—	—	—
ρ_g	B	0.447	0.745	0.935	0.489	0.644	0.775	—	—	—
σ_g	IG1	0.333	0.687	2.473	0.373	0.495	0.669	—	—	—
$\Gamma_{p,IT}$	G	1.607	1.990	2.428	1.718	2.077	2.477	1.339	1.575	1.886
$\Gamma_{y,IT}$	G	0.171	0.459	0.969	0.005	0.013	0.029	0.002	0.005	0.012
$\rho_{m,IT}$	B	0.713	0.803	0.877	0.856	0.886	0.911	0.796	0.833	0.865
$\sigma_{m,IT}$	IG1	0.333	0.687	2.473	0.157	0.184	0.219	0.230	0.259	0.295
ρ_ζ	B	0.447	0.745	0.935	0.605	0.710	0.798	0.628	0.703	0.770
σ_ζ	IG1	0.333	0.687	2.473	0.983	1.431	2.073	0.887	1.146	1.483
mg Lik						3921.6			3917.9	

MONETARY REGIME CHANGE AND BUSINESS CYCLES

Table 2: Variance decomposition for 1 quarter ahead

	Pref	Tech	Mon	Foreign Shocks	Labor Supply	Price Markup	Wage Markup	Risk Premium
Target Zone Regime								
Y	0.094	0.082	0.005	0.066	0.652	0.074	0.011	0.007
π	0.001	0.042	0.001	0.012	0.014	0.919	0.008	0.000
i	0.003	0.009	0.541	0.036	0.046	0.120	0.001	0.225
e	0.016	0.002	0.575	0.048	0.092	0.009	0.000	0.241
q	0.017	0.001	0.482	0.027	0.057	0.188	0.001	0.206
Inflation Targeting Regime								
Y	0.186	0.078	0.049	0.012	0.550	0.100	0.010	0.008
π	0.010	0.026	0.007	0.003	0.041	0.881	0.007	0.021
i	0.005	0.012	0.537	0.001	0.020	0.409	0.003	0.010
e	0.001	0.023	0.057	0.029	0.213	0.002	0.003	0.661
q	0.000	0.031	0.054	0.020	0.198	0.024	0.004	0.658
No Regime Change Estimation								
Y	0.118	0.141	0.117	0.011	0.489	0.098	0.011	0.005
π	0.009	0.023	0.031	0.007	0.082	0.811	0.010	0.020
i	0.003	0.007	0.714	0.002	0.024	0.239	0.003	0.006
e	0.005	0.029	0.130	0.052	0.185	0.001	0.001	0.587
q	0.004	0.038	0.121	0.043	0.164	0.023	0.002	0.594

MONETARY REGIME CHANGE AND BUSINESS CYCLES

Table 3: Variance decomposition for 4 quarters ahead.

	Pref	Tech	Mon	Foreign Shocks	Labor Supply	Price Markup	Wage Markup	Risk Premium
Target Zone Regime								
Y	0.083	0.113	0.001	0.056	0.687	0.031	0.016	0.003
π	0.002	0.087	0.001	0.035	0.059	0.791	0.016	0.000
i	0.004	0.041	0.268	0.101	0.187	0.076	0.006	0.286
e	0.025	0.010	0.491	0.064	0.189	0.012	0.001	0.185
q	0.030	0.032	0.383	0.095	0.056	0.221	0.008	0.149
Inflation Targeting Regime								
Y	0.127	0.114	0.028	0.006	0.663	0.028	0.016	0.009
π	0.026	0.058	0.013	0.005	0.083	0.764	0.015	0.025
i	0.031	0.064	0.449	0.006	0.102	0.286	0.016	0.027
e	0.002	0.033	0.065	0.041	0.357	0.001	0.004	0.485
q	0.000	0.062	0.059	0.021	0.319	0.020	0.009	0.499
No Regime Change Estimation								
Y	0.062	0.210	0.079	0.007	0.578	0.033	0.018	0.005
π	0.018	0.039	0.052	0.013	0.165	0.662	0.017	0.021
i	0.015	0.031	0.592	0.011	0.141	0.171	0.014	0.015
e	0.009	0.041	0.139	0.067	0.320	0.001	0.001	0.409
q	0.005	0.075	0.124	0.051	0.262	0.018	0.006	0.447

MONETARY REGIME CHANGE AND BUSINESS CYCLES

Table 4: Variance decomposition for 20 quarters ahead.

	Pref	Tech	Mon	Foreign Shocks	Labor Supply	Price Markup	Wage Markup	Risk Premium
Target Zone Regime								
Y	0.011	0.090	0.000	0.027	0.854	0.003	0.011	0.000
π	0.002	0.075	0.000	0.053	0.305	0.530	0.013	0.000
i	0.006	0.110	0.062	0.097	0.593	0.020	0.016	0.075
e	0.009	0.081	0.135	0.057	0.630	0.007	0.011	0.052
q	0.012	0.149	0.088	0.200	0.399	0.062	0.025	0.035
Inflation Targeting Regime								
Y	0.020	0.067	0.005	0.001	0.894	0.002	0.008	0.001
π	0.048	0.098	0.012	0.007	0.111	0.659	0.022	0.024
i	0.139	0.238	0.205	0.013	0.177	0.104	0.053	0.016
e	0.026	0.017	0.030	0.073	0.700	0.004	0.003	0.135
q	0.002	0.076	0.027	0.012	0.693	0.007	0.009	0.164
No Regime Change Estimation								
Y	0.006	0.159	0.014	0.001	0.805	0.002	0.009	0.000
π	0.020	0.046	0.053	0.015	0.204	0.605	0.020	0.022
i	0.033	0.067	0.348	0.018	0.382	0.095	0.031	0.012
e	0.017	0.021	0.073	0.071	0.697	0.003	0.002	0.105
q	0.006	0.109	0.059	0.029	0.608	0.007	0.006	0.169

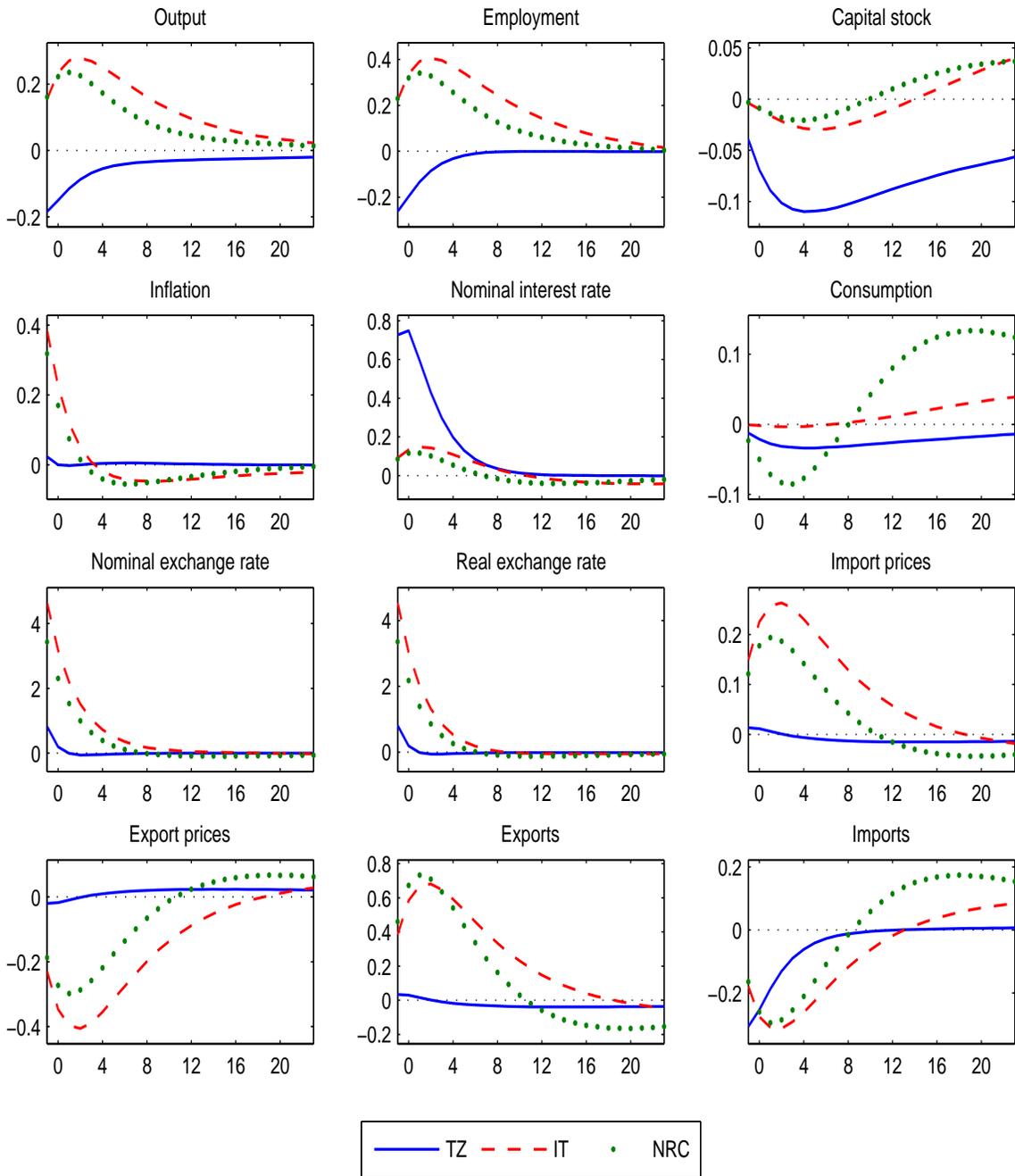
MONETARY REGIME CHANGE AND BUSINESS CYCLES

Table 5: Moments for some variables during the target zone period under the estimated policy for that period's policy regime (TZ Policy) and under the counterfactual experiment in which the estimated policy for the inflation targeting regime is used to respond to the shocks (IT Policy): mean and standard deviation.

	Mean			Std		
	TZ Pol	IT Pol	Diff	TZ Pol	IT Pol	Diff
Output	1.336	8.522	7.186	2.197	2.950	0.753
Employment	1.265	8.619	7.354	3.213	4.806	1.593
Inflation	0.527	1.409	0.882	3.392	3.921	0.529
Nominal interest rate	1.034	-2.513	-3.546	1.667	2.503	0.837
Consumption	1.087	3.879	2.792	3.188	3.790	0.602
Nominal exchange rate	1.451	14.405	12.954	1.037	6.887	5.850
Real exchange rate	2.989	11.387	8.398	3.100	4.089	0.989
Real wage rate	1.067	-0.145	-1.213	4.897	6.007	1.110

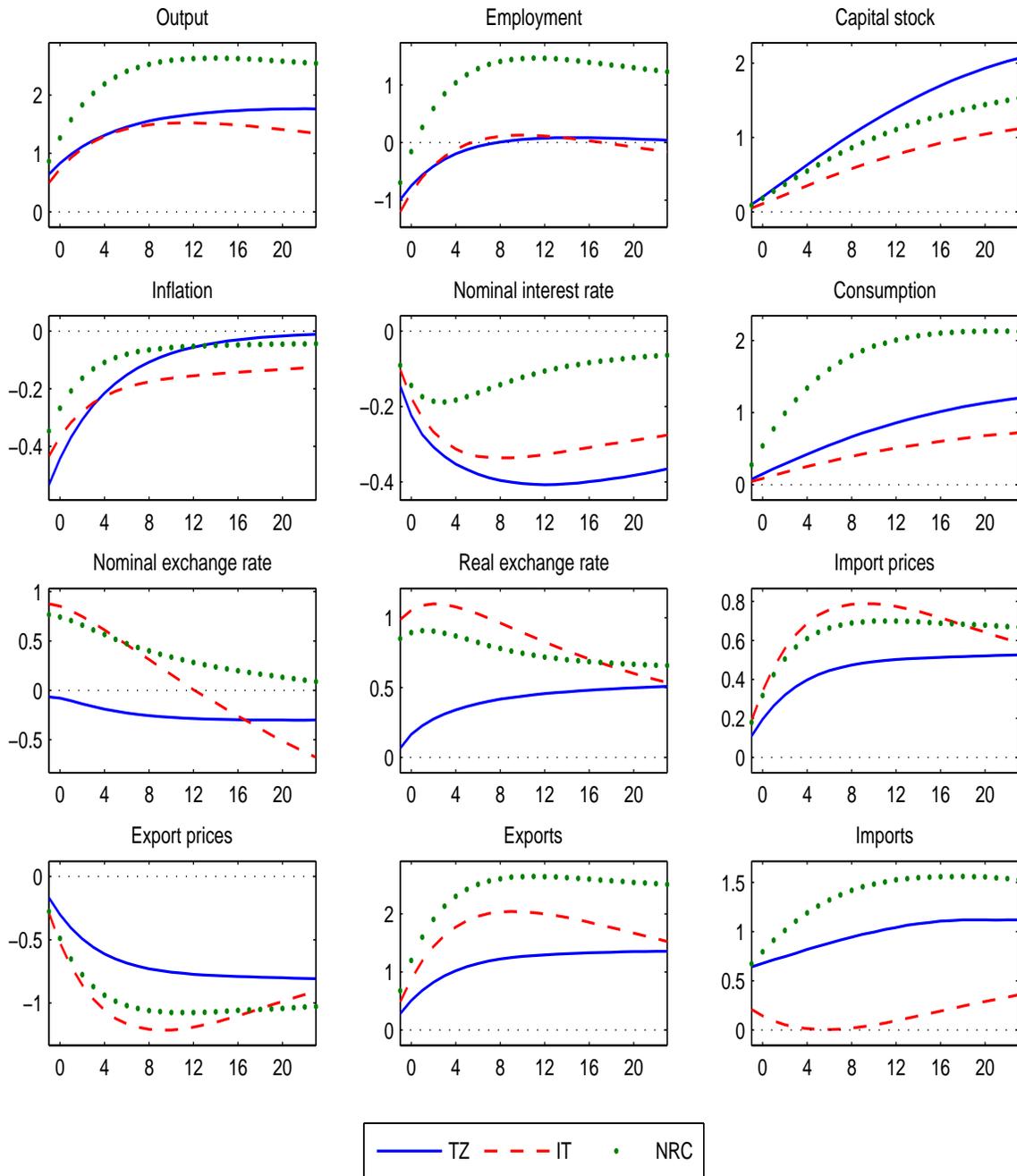
MONETARY REGIME CHANGE AND BUSINESS CYCLES

Figure 1: Responses to a realignment expectation and a risk premium shock.



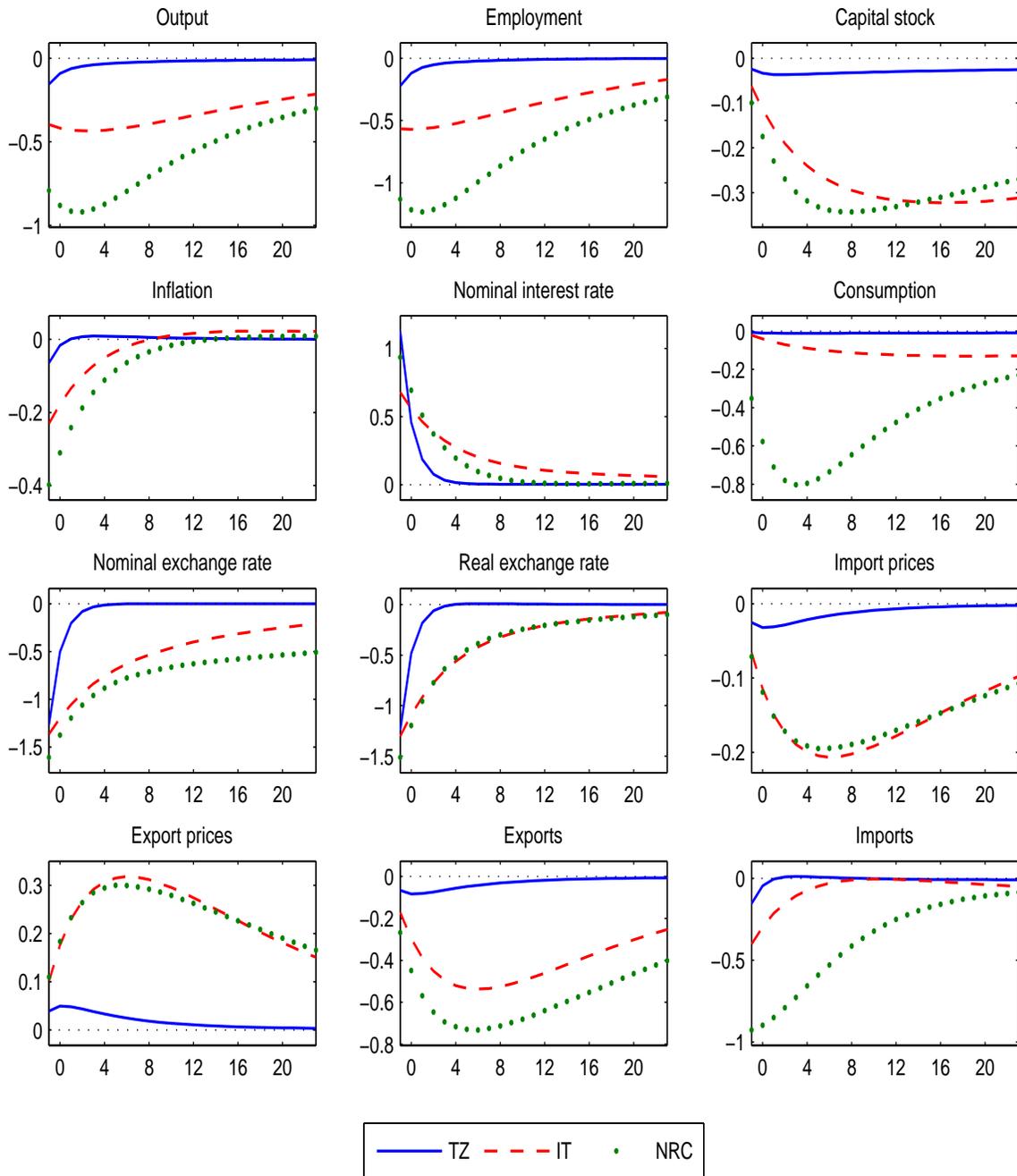
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Figure 2: Responses to a technology shock.



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Figure 3: Responses to a monetary shock.



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Figure 4: Evolution of some variables during the target zone period under the estimated policy for that period and under the estimated policy for the inflation targeting regime.

