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Central bank policy paths and market forward rates: A simple model

Ferre De Graeve and Jens Iversen*

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Abstract

Increasingly many central banks announce likely paths for future policy rates. Recent experience suggest that market forward rates can differ substantially from those announced. Models commonly adopted in policy analysis ignore such differences. This paper studies a simple model that can capture deviations between announced paths and market forward rates. We detail the macroeconomic transmission of such deviations both in the model and in the data and show how the model can inform policy deliberations.

Keywords: Policy path, forward rate, forward guidance

JEL: E43, E44, E58

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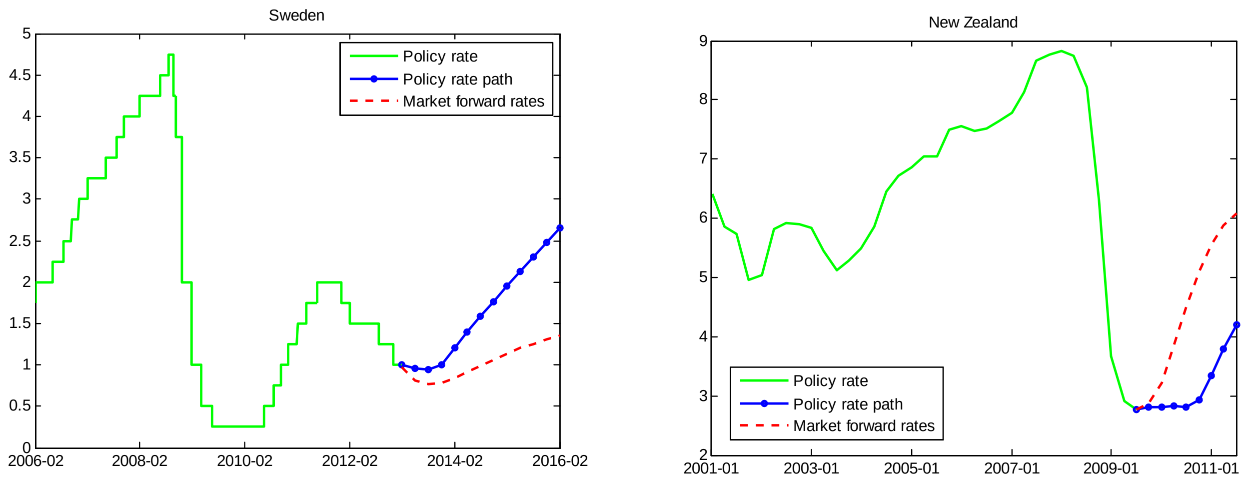
1 Introduction

For a number of years inflation-targeting central banks have published paths for their policy instrument. Since before the Great Recession the central banks of New Zealand (since 1997), Norway (since 2005) and Sweden (since 2007), for instance, all publish the most likely path for their main policy instrument for one to three years following the date of the policy decision. More recently, central banks more broadly (e.g. Federal Reserve, Bank of England, Czech National Bank) have engaged in similar forward guidance about future policy rates - typically constrained by the zero lower bound and aiming to provide additional stimulus by signaling policy rates will be low for a sustained period of time.

While the central bank may announce a path for policy rates down the road, that need not imply that it is able to steer actual market forward interest rates. In fact, experience so far suggests potentially substantial deviations between the path announced by the central bank and market expectations about those interest rates. Figure 1 shows two examples of deviations between the central bank's announcement and the market's expected forward rates. The examples are for Sweden and New Zealand, two countries with substantial historical experience with path announcements, and where the existence of futures contracts allow distilling market expectations that can be compared to the central bank path. The left-hand panel of Figure 1 contains the development of the Swedish repo rate (the Riksbank's policy instrument) up until February 2013, along with the announced path for the repo rate and the market's expectation at that date. The announced path lies substantially above the market forward rates for the entire duration of the forecasting period. The average policy rate over the announcement horizon is 1.64%, while the market expects it to be only 1.03% on average over that same period. The right-hand panel shows another example of divergence between policy and market, now for New Zealand in September 2009. In this instance, the market expected a much faster increase in policy rates than the Reserve Bank of New Zealand announced. The average policy rate over the announcement horizon was 3.14%, while that of the market was much higher at 4.43%.

Such divergence is not necessarily the norm. Market expectations are well aligned with the path announced by the central bank on plenty of occasions. Figure 2 provides historical

Figure 1: Two examples of announced path and market forward rates: Sweden (February 2013) and New Zealand (September 2009)

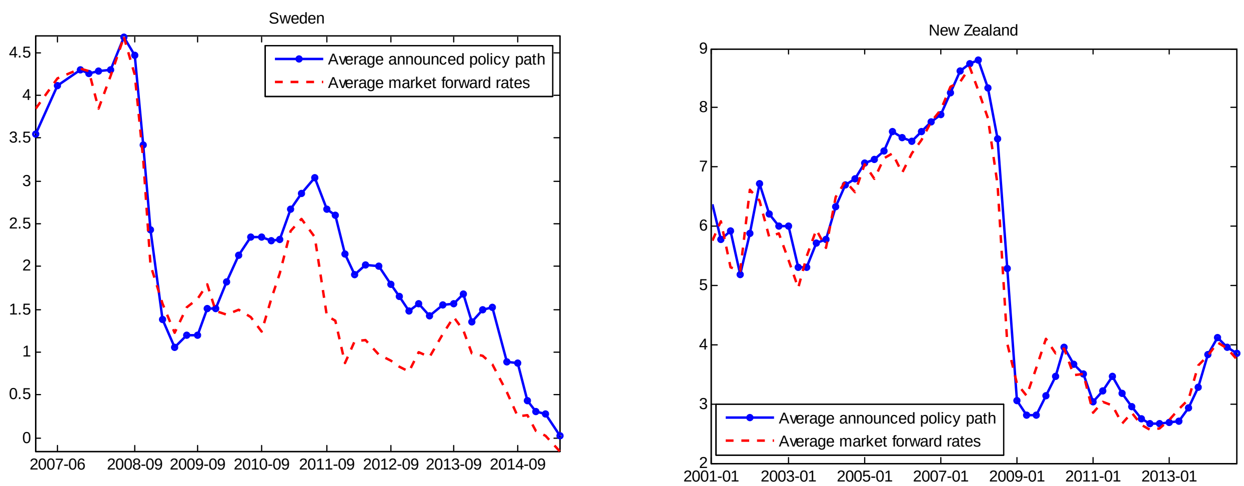


Note: Sweden: Repo rate; New Zealand: 90-day rate. The Reserve Bank of New Zealand sets the Official Cash Rate (OCR) and publishes paths for the 90-day rate, which is generally very similar to the OCR.

perspective on announced and expected rates in both Sweden and New Zealand. For each policy date, the figure plots the average of central bank announced and market expected rates over the announcement horizon. The discrepancy between the paths shown earlier in Figure 1 is now apparent in Figure 2 in the February 2013 observation for Sweden, and the September 2009 observation for New Zealand.

By plotting the average central bank and market paths over time, Figure 2 indicates that the wedge between what is announced by the central bank and what is expected in the market is at times substantial, with possible differences in average forward rates of over a percentage point. The figure also reveals that such differences are not constant. Particularly, in Sweden, the early years of announcements (2007-08) resulted in a central bank path that largely overlapped with market forward rates. Throughout 2009, however, the market path exceeded the central bank's announced path. By contrast, from 2010 onward, there has been an opposite and much larger wedge between the two: the central bank path has consistently layed above that expected by the market. The right-hand panel of Figure 2 summarizes the New Zealand experience. By and large, it suggests much more short-lived deviations between the central bank announcement and market forward rates compared to the Swedish case.[1] The New Zealand experience also showcases that market perceptions occasionally deviate substantially from central bank paths already before the Great Recession. Overall, the short experience with the announcement of intended policy paths reveals that there can be significant differences between what is announced by the central bank and what is priced by the market.

Figure 2: Central bank and market path: Average forward rate over announcement horizon



Note: Average of short-term forward interest rates over the announcement horizon at each policy meeting. The announcement horizon can vary through time. The horizon over which the average is taken is the longest common announcement horizon across all time periods in our sample: 3 years for Sweden, 1 year for New Zealand.

Contemporary DSGE models in the literature, particularly those used for policy analysis at central banks, do not distinguish between a central bank's announced path and market forward rates. As a result, model-based analysis effectively assumes the path announced by

[1] Svensson (2015) provides a detailed discussion of several particular policy experiences in Sweden, New Zealand and the US.

the central bank is the one that is relevant for the economy. Clearly this may have implications. If the central bank's forecasts are model-based, these forecasts will be erroneous if there are macroeconomic consequences of market forward rates departing from announced policy paths. Ignoring those deviations can thus mean that the central bank will at times miss hitting targets and miss achieving its objectives, even in the absence of new shocks hitting the economy. It may well turn out that the central bank's policies are more expansive or restrictive than intended. As a result, the existence of fluctuations in the wedge between announced and market interest rates raises a number of issues important in policy deliberations, such as: What are the macroeconomic implications of such deviations? Should macroeconomic forecasts be adapted in view of this difference? How would policy be set if it takes account of the wedge?

This is not to say that policy deliberations thus far do not take into account potential departures of market expectations from announced policy paths. But if they do, it is necessarily done through judgment or through the use of non-structural models. We present a model that can account for the existence of a wedge between the market and the announced path and can thus address these issues. The crux of the model is that not all agents in the economy have access to the same savings technology. This entails that while some agents may be able to invest at (forward) interest rates that coincide with those announced by the central bank, others may not have that opportunity and they rely fully on market forward rates instead. The model is essentially a stripped down version of the preferred habitat models advocated by Andrés, López-Salido and Nelson (2004) and Chen, Cúrdia and Ferrero (2012). Our contribution is fourfold.

First, we reinterpret this type of models. We preserve the building blocks, which are agent heterogeneity in savings technologies and limitations in the degree of arbitrage between them. While Andrés et al. (2004) and Chen et al. (2012) use this framework to study term premia, we map the interest rate each agent faces to the central bank announced path and the market expected path of interest rates, respectively. The model allows these interest rate paths to differ from one another, and such differences can have macroeconomic implications.

Second, we intentionally keep the model very simple. On the one hand, this enables us to highlight the key mechanisms at work, without interaction with other frictions. On the other hand, one comparative advantage of this model relative to others that can generate a wedge between market and policy-announced forward rates is simplicity. Particularly, the model enables studying the effects of such deviations without endowing agents with alternative expectation formation mechanisms or asymmetric information compared to the central bank. In principle, the model's transmission mechanism can both substitute and complement these alternative theories. The latter tend to be more involved (e.g. in terms of explanation, estimation) and are thus typically less easily adopted in policy deliberations. We set up the main mechanism in such a way that it can easily be appended to a variety of models, without changing the transmission channels already present in them.

Third, we provide empirical evidence on the macroeconomic effects of divergence between central bank paths and market forward paths. Specifically, we extend standard monetary policy VARs to include information on the wedge between the two paths. We then estimate these for Sweden and New Zealand, two countries with a sufficiently long historical experience with central bank path announcements. For Sweden, where the difference between bank announcement and market expectation has been both substantial and persistent (Figure 2, left panel), the evidence is consistent with the main model features. For New Zealand, where fluctuations in the wedge have been less of a concern (Figure 2, right panel), macroeconomic effects are absent.

Fourth, we show how the model can easily be of use in a policy context. Models commonly adopted in policy analysis need to turn a blind eye to the issue since they imply the central bank path coincides with that of the market. As a result, model-based forecasts and policy prescriptions ignore the presence of the wedge, which can be substantial and most certainly is of concern in policy deliberations. The model enables one to consider alternative forecasts that incorporate the wedge and study alternative policy paths.

The paper is structured as follows. We first describe the building blocks of the model and discuss how it can capture the effects of deviations between market forward rates and the announced path in Section 2. Section 3 discusses interpretation and related models. Next, Section 4 details model dynamics, parameter sensitivity and other properties. In Section 5 we turn to the data and estimate the macroeconomic effects of changes in the wedge. Subsequent to a calibration of key model parameters, Section 6 considers how the model can inform policy analysis.

2 The model

The model economy is populated by a continuum of households, a continuum of producers and a government. Two types of bonds can be traded. The interest rate on the first type of bond, B^{CB}, is controlled by the central bank. The interest rate on the second type of bond, B^{M}, is determined in the market. The household sector consists of restricted and unrestricted households. The unrestricted type, which constitutes a share $0 \leq \omega \leq 1$ of all households, can trade in both bonds. Specifically, they can trade the central bank bond freely, but face a financial transaction cost when purchasing the bond carrying the market determined interest rate. Transaction costs are paid to financial intermediaries owned by all households. Restricted agents, the remaining share $1-\omega$ of households, can only trade in the bond carrying the market determined interest rate and do not pay the transaction cost. Both bonds are one-period securities. Foreshadowing our subsequent analysis, the expected future values of the interest rate on B^{CB} will correspond to the central bank path. The expected future values of the interest rate on B^{M} will correspond to the forward rates in the market.

The remainder of the model closely adheres to prototype New-Keynesian DSGE models. In particular, as in Galí (2008), producers use labor input to produce a differentiated good which is sold under monopolistic competition to both types of households. Prices are staggered as in Calvo (1983). The government's budget consists of transfer payments and government spending and is balanced on a period-by-period basis.

2.1 Unrestricted households

The unrestricted households solve

$$\max E_0 \sum_{t=0}^{\infty} (\beta^u)^t \left[\frac{(C_t^u)^{1-\sigma}}{1-\sigma} - \frac{(L_t^u)^{1+\varphi}}{1+\varphi} \right]$$

subject to the flow budget constraint

$$P_t C_t^u + B_t^{CB,u} + \Phi_t B_t^{M,u} = I_{t-1}^{CB} B_{t-1}^{CB,u} + I_{t-1}^{M} B_{t-1}^{M,u} + W_t L_t^u + P_t T_t + P_t D_t. \qquad (1)$$

C_t^u is consumption in period t, L_t^u is labor supply, P_t is the consumer price index, W_t is the nominal wage rate, T_t denotes transfers, D_t is dividends from ownership of the producers and financial intermediaries in the economy. β^u is the discount factor, σ is the coefficient of relative risk aversion, φ is the inverse of the Frisch elasticity of labor supply. $B_t^{CB,u}$ denotes unrestricted households' holdings of central bank bonds at the end of period t. I_t^{CB} is the gross nominal interest rate on these bonds held between period t and $t+1$, $B_t^{M,u}$ denotes holdings of market bonds issued in period t, and I_t^M is the nominal interest rate on these bonds. Unrestricted households have to purchase the market bonds through financial intermediaries. These intermediaries charge an additional cost when selling the bonds implying that the total cost for unrestricted households of a market bond is Φ_t, which can be different from 1.[2] The profits of the financial intermediaries are distributed to all households in the economy.

Maximizing utility subject to the budget constraint yields

$$\Xi_t^u = (C_t^u)^{-\sigma} \tag{2}$$

$$(L_t^u)^{\varphi} = \Xi_t^u \frac{W_t}{P_t} \tag{3}$$

$$\Xi_t^u = \beta^u I_t^{CB} E_t \left[\Xi_{t+1}^u \frac{P_t}{P_{t+1}} \right] \tag{4}$$

$$\Xi_t^u = \beta^u \frac{I_t^M}{\Phi_t} E_t \left[\Xi_{t+1}^u \frac{P_t}{P_{t+1}} \right] \tag{5}$$

where Ξ_t^u is the marginal utility of income in period t. The first two first order conditions are the typical optimality conditions for consumption and labor choice that prevail in the simple representative agent New-Keynesian model (e.g. Galí, 2008). The first order conditions for bond holdings (4) and (5) are equally standard. Equation (5) reflects that the effective return obtained by unrestricted agents when purchasing the market based bond is I_t^M/Φ_t, the market based return adjusted for the transaction cost.

[2] As in, e.g., Andrés et al. (2004), Curdia and Woodford (2010) and Chen et al. (2012) we assume that agents cannot offset the market incompleteness by trading firm shares.

2.2 Restricted households

The restricted households only trade in the market bond B^M but do not pay the financial intermediation cost. Hence, they solve

$$\max E_0 \sum_{t=0}^{\infty} (\beta^r)^t \left[\frac{(C_t^r)^{1-\sigma}}{1-\sigma} - \frac{(L_t^r)^{1+\varphi}}{1+\varphi} \right]$$

subject to the constraint

$$P_t C_t^r + B_t^{M,r} = I_{t-1}^M B_{t-1}^{M,r} + W_t L_t^r + P_t T_t + P_t D_t. \tag{6}$$

The first order conditions are given by

$$\Xi_t^r = (C_t^r)^{-\sigma} \tag{7}$$

$$(L_t^r)^{\varphi} = \Xi_t^r \frac{W_t}{P_t} \tag{8}$$

$$\Xi_t^r = \beta^r I_t^M E_t \left[\Xi_{t+1}^r \frac{P_t}{P_{t+1}} \right]. \tag{9}$$

2.3 Production Sector

There is no capital formation in the model so goods are produced using only labor as input. Labor is sold under perfect competition in an economy-wide market. The production function for firm j is

$$Y_t(j) = U_t^z L_t(j)$$

where $Y_t(j)$ is total production, $L_t(j)$ is the amount of labor input, and U_t^z is an aggregate productivity shock.

Nominal price setting is subject to frictions modelled as in Calvo (1983). In each period a constant fraction, $1-\alpha$, of producers receives a signal to revise their price. Producers that do not receive a signal update their price according to the rule $P_t(j) = P_{t-1}(j)\bar{\Pi}$ where $\bar{\Pi}$ is the steady state inflation level. Producers that receive a signal in period t solve

$$\max E_t \sum_{k=0}^{\infty} \alpha^k \tilde{\Lambda}_{t,t+k} \left(\tilde{P}_{t,t+k} \tilde{Y}_{t,t+k} - W_{t+k} \tilde{L}_{t,t+k} \right)$$

subject to

$$\tilde{Y}_{t,t+k} = \left(\frac{\tilde{P}_{t,t+k}}{P_{t+k}}\right)^{-\theta} Y_{t+k}$$

$$\tilde{Y}_{t,t+k} = U^z_{t+k}\tilde{L}_{t,t+k}$$

and subject to the price updating rule, where $\tilde{P}_{t,t+k}$ is the optimal price applying in period $t+k$ of producers that last changed their price in period t, $\tilde{Y}_{t,t+k}$ is demand in period $t+k$ for the good of producers that last changed their price in period t, $\tilde{L}_{t,t+k}$ is these producers' demand for labor in period $t+k$, Y_{t+k} is total output in period $t+k$, and

$$\tilde{\Lambda}_{t,t+k} = \omega \frac{(\beta^u)^k \, \Xi^u_{t+k}}{\Xi^u_t} + (1-\omega)\frac{(\beta^r)^k \, \Xi^r_{t+k}}{\Xi^r_t}.$$

Hence, future cashflows are discounted with the average of the stochastic discount factors of the unrestricted and restricted agents following Chen et al. (2012).

Notice that because of the price update rule we may write $\tilde{P}_{t,t+k} = \tilde{P}_{t,t}\left(\bar{\Pi}\right)^k$. Optimal price setting satisfies

$$E_t \sum_{k=0}^{\infty} \alpha^k \tilde{\Lambda}_{t,t+k} \tilde{Y}_{t,t+k} \left\{ \tilde{P}_{t,t} - \frac{\theta}{\theta-1}\frac{W_{t+k}}{\bar{\Pi}^k}\frac{1}{U^z_{t+k}} \right\} = 0. \tag{10}$$

2.4 Government

There are two items in the government's budget constraint, transfer payments and government spending. We assume that the budget is balanced on a period-by-period basis, a common assumption in many contemporary DSGE models. Hence, the government does not issue bonds ($B^{CB}_t = B^M_t = 0$). The government budget constraint reads

$$0 = P_t T_t + P_t G_t. \tag{11}$$

In contrast to the standard model, issuance of different types of bonds has real consequences in the present context. The reason is there is a type of agent in the model that cannot trade in the central bank bonds. As a result, $B^{CB}_t \neq 0$ implies allocational effects across different households. Our fiscal block thus differs from that in Andrés et al. (2004) and Chen et al. (2012), where short term bonds are used as a residual means of financing. The reason is twofold. On the one hand, we aim to stay close to the representative agent New

Keynesian model. The present assumption ($B_t^{CB} = B_t^M = 0$) eliminates the aforementioned allocational effects. It thereby avoids non-Ricardian effects that arise when issuing all debt to only a fraction of households, which is the case in the setup of Chen et al. (2012). Second, modeling consequences of the government maturity structure is essential for some purposes (e.g. the evaluation of quantitative easing in Chen et al., 2012), but not strictly required for modeling differences between announced and market rates.

Finally, the central bank sets the nominal interest rate according to

$$i_t^{CB} = \rho_i i_{t-1}^{CB} + (1 - \rho_i) \left(\psi_\pi \pi_t + \psi_y y_t \right) + u_t^i \tag{12}$$

where lower case letters indicate log-deviations around the steady state of the corresponding upper case variables, ρ_i measures the degree of interest rate smoothing, ψ_π and ψ_y the response to inflation and output respectively, and u_t^i is a monetary policy shock.

2.5 Market clearing

The labor market clears when

$$\omega L_t^u + (1 - \omega) L_t^r = L_t = \int_0^1 L_t (j) \, dj. \tag{13}$$

The market for product j clears if

$$U_t^z L_t (j) = \left(\frac{\tilde{P}_t (j)}{P_t} \right)^{-\theta} Y_t$$

where total output is given as the sum of consumption and government expenditure

$$Y_t = C_t + G_t \tag{14}$$

and aggregate consumption is defined as

$$C_t = \omega C_t^u + (1 - \omega) C_t^r. \tag{15}$$

Integrating the goods market clearing condition across all producers yields

$$U_t^z \int_0^1 L_t (j) \, dj = U_t^z L_t = \left(\frac{\check{P}_t}{P_t} \right)^{-\theta} Y_t \tag{16}$$

where

$$\left(\check{P}_t\right)^{-\theta} = \int_0^1 P_t\left(j\right)^{-\theta} dj.$$

The $CB-$bond market clears if

$$0 = \omega B_t^{CB,u} \tag{17}$$

and the $M-$bond market clears when

$$0 = \omega B_t^{M,u} + \left(1-\omega\right) B_t^{M,r} \tag{18}$$

where we use that the government does not issue any bonds.

2.6 Steady state and solution method

We linearize the equilibrium conditions around a steady state with zero inflation and no spread between the yield of the two bonds ($\beta^u = \beta^r$) and solve the resulting system using standard methods. Variables in deviations from steady state are written in lower case.

In the absence of additional assumptions, the non-stochastic steady state of the model is indeterminate and, furthermore, the linearized model will contain a unit root. This is a common feature of heterogeneous agent models with incomplete financial markets. In view of this we assume that

$$\phi_t = \tau b_t^{M,u} + u_t^{\phi}. \tag{19}$$

The last term u_t^{ϕ} is the (possibly persistent) exogenous process determining the evolution of transaction costs ϕ_t. The first term implies that larger market bond holdings for the unrestricted households result in a larger financial transaction cost. This, in turn, mitigates their incentive to invest in these bonds. As a result, this mechanism suffices to prevent $M-$bond holdings from growing unboundedly. Hence, $\tau > 0$ implies a well-defined steady state as well as stable dynamics (see Schmitt-Grohé and Uribe, 2003). In our numerical exercises, we set τ close to zero, albeit sufficiently large to avoid numerical problems. Since the financial transaction cost depends on aggregate variables individual agents do not internalize the effect their actions have on these costs.

2.7 Interest rate forward paths

The model implies two types of agents who trade subject to limited arbitrage. The extent of arbitrage is determined by fluctuations in the transaction cost ϕ_t. To see that, consider each agent's (linearized) consumption Euler equation(s)

$$c_t^u = E_t c_{t+1}^u - \frac{1}{\sigma}\left(i_t^{CB} - E_t \pi_{t+1}\right) \tag{20}$$

$$c_t^u = E_t c_{t+1}^u - \frac{1}{\sigma}\left(i_t^{M} - \phi_t - E_t \pi_{t+1}\right) \tag{21}$$

$$c_t^r = E_t c_{t+1}^r - \frac{1}{\sigma}\left(i_t^{M} - E_t \pi_{t+1}\right). \tag{22}$$

The unrestricted agent trades at the central bank rate while the restricted agent trades at the market determined interest rate. Optimal behavior of the unrestricted agent ensures that

$$i_t^M = i_t^{CB} + \phi_t. \tag{23}$$

Thus a basic property of the model is that it features agents trading bonds at different prices.

Solving equations (20) and (22) forward implies

$$c_t^u = -\frac{1}{\sigma}\sum_{k=0}^{\infty} E_t\left(i_{t+k}^{CB} - \pi_{t+1+k}\right) \tag{24}$$

$$c_t^r = -\frac{1}{\sigma}\sum_{k=0}^{\infty} E_t\left(i_{t+k}^{M} - \pi_{t+1+k}\right). \tag{25}$$

Let us define the average forward rate over horizon n:

$$i_t^{L,CB} = \frac{1}{n}\sum_{k=0}^{n-1} E_t i_{t+k}^{CB} \tag{26}$$

and

$$i_t^{L,M} = \frac{1}{n}\sum_{k=0}^{n-1} E_t i_{t+k}^{M}. \tag{27}$$

The above equations show that, for sufficiently large n, $i_t^{L,CB}$ is the long-term interest rate relevant for the consumption choice of the unrestricted agents, via (24). Similarly, $i_t^{L,M}$ is the long-term interest rate that matters for the consumption choice of restricted agents, via (25).

When n is taken to be the announcement horizon of the central bank, these rates correspond exactly to the average bank and market forward rates plotted in Figure 2. As such the model easily allows for an interpretation where some agents trade at the announced policy path ($E_t i^{CB}_{t+k}$), whereas others trade at market forward interest rates ($E_t i^{M}_{t+k}$). Under the above interpretation the interest rate $i^{L,CB}_t$ captures the long rate implied by the announced path of policy rates. Similarly, market forward rates imply another long rate, $i^{L,M}_t$. It is worth emphasizing that neither of the above long rates has a readily observed counterpart in the data. They are simply constructs that summarize paths of (market and central bank) forward rates over a certain horizon, as in Figure 2.

The absence of arbitrage between different types of agents is driven by fluctuations in the transaction cost ϕ_t. Specifically, the *wedge* between the two paths (or equivalently between the two long-term interest rates) is

$$\begin{aligned} wedge_t &\equiv i^{L,CB}_t - i^{L,M}_t \\ &= -\frac{1}{n}\sum_{k=0}^{n-1} E_t \phi_{t+k}. \end{aligned} \tag{28}$$

This makes clear how fluctuations in transaction costs create heterogeneity in returns. This, in turn, creates heterogeneity in consumption dynamics across agents, through (20)-(22). Aggregate effects then follow suit. Total consumption is the sum of both agents' consumption. Because different agents' consumption is driven by different interest rates, aggregate consumption is driven by multiple interest rates. As a result, aggregate output fluctuations are a function of both interest rates

$$y_t = \omega c^u_t + (1-\omega)\, c^r_t. \tag{29}$$

It is worth emphasizing these essential ingredients of the model. Recall that the standard New Keynesian model cannot account for the wedge, nor explain why it might have macroeconomic consequences. These modifications aside, the remainder of the model is identical to the representative agent New Keynesian model, i.c. the policy rule (12) and the Phillips curve

$$\pi_t = \kappa\left(w_t - u^z_t\right) + \beta E_t \pi_{t+1} \tag{30}$$

where we have used $\beta = \beta^u = \beta^r$, and $\kappa = (1-\alpha)(1-\alpha\beta)/\alpha$.

3 Interpretation and relation to the literature

The model presented is a variant of Andrés et al. (2004). Theirs is a model in which unrestricted agents can trade in both short and long term bonds while restricted agents trade only in long term bonds. The real-world counterpart of that heterogeneity, they argue, can be thought of as households saving through banks and pension funds respectively. Some agents wish to save through commercial bank deposits. Commercial banks typically fund themselves short term (their preferred habitat) or, put differently, they incur a cost when funding through less liquid longer term securities. This much in contrast to institutional investors like pension funds, whom often prefer or are institutionally required to invest in longer term assets. In such an environment, the transactions cost shocks can act as a stand-in for fluctuations in the degree to which arbitrage between these different agents occurs.

The present model shares with the model of Andrés et al. (2004) both the heterogeneity across agents and fluctuations in the degree of arbitrage between them.[3] That said, the model is distinct in that the heterogeneity does not span the *maturity* of the assets in which the agents invest. In fact, in the present model both bonds have the same maturity. The assets are characterized by a different return, though not necessarily in steady state.[4] Moreover, so long as the fraction of (un)restricted agents lies strictly between 0 and 1, each interest rate will have distinct effects on private consumption and thus the macroeconomy.

As such the model can capture different real world counterparts. One possibility, not unrelated to the motivation in Andrés et al. (2004), is that households have different savings vehicles. As but one example, in Sweden retirement savings are channeled through either government or private pension funds. Both funds deliver a distinct return, which is not necessarily different ex ante, or in steady state. Switching between the different funds,

[3] In Andrés et al. (2004) limited arbitrage is modelled by means of portfolio adjustment costs that enter the utility function of the unrestricted agents. We follow Chen et al. (2012) and incorporate transaction costs in the budget constraint.

[4] In our calibration, where agents have the same discount factors, there is no steady state spread between the two interest rates.

however, is subject to (real or preference) costs which could vary through time. These features accord well with essential characteristics of the model, notably heterogeneity in savings opportunities and limited arbitrage between them.

More broadly the model can reflect various types of heterogeneity in access to finance or savings technologies across agents. Examples include firms (or strictly speaking, households owning firms) that finance through bank versus market finance; households and firms that borrow under different contracts, at banks that differ in the degree to which they pass through changes in policy rates, or at narrow vs. risky or shadow banks. In such environments it may be natural to think of one of the interest rates as more closely tied to the central bank rate than the other, as is the case in the model. As a concrete example, consider the increase in the wedge in Sweden following the financial crisis, observed in Figure 2. One interpretation of this policy path exceeding the market path is the following. At the time, the central bank and financial regulator were considering measures to cope with financial stability and systemic risk. If anything, these hinted at higher policy rates in the future (at given macroeconomic outcomes): for fears of instigating risk-taking channels of monetary policy or feeding (e.g. house price) bubbles. The dire macroeconomic environment aside, these upward pressures are local to that part of the financial market. The rate at which firms could finance themselves (be it through internally generated funds, via the corporate bond market, or internationally) is not immediately affected.[5] As an empirical matter, different asset classes exhibit different yield responses to central bank path announcements (e.g. Rogers et al., 2014). There is also ample heterogeneity in how different banks respond to policy changes (e.g. De Graeve et al., 2007). Against this background, the view that certain interest rates are tied more closely to the central bank path than others does not appear particularly controversial.

Thus, the model captures differences in interest rates across agents which, in the presence of fluctuations in transaction costs, can only be partially arbitraged away. It thereby provides a way to capture differences in interest rates important for aggregate dynamics. In doing so, it relates to a number of alternative models.

[5] Of course, both market and policy rates *do* respond to the macroeconomic environment. The argument here pertains to the *difference* between both rates.

First, by having multiple interest rates, it severs the tight link between money market rates and aggregate consumption implied by the Euler equation. As shown in Canzoneri et al. (2007), the absence of such a tight link in the data is a more fundamental problem facing representative agent macro models. The ensuing discrepancy is often subsumed in shocks to the Euler equation or to the budget constraint. For instance, the model of Smets and Wouters (2007) has a typical short term (policy) interest rate, while the budget constraint is also affected by a shock which captures deviations from that rate. The sum of those then maps into the effective interest rate that determines consumption through the Euler equation. Fisher (2015) provides an alternative structural motivation for that effective interest rate, based on households having preferences defined over assets with different liquidity characteristics.

Second, the model relates to models with financial frictions in that it has multiple interest rates determining aggregate demand. Here, the difference in these interest rates is not driven by a difference in preferences (e.g. Iacoviello, 2005; Curdia and Woodford, 2010) or an underlying agency problem (e.g. Bernanke et al., 1999), but rather a difference in savings oppportunities across agents in the economy. From this perspective, the model relates to the broader class of models that study the aggregate implications of limited participation (e.g. Galí et al., 2004; Guvenen, 2009).

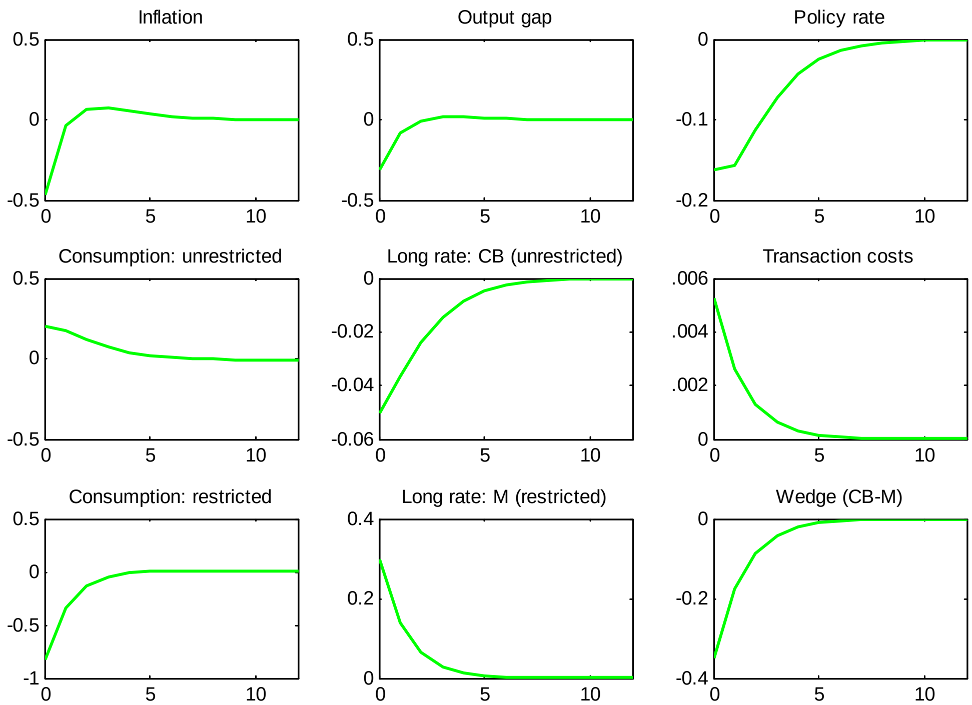
4 Model dynamics and transmission

4.1 Transaction cost shocks

We here describe the transmission mechanism of changes in the transaction cost in the model. We lay out intuition through a series of partial equilibrium effects which, when combined, explain the impulse responses to a financial cost shock shown in Figure 3.

Consider an innovation to the transaction cost $u_t^{\phi} > 0$. First, this leads to a (persistent) increase in the transaction cost, ϕ_t, unrestricted agents have to pay to buy market bonds. This makes $CB-$bonds more attractive, inducing unrestricted agents to rebalance their portfolio: they wish to sell $M-$bonds and buy CB ones. Ceteris paribus, these agents have

Figure 3: Impulse responses to a transaction cost shock



Note: Parameters related to household types and transaction costs: $\omega = .5, \rho_\phi = .5$. Other parameters are described in appendix.

no incentive to alter their consumption plans as the expected path of future real short rates has not changed. They merely arbitrage between the two bonds.

Second, the fact that unrestricted agents sell off their $M-$bonds implies that the price of these bonds falls. While restricted households do not face a transaction cost when trading the $M-$bond, they have no alternative means of saving. As a result, the reduction in price makes $M-$bonds more attractive. Because these bonds now offer a higher return, restricted agents save more and consume less.

Third, the reduction in consumption of restricted households acts as a drain on aggregate demand. Faced with such downward pressure on output and prices, the central bank responds by lowering the short-term interest rate, i_t^{CB}.

Fourth, the reduction in the policy rate makes saving less attractive for the unrestricted households. They therefore sell off part of their bond portfolio and increase consumption.

Of course, in general equilibrium all these effects occur simultaneously. Yet the breakdown in steps is helpful to understand the transmission mechanism in the model. Most clearly, it reveals how unrestricted agents essentially evade the increased transaction costs, by substituting into $CB-$bonds. The resulting $M-$bond price fluctuations primarily impact the restricted agents who, while not facing the transaction cost, cannot substitute into alternative assets.

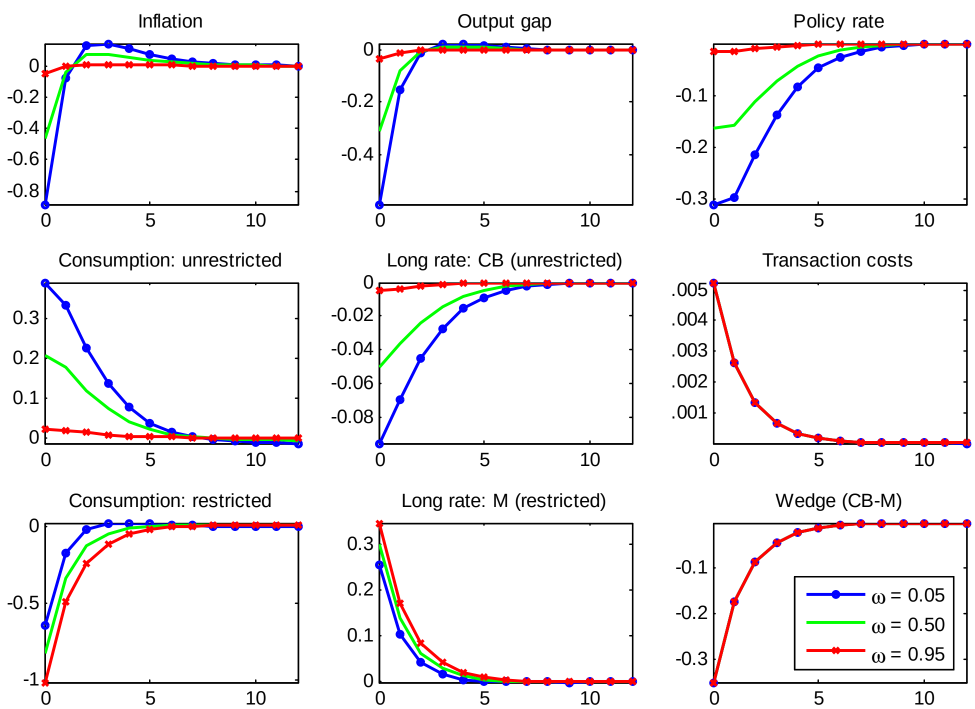
Taking everything into account, an exogenous increase in transaction costs reduces both output and inflation. Transactions cost shocks act as demand shocks. A market path above that of the central bank - a negative wedge - serves as a drag on economic activity.

4.2 Parameter sensitivity

The strength of these mechanisms is determined by the different parameters underlying the friction. Two parameters are key in determining the size and shape of these impulse responses.

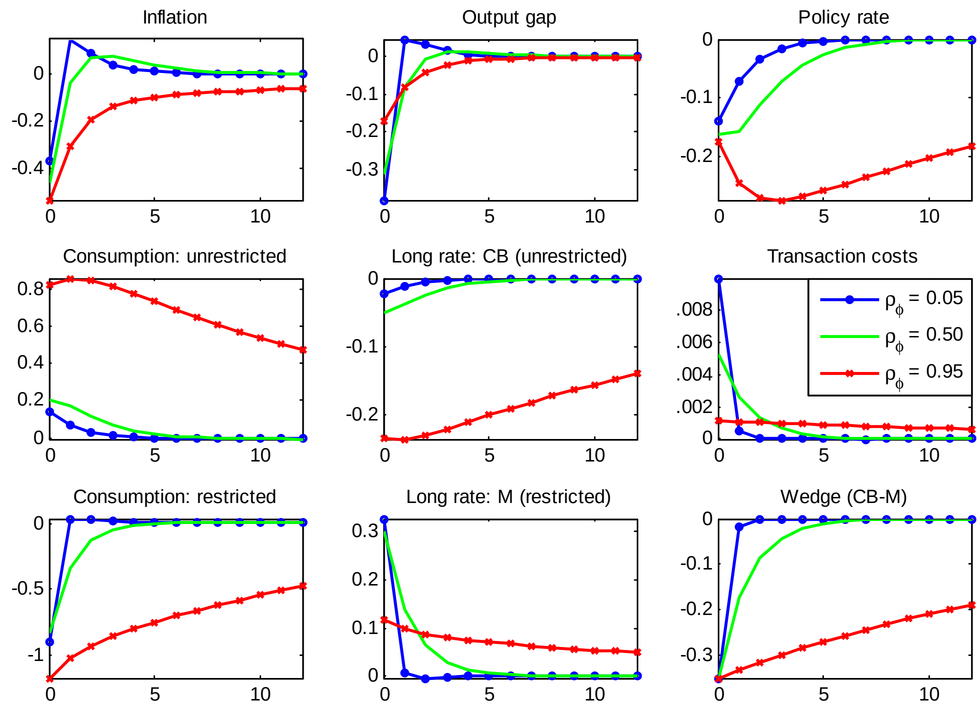
Regarding the size of the response, ω, the fraction of unrestricted agents in the economy is crucial. Figure 4 documents how transmission changes as a function of ω. The more unrestricted agents there are, the higher the fraction of people that can substitute away from the transaction cost. This implies that a given increase in the transaction cost will induce a stronger fall in the price of the $M-$bond (or, equivalently, a stronger increase in the long rate for restricted agents, $i_t^{L,M}$). As a result, restricted agents' consumption will be reduced more than for lower values of ω. At the same time, because they are less numerous, this larger fall in restricted agents' consumption has less of an aggregate impact. It will therefore not imply a strong response from the central bank. The virtual absence of changes in the policy rate implies unrestricted agents do not alter their consumption behaviour much. In sum, the larger the fraction of unrestricted agents, the smaller aggregate effects of transaction costs are. In the limit, as $\omega \longrightarrow 1$, transaction cost shocks no longer have macroeconomic effects. Conversely, note that the model nests the possibility that the central bank's announced path is irrelevant. Particularly, as $\omega \longrightarrow 0$ the central bank may announce what it will, it's announced rate only affects the unrestricted agents directly, of whom there are virtually none populating the economy. Consumption and output are then driven solely by decisions of the restricted agents, for whom it is the market path $(i_t^M, E_t i_{t+1}^M, ...)$ that matters, not the policy path. So long as $\omega > 0$, the policy path does have direct macroeconomic consequences.

Figure 4: Impulse responses to a transaction cost shock: fraction of unrestricted agents



Regarding the shape of the response, the persistence of the cost shock ρ_ϕ is both important and straightforward to understand. Additional persistence in transaction costs translates into more persistent forward rate movements (both i_t^{CB} and i_t^M) and longer lasting macroeconomic dynamics. Note that both ω and ρ_ϕ affect the relative volatility of the different implied long rates ($i_t^{L,CB}$ and $i_t^{L,M}$) in the model.

Figure 5: Impulse responses to a transaction cost shock: shock persistence



4.3 Alternative shocks

In the present model fluctuations in the transaction cost are entirely driven by exogenous cost shocks. This is apparent from (19), where the stabilizing term is numerically small enough to ignore. While it is possible (and for some applications of interest) to make the transaction cost a function of additional endogenous state variables (e.g. Andrés et al., 2004; Chen et al., 2012) we do not pursue that route here. One motivation for this choice is transparency: the model becomes particularly straightforward to understand and analyse, yet retains numerous interesting features.

Perhaps the main feature is that, in the absence of fluctuations in the transaction cost, model dynamics are isomorphic to the standard representative agent New Keynesian model. To see that, consider the Euler equations (20) through (22). Note that because standard business cycle shocks leave the transaction cost ϕ_t unaffected, all three equations collapse into the standard Euler equation of the representative agent model.

This has two immediate implications. First, common business cycle shocks, such as productivity, preference or monetary policy shocks, have the same effects as in the standard representative agent New Keynesian model. This happens because the heterogeneity within the model is really only operative conditional on one type of shock, i.c. the transaction cost shock. All other shocks affect both types of households in a similar fashion.

Second, as such, the key friction of the present model is immediately appendable to many existing DSGE models without it changing the transmission mechanisms they already contain. A practical advantage is that this enables one to consider consequences of the market deviating from the announced path *within* models presently used for policy analysis. Put differently, there is no need to depart much from extant policy models. This is arguably not the case for alternative channels that can capture deviations between path and market forward rates.

4.4 Discussion

The fact that fluctuations in the wedge between market expected rates and the central bank's announced path have real effects has several implications. First, it implies that model-based evaluation of the current stance of the economy may need to change. Note that the impulse responses to a cost shock have similar aggregate implications for output, inflation and the policy rate as demand shocks in the representative agent model. In that model, positive comovement between output and inflation could, for instance, indicate the occurrence of traditional preference shocks. Figure 3 makes clear that similar comovement can be generated by an alternative source of fluctuations, viz. transaction cost shocks. Because different shocks generate different dynamics they may also require different policy responses. While transaction cost shocks imply similar impulse response functions for certain macroeconomic aggregates, they clearly have one distinct feature: they induce a wedge between announced policy rates and forward rates. This suggests that empirical identification is possible. At the very least, it signals that a substantial wedge between path and forward rates should make one wary of traditional identification. For instance, if the central bank were convinced that preference shocks were hitting the economy but at the same time a substantial wedge is observed, perhaps it ought to reassess the source of shock.

A second implication regards monetary policy and stabilization. In the standard DSGE model, conditional on demand shocks, full stabilization is attainable for the central bank. The discussion of the transmission of transaction cost shocks reveals how monetary policy works in this economy. While the central bank "leans against" fluctuations in output and inflation, it does not symmetrically affect the consumption responses of the two agent types. As is apparent from Section 4.1, in response to the transaction cost shock the monetary authority limits the fall in consumption of restricted households, while at the same time causing an increase in consumption of the unrestricted households. It is by creating such an opposite response across different types of households that the central bank achieves *aggregate* stabilization.

5 Empirical evidence

We now turn to the data and provide empirical evidence on fluctuations in the wedge and macroeconomic outcomes. While there exist studies that analyse the high frequency relation between central bank and market paths (e.g. Woodford, 2013; Svensson 2011, 2015), such event-studies are not directly informative about the macroeconomic impact of changes in the wedge. In light of that, we here extend a standard VAR framework often used for monetary policy analysis to include information about the wedge between the policy path and the corresponding market expectation.

5.1 Data and specification

Three countries in particular have accrued a significantly long history of policy path announcements. These are New Zealand, Norway and Sweden. The central banks of these countries have rather systematically published policy paths since 1997, 2005 and 2007, respectively. The horizon over which the announcement stretches ranges from one to three years. The horizon varies across countries as well as over time. In what follows, we study New Zealand and Sweden in more detail. For both these countries there exist sufficiently liquid futures contracts that allow a systematic comparison of market expectations with the policy path over a longer sample period. This is not the case for Norway, which is why we do not include it in the empirical analysis.

Let X_t be a vector of endogenous variables containing the price level, output, the policy rate and the wedge between the policy path and the market expectation of that path: $X_t = [p_t, y_t, r_t, wedge_t]'$, where $wedge_t = i_t^{L,CB} - i_t^{L,M}$ and $i_t^{L,CB}$ and $i_t^{L,M}$ refer to the average forward rates plotted in Figure 2. For each country, we estimate

$$\begin{aligned} X_t &= A + B(L)X_{t-1} + u_t \\ u_t &\sim N(0, \Omega). \end{aligned} \tag{31}$$

The data for Sweden spans 2007-2015 and is at a monthly frequency.[6] The New Zealand sample covers the period 2001-2014 and is at a quarterly frequency.[7] Lag-length L is 2 months and 1 quarter, respectively.[8] Note that, in principle, it is possible to include the policy path ($i_t^{L,CB}$) and the market's expected path ($i_t^{L,M}$) separately in the VAR. This allows to follow the evolution of path and market responses individually. We refrain from doing so as the time span of the data is insufficiently long to reliably estimate systems with more endogenous variables.

5.2 Identification

We follow the approach initiated by Sims (1980) and impose a small set of identifying assumptions on the reduced form (31) to study the effect of exogenous, arguably structural,

[6] The choice for monthly frequency is driven by two considerations. First, Sveriges Riksbank policy announcements occur bi-monthly, generally. Second, given the relatively short experience of Sweden with path announcement, the higher frequency provides more information. We use industrial production as a monthly proxy for output, the price index is CPIF (CPI with a fixed mortgage rate), and the market forward rates are end-of-month observations.

[7] While the Reserve Bank of New Zealand published policy projections since the late nineties, in the first years these pertained to a Monetary Conditions Index, rather than a single policy rate. Policy announcements of the RBNZ occur quarterly. The price index is CPI and the output measure is GDP. The market forward rates used are end-of-quarter observations.

[8] Lag length is set at the maximum length that enables stable inference. The reason for instability at longer lag lengths stems from the relatively short sample period, the preference for longer lag length from comparability to standard monetary policy VARs.

disturbances to the policy rate and the wedge. Prototypical VARs used for the study of monetary policy transmission invariably include at least a measure of output, prices and the policy interest rate. In such a framework, the policy instrument is typically ordered after the output and price measures. A Choleski decomposition C of the error variance-covariance matrix ($\Omega = CC'$) then identifies a monetary policy shock as one that contemporaneously affects the interest rate, but not output or prices. We follow that tradition here. Moreover, we add the wedge to the VAR and order it last. The (S)VAR to be studied is thus:[9]

$$\begin{aligned} X_t &= A + B(L)X_{t-1} + C\varepsilon_t \\ \varepsilon_t &\sim N(0, I). \end{aligned} \tag{32}$$

The addition of the wedge to a monetary policy VAR has several implications. First, since the wedge now appears in the output and price equations, the model allows for macroeconomic outcomes to depend on fluctuations in the wedge. Second, the last equation of (32) recognizes that the central bank and/or the market path can respond endogenously to macroeconomic outcomes. Third, given the recursiveness embedded in the Choleski decomposition, the wedge can respond contemporaneously to standard monetary policy shocks. Fourth, as the flip side of this assumption, the policy rate cannot immediately respond to exogenous changes in the wedge.

The identifying assumptions implied by the ordering of the variables (or the lower triangularity of C) come natural for a number of reasons. Consider a standard monetary policy shock. On the one hand, there is no reason to assume a different impact on output and prices from the standard SVAR. On the other hand, a policy shock will naturally have the policy path adjust. Ordering the wedge after the policy rate then allows measuring the extent to which the market adjusts to the change in policy path. There is ample evidence suggesting that the market (and thus the wedge) responds contemporaneously (in fact, within minutes) to monetary policy announcements. Numerous event-studies support that assumption, e.g. Woodford (2013).

Now consider the identification assumptions underlying the "wedge shock". Similar to a

[9] Reduced form estimation is performed under non-informative conjugate priors for B and Σ, see e.g. Uhlig (2005).

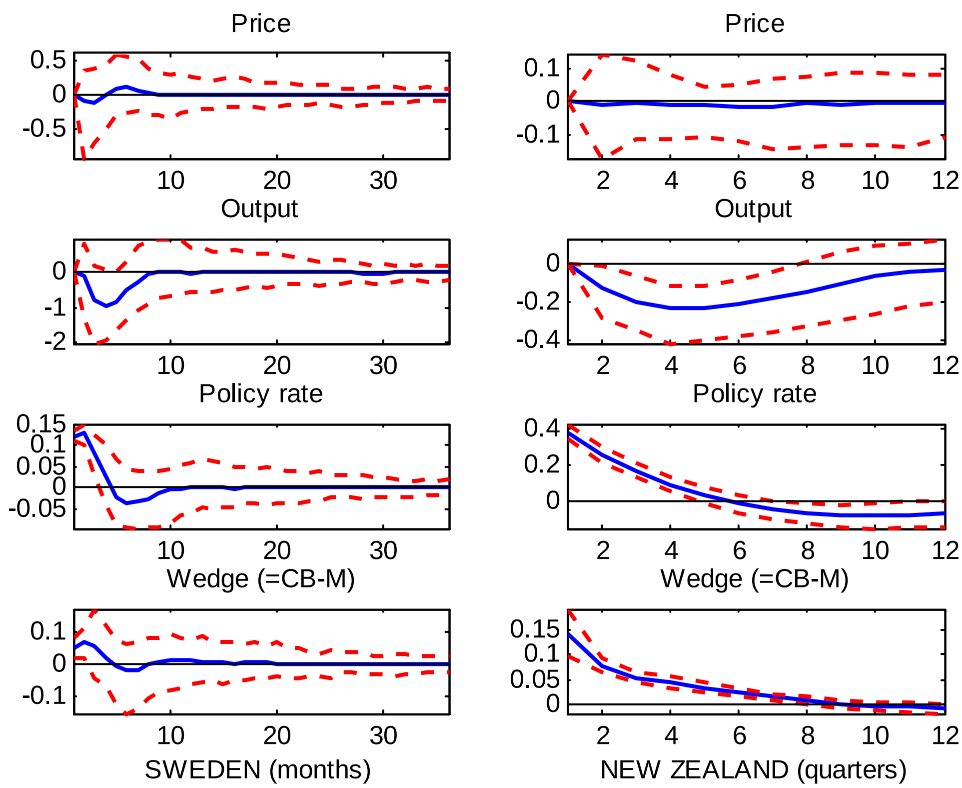
policy shock, there is no contemporaneous effect on either output or prices. Additionally, the shock has no immediate effect on the policy rate. Thus, the central bank does not respond contemporaneously to a change in the market. This appears a reasonable assumption from at least two perspectives. On the one hand, many would agree that central banks do not respond much to short-term fluctuations in financial markets generally, and to contemporaneous market anticipation of policy rate changes in particular. Evidence supporting that is provided in Fuhrer and Tootell (2008). Relatedly, many monetary VARs which incorporate asset market information order those variables after the policy variable, thus imposing the assumption of no contemporaneous policy response (e.g. Galí and Gambetti, 2015). On the other hand, the mere fact that policy decisions are only made infrequently while markets operate more continuously hints at an institutional feature corroborating the absence of an immediate policy response to exogenous fluctuations in market expectations of the policy rate. But the wedge can also move because the central bank's policy path changes. It is worth mentioning that (away from the zero lower bound) changes in the path tend to coincide with changes in the policy rate. That naturally implies that exogenous changes in the policy path will be subsumed in the more standard policy shock (i.e. the third element of ε_t). This is consistent with the ordering adopted here, where the policy rate cannot adjust on impact to an exogenous change in the wedge. As a result, a "wedge shock" is best interpreted as a change in the market expectation of the path.

5.3 Results

As a precursory note, the time span of the samples considered here is not as long as that of many SVAR studies of monetary policy. This obviously a consequence of the relatively short history of central banks publishing policy paths, it is worth bearing in mind that this most likely entails our estimates will be accompanied by larger uncertainty estimates.

Consider the effect of a standard monetary policy shock, shown in Figure 6. The policy interest rate increases exogenously and persistently. By assumption, prices and output do not respond instantaneously. As time passes, the increase in the policy rate causes output to fall in both countries. This is consistent with the evidence of monetary policy shocks in other periods and countries. Inflationary effects, however, do not appear: the median

Figure 6: Impulse responses to a monetary policy shock: Sweden and New Zealand



Note: 16^{th}, 50^{th} and 84^{th} percentile.

estimates of the impulse responses are close to zero for both economies. The absence of any effect on prices is likely related to the very recent sample period studied here. The altered behaviour of inflation in more recent years is a widely studied phenomenon (see e.g. Stock and Watson, 2007).

Note that in both countries the wedge responds immediately to the monetary policy shock. It rises by approximately half the size of the policy rate increase. This suggest that the policy path, which automatically adjusts to reflect the new policy rate, is not immediately fully incorporated into market expectations ($i_t^{L,CB} > i_t^{L,M}$). In fact, the market slowly adjusts to reflect the new policy path. The policy-induced increase in the wedge lasts only briefly in Sweden, but persists in New Zealand.

Let us now turn to the effects of a shock to the wedge. The case of New Zealand is clear-cut. A change in the wedge has no measurable impact whatsoever on aggregate activity or prices. In Sweden, by contrast, point estimates hint that activity and prices actually increase in response to positive wedge shock. The statistical significance of the increase is not immediately apparent. It is worth bearing in mind that some of that uncertainty is bound to be due to the short sample. More importantly, the point estimate of the output impulse response is of similar magnitude as the output effect of monetary policy shocks. Against this background the results suggest that the Swedish macroeconomy booms in response to an exogenous increase in the wedge, while the New Zealand economy is unaffected. One candidate explanation for this finding is that the Swedish deviations between central bank and market path have been both substantial and persistent, while much less so for New Zealand. This is clear from comparing the two panels of Figure 2, which plot the fluctuations in the wedge over time in both countries.

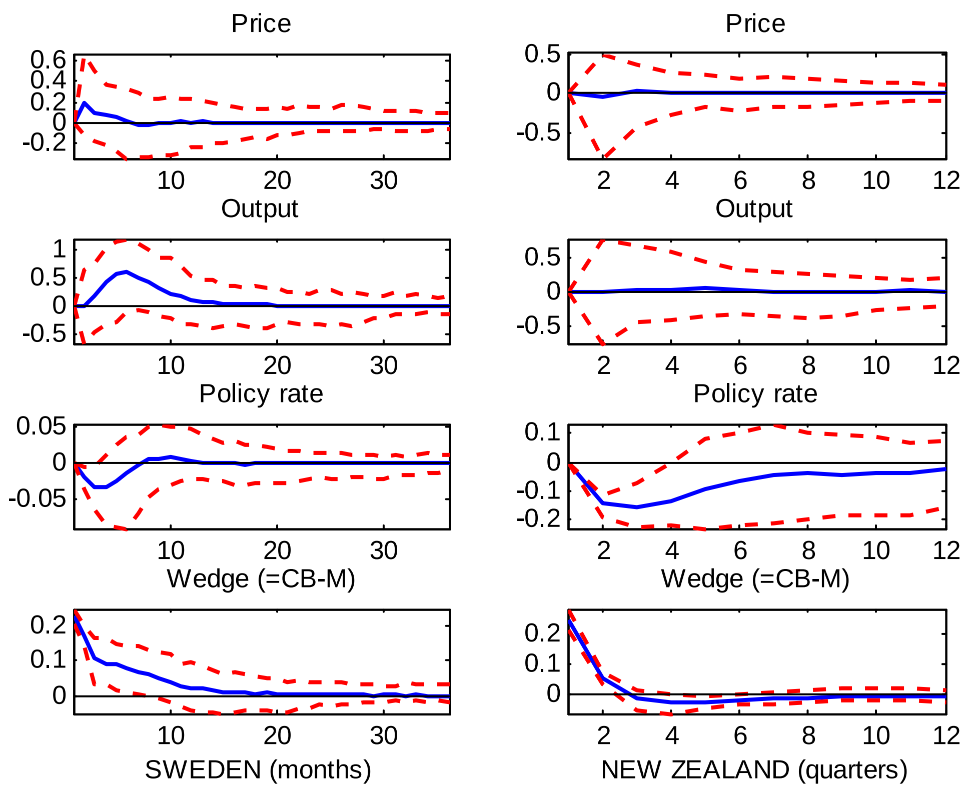
Note, finally, that in both countries the policy rate reduces following an increase in the wedge. Put differently, the central bank rate eventually tends to move in the direction the market expected. This is conform the observations of Svensson (2015) who provides an in-depth discussion of the central bank and market paths for a selected number of policy meetings.

5.4 Interpretation

We now ask to what extent this evidence lines up with the qualitative implications of the model and alternative explanations for the existence of the wedge.

Perhaps the most distinct model feature of exogenous increases in the wedge is that they act as demand disturbances. As apparent from the model's impulse response functions in Figure 3, both output and prices increase. This lines up pretty well with the Swedish evidence provided in Figure 7. Beyond the strict interpretation given by the model, the evidence is also consistent with the views expressed in Svensson (2011). The latter argues that a market path below that published by the central bank, i.e. a positive wedge, acts as a stimulus to economic activity. In this view, the market implements a more accommodative policy than the one the central bank projects. To the extent that market-expected rates are

Figure 7: Impulse responses to a wedge shock: Sweden and New Zealand



Note: 16^{th}, 50^{th} and 84^{th} percentile.

what matters for real outcomes rather than central bank path announcements, this implies that macroeconomic outcomes will turn out more favorable: output and prices increase. In the model, the fraction of unrestricted agents ω is a direct measure for the importance of the central bank path relative to the market path $(1-\omega)$.

Given the formulation of the policy rule (12), the reduction in the policy rate following a wedge shock (Figure 7) is not consistent with the model (Figure 3). That is, the policy rule only contains the typical leaning against the wind arguments, with no response to fluctuations in the transactions cost. There may well be a role for allowing such a response. Particularly, full output stabilization in response to transactions costs is attainable. However, it is achieved by creating additional consumption heterogeneity. Recall from Figure 3 that the transaction cost shock (and the policy response to its output and inflation consequences) drives restricted and unrestriced agents' consumption in different directions. A direct policy response to the wedge can alter the absolute and relative response of the different agent types. Depending on one's view on welfare functions - particularly the trade-off between aggregate stabilization on the one hand and consumption inequality across agent types on the other - a response to the wedge could thus be desirable. The analysis of optimal monetary policy in the presence of a wedge is, however, beyond the scope of the present paper.[10] Instead, we note that allowing the policy rule to respond to the wedge directly (with a negative response coefficient) can result in the policy rate falling, while preserving the demand-like consequences for output and inflation.

The model presented in Section 2 is not the only one that can conceivably rationalize the existence of a wedge between the policy path and the market expectation of short-term interest rates. For instance, theories of imperfect credibility or differences in beliefs can, in principle, also induce possible fluctuations in the wedge. While we know of very few papers using either framework to study the wedge between the announced policy path and the market equivalent explicitly, we here ask to what extent these theories line up with the main features of the evidence presented.

Let us start with imperfect credibility environments, such as Ball (1995). If the central bank is less than perfectly credible, an increase in the projected path of policy rates will be less than fully followed by the market. While less pronounced, market expectations would still (weakly) rise. As a result, a policy induced change in the wedge in an imperfect credibility environment would engender a fall in economic activity. These effects are very much akin to the traditional impulse responses to a monetary policy shock, and conform the evidence presented in Figure 6. In addition, the impulse response of the wedge to monetary policy shocks follows exactly that pattern: on impact the market does not fully adjust its expectations to the novel policy path, inducing the wedge to increase, and substantially less so than the increase in the policy rate. This conformity in spite, it is harder to conceive what exogenous fluctuations in the wedge represent in an imperfect credibility environment.

[10] Curdia and Woodford (2010) analyze the desirability of augmenting policy rules with credit spreads and aggregates in a model with heterogeneity of a different kind.

Bodenstein et al. (2012) build a model that can endogenously rationalize deviations between the two paths at the zero lower bound. They argue that communication of lower-for-longer announcements by the central bank (which are optimal at the lower bound) imply a time inconsistency: the central bank is promising to let inflation overshoot the target as the economy comes out of the lower bound. This induces a discretionary incentive to renege on that promise once the rebound actually occurs. As Bodenstein et al. (2012) show, this can explain the 2009 experience in Sweden: the interest rate at that time was (arguably) at the zero lower bound (Figure 1) and the announced path lies below that of the market (as apparent in Figure 2).[11] In other words, the market did not believe the central bank could commit to such a long episode of zero interest rates when inflation and output were expected to be on the rebound again.

The data following 2009, as well as some of the New Zealand data are not easily reconciled with this theory. First, the data show that the wedge can be substantial away from the zero lower bound. Second, the sign of the wedge in Sweden has been positive from 2010 onward, also when rates were at the lower bound. In the credibility theory of Bodenstein et al. (2012) neither feature of the data would arise. That is because, on the one hand, away from the zero lower bound the time-inconsistency inherent in the announcement of forward paths disappears. On the other hand, at the zero lower bound the wedge is predicted to be negative, not positive. Those same observations pose by no means a problem for the model of Section 2.[12]

Credibility aside, another possible source behind a wedge is disparity between the expectations of the market and the central bank. Such distinct beliefs can be due to differences between the central bank and the market in information at their disposal, differences in model-views of the world, differences in expectation-formation mechanisms, etc. Examples of such settings of asymmetric information include Svensson and Woodford (2002), Erceg and Levin (2003), Nimark (2005) and Carboni and Ellison (2011). We know of no such models addressing the wedge between the policy path and market forward rates. In princi-

[11] The Swedish repo-rate went below .25 in October 2014 and into negative territory in February 2015.

[12] These observations do not imply the credibility story is false. It only implies it does not offer an immediate explanation for movements in the wedge observed on other occasions.

ple, it is conceivable that one can engineer a constellation of model views of the world held by different agents, information sets, or alternative mechanisms that is consistent with the empirical responses. Because of this richness in potential explanations, we do not assert the evidence presented to be conclusive on the present model as the penultimate or even sole explanation for comovement between the wedge and the macroeconomy.

The present model does propose a clear transmission channel of the wedge to the macroeconomy, is easily capable of explaining patterns found in the data and in doing so succeeds where alternative theories may have a harder time. In particular, it is consistent with the demand-like patterns observed following a wedge shock in the empirical evidence for Sweden. To the extent that the source of the wedge is exogenous, the present model can rationalize its macroeconomic effect. The model allows one to consistently take account of both the central bank announced path and the market forward path, thus avoiding inconvenient assumptions about either one or the other being the only relevant one for the economy.[13] Arguably the same transmission channels are at work for endogenous factors, or for some of the alternative theories that could rationalize a wedge. For instance, Svensson (2015) argues that during 2010-2011 the Riksbank had higher expectations about future foreign interest rate developments compared to market expectations, which caused a positive wedge. From the perspective of the model of Section 2, foreign interest rates are exogenous, but through their effect on the wedge their macroeconomic consequences can be understood. In this sense, the present model is complementary to alternative theories about the wedge.

6 Policy

With these empirical results in mind, we now turn to policy issues. Specifically, we show how the model can inform policy deliberations in the presence of differences between central bank announced paths and market expectations of future interest rates. We focus on the Swedish case where wedge fluctuations have been substantial (Figure 2) and the VAR-evidence sug-

[13] For an example of this, see Svensson (2010). Through a series of thought experiments, he contemplates the possible implications of differences in market and central bank paths in a model which does not capture such differences.

gests these have had aggregate effects. We start by parametrizing the model.

6.1 Calibration

We estimate a subset of the parameters by means of the simulated method of moments.[14] The parameters to be determined are $(\rho_\phi, \sigma_\phi, \omega)$. We choose those parameters aiming to match the following set of observations. First, experience with path announcement thus far is not suggestive of a clear difference in the level nor in the variability of central bank path and market forward rates. The data in Figure 2 is illustrative in this respect. Regarding the level, announced and market forward rates were very similar troughout the New Zealand experience, as well as in the first couple of years of the Swedish case. While the data for the second half of the Swedish sample suggest the difference between announced and market forward rates is mostly positive, other countries' experience suggests the opposite occurs frequently, too. Most notably, in many countries at the zero lower bound, forward guidance has not immediately, nor invariably translated into market forward rates as low as those announced for the entire announcement horizon. Across the board, the data do not suggest that market and announced rates are different on average. In the model, the steady state level of central bank and market rates is equal as a result of assuming equal discount factors across agents ($\beta^u = \beta^r$).

Second, as is clear from Figure 2, the wedge between the announced path and market forward rates is both volatile and quite persistent. We therefore additionally aim to match both the wedge's volatility and its persistence.

Third, regarding the relative volatility, one can observe different patterns across time and countries. In particular, the Swedish experience (Figure 2, left panel) suggests that both paths were equally volatile in the first part of the sample, while since 2009 the announced path has fluctuated more compared to market forward rates. The opposite pattern, with

[14] We refrain from full-information estimation for two reasons. First, the model as such is too stylized to be thoroughly matched to the data. It does not contain a series of shocks and frictions typically introduced when estimating models, as in e.g. Smets and Wouters (2007) or Adolfson et al. (2008). Second, historical experience with path announcements thus far is limited and too short to enable reliable full-information estimation.

announced paths being stable relative to market forward rates occurs in some countries at the zero lower bound. The New Zealand data (Figure 2, right panel) suggests no apparent difference in volatility between the two paths. In light of these observations we require the parameters to not generate a difference in volatility between policy path and forward rates.

Finally, we ask the model to match the cyclicality of the wedge. From the Swedish experience, it turns out that the correlation between the wedge and GDP-growth is around 0.30.

The remaining parameters of the model take values roughly corresponding to those in RAMSES, i.e. the main estimated DSGE model of Sveriges Riksbank (Adolfson et al., 2013), and are described in the appendix. The data used is quarterly and the model is calibrated accordingly.

Table 1: SMM: Targets and model

	Target	Model
Wedge variance	0.1852	0.1854
Wedge persistence	0.8041	0.8206
Variance ratio of policy path and forward rates	1	0.9999
Wedge cyclicality	0.2977	0.3130

Note: Wedge variance, persistence and cyclicality estimates based on Swedish data (2007:Q1-2015:Q1).

Table 1 summarizes all the targeted moments and documents that the estimation comes reasonably close to matching all of them. Table 2 shows the estimated parameters. Most notably, the fraction of unrestricted households is 0.40.

Table 2: SMM: Parameters

Parameter	Value
ω	0.4017
ρ_ϕ	0.8253
σ_ϕ	0.0082

6.2 Scenarios

We now show how the model can inform policy deliberations in the presence of differences between central bank announced paths and market expectations of future interest rates. Specifically, we consider the following situation. At each policy meeting the central bank announces a certain path of interest rates. This announcement is communicated along with a forecast for key macroeconomic aggregates. Recall that typical models used in policy analysis have no scope for deviations between the announced path and market forward rates. Thus, if the announced path were fully model-based, we know it ignores the presence of a wedge between that path and the market forward rates. We now ask what policy would have looked like if the model acknowledged the existence of such deviations.

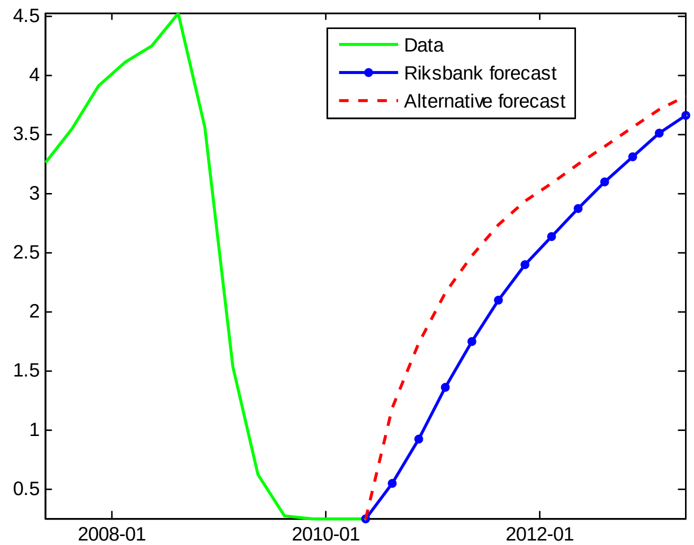
As an example, in Figures 8 to 10 the solid line plots Swedish data for three key variables up to Sveriges Riksbank's monetary policy meeting of September 2010. From that date onward, the solid circled line depicts the Riksbank's forecast. Thus, in Figure 8 the circled line shows the interest rate path that the Riksbank announced following that particular policy meeting. The published forecast for inflation (resp. GDP) from that meeting is depicted in Figure 9 (resp. Figure 10). These forecasts reflect the view of a majority of the board of Sveriges Riksbank. They are judgmental forecasts informed by both DSGE and time-series models.

From Figure 2 (left-hand panel) we know that the wedge was substantial at the time of these forecasts. Particularly, the announced path was 110 basis points higher than the path of market forward rates, on average over the horizon of the forecast. In the model of Section 2, such a difference is captured by a negative shock to the wedge.

If policy took into account that market forward rates were below its announced path the following things would occur ("Alternative forecast", dashed line).[15] First, inflation would substantially overshoot the projected inflation rate (Figure 9). Second, GDP would be well above the projected path (Figure 10). As a result, given its typical response function, the central bank would not have announced the path it did. Instead, in view of attaining its

[15] For the particular shock considered here, the impulse response functions for all variables in the calibrated model are contained in Appendix. The "Alternative forecasts" here add those impulse responses to the Riksbank's published forecasts.

Figure 8: Policy rate - published and alternative forecast (September 2010 policy meeting)



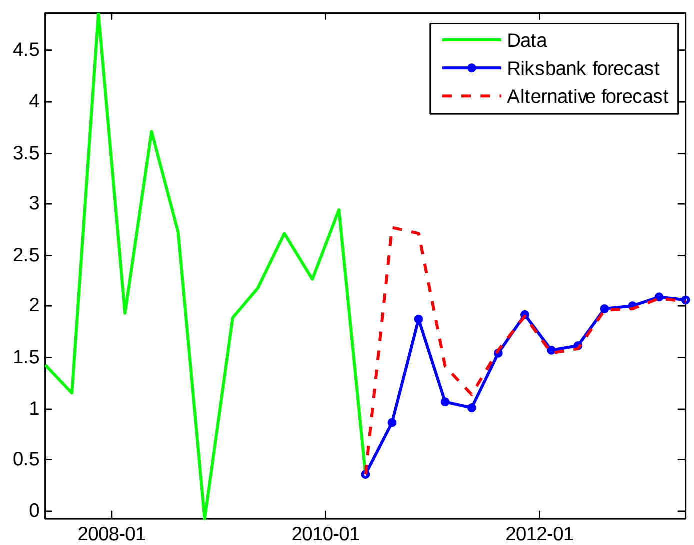
Note: Repo rate in percent.

objectives the announced policy rates down the road would be substantially higher. Particularly, as is apparent from Figure 8, the Riksbank would have announced a fiercer increase in policy rates going forward.

This change in forecast scenario shows how the model interprets deviations of forward rates from announced policy paths. Essentially, forward rates below the path announced by the central bank signal to the monetary policymaker that there is additional (demand-like) stimulus in the economy compared to its main scenario. As a result, low market forward rates induce the central bank to tighten relative to its announced path. As shown in Section 4.1, the change in policy rates serves to offset the demand-like pressures generated by transaction cost shocks in the model.

Finally, let us briefly dwell on two simplifying assumptions maintained in the above experiment. First, we assume the observed deviation between path and market rates at the policy date did not exist in the previous period. That is, the entire difference observed at the time of the policy round is absorbed by a surprise cost shock. Alternatively, one can have the

Figure 9: Inflation - published and alternative forecast (September 2010 policy meeting)

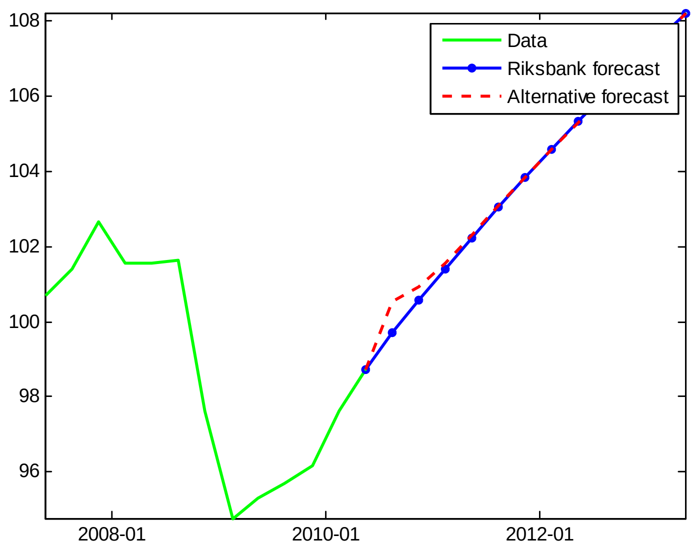


Note: CPIF inflation, QoQ, annualized.

shock absorb only the change in the wedge, after accounting for persistence. While the exact quantitative forecasts change a bit, the substantive implications remain: the announced path is based on inflation and output forecasts that are too low. Considering that market forward rates are below those announced will then imply a more restrictive monetary policy stance. For the particular policy meeting considered here, this implies announcing a faster increase in the policy rate.

Second, we assume the actually announced policy path is the path for whatever reason it may be, but it is not taking into account the deviation relative to market forward rates. The experiment we conduct then asks: suppose the central bank did take that deviation into account, how different would the announced path be? In this regard, it is worth revisiting the policy rule in the model, (12). The rule considered contains the typical response to output and inflation, but no additional arguments. This is conform our assumption that the baseline forecast does not involve any response to the wedge or the transaction cost. As a result, in the basic model the policy rate's response to an increase in the wedge is positive. The

Figure 10: GDP - published and alternative forecast (September 2010 policy meeting)



Note: Index, 2007:Q1=100.

policy response in the alternative scenario of Figure (8) thus *only* accounts for the central bank leaning against the boom induced by the wedge. Adding additional arguments to the policy rule could obviously overturn the present policy prescription. While extending the policy rule is possible, perhaps even desirable, these matters have proven to be the subject of much controversy in actual policymaking (see e.g. Sveriges Riksbank, 2010). The question of optimal policy design is beyond the scope of the present study. That said, the model does provide a framework for coherently addressing these issues.

7 Conclusions

The paper studies the wedge between central bank path announcements and corresponding market forward rate paths. Recent experience with path announcements has shown that there can be substantial differences between the two. Models presently in use for policy analysis do not allow for such discrepancies. The paper provides a DSGE model that does.

In the model, fluctuations in the wedge have real aggregate effects. Specifically, market interest rate expectations below the announced policy path act as a demand-like factor in the economy.

The mechanism in the model is not the only one that can generate a wedge between these paths. It can be both a complement and a substitute to other theories. Compared to alternative explanations the present model has some virtues. The empirical analysis provides evidence that discrepancies between central bank announcements and market expectations indeed can have macroeconomic effects. Specifically, in Sweden, where the wedge has been substantial in size as well as very persistent, exogenous increases in the wedge (market expectations below central bank path) result in increased economic activity. The model is consistent with that evidence. Additionally, transmission channels in the model are straightforward and the key friction is easily appended to more rigourous models. Therefore, model-based policy deliberations need not turn a blind eye to deviations between announced and market forward rates. Because the model allows market deviations from the announced policy path to have real effects, model-based evaluations of the state of the economy can change. This may necessitate a change in forecasts and may therefore imply different policy prescriptions.

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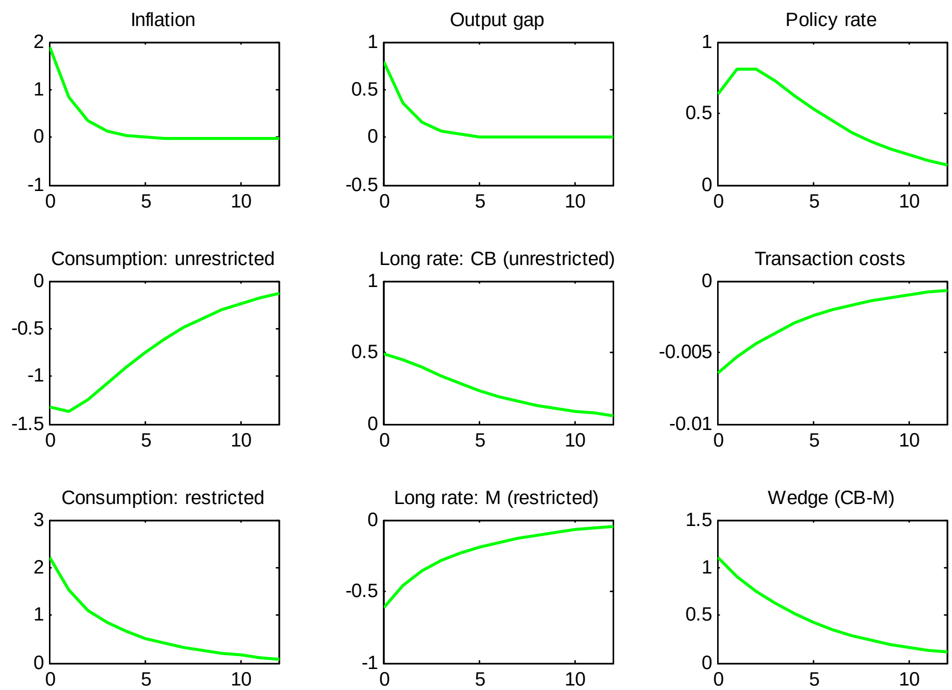
Appendix: Parameters and impulse responses to a transaction cost shock in the policy scenario

Non-wedge related parameters are similar to those in RAMSES (Adolfson et al., 2013). Specifically, we use $\beta = (1.026417)\hat{}(-1/4)$, $\sigma = 1$, $\varphi = 3$, $\alpha = 0.75$, $\theta = 11$, $\rho_i = 0.85$, $\psi_\pi = 2$, $\psi_y = 0.125$. For the policy scenario of Section 6.2, the wedge-related parameters used are those contained in Table 2. The shock to $u_t^\phi = \rho_\phi u_{t-1}^\phi + \left(1 - \rho_\phi\right) \epsilon_t^\phi$ is such that the wedge attains the value observed in the data in September 2010 ($\epsilon_t^\phi = -0.037$).



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