

# The Relativity Theory Revisited: Is Publishing Interest Rate Forecasts Really so Valuable?\*

Michał Brzoza-Brzezina<sup>†</sup>

Adam Kot<sup>‡</sup>

October 21, 2009

## Abstract

In a New Keynesian model with asymmetric information and learning we analyse the potential gains that can be achieved when a central bank publishes a macroeconomic projection and then, additionally shows its expected interest rate path. In our framework both improve macroeconomic outcomes. However, the gains from publishing interest rate paths are small relative to those from publishing macroeconomic projections. Given that most inflation targeting central banks are already publishing macroeconomic projections this means that most gains from increasing transparency in this area may already have been reaped. This, together with the potential costs, may explain the relative reluctance of central banks to publish interest rate paths.

JEL: E52, E58, E43

Keywords: interest rate path, monetary policy, adaptive learning

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\*We would like to thank E.Engel, M.Kolasa, B.Preston, A.Sławiński, P.Soderlind, J.Suda, P.Welz and J.C.Williams as well as participants of the WIEM 2008 conference and participants of the seminars at the NBP and ZEI for helpful comments. The views expressed in this paper are our own and do not necessarily reflect the position of the represented institutions.

<sup>†</sup>National Bank of Poland and Warsaw School of Economics, e-mail: [michal.brzoza-brzezina@mail.nbp.pl](mailto:michal.brzoza-brzezina@mail.nbp.pl)

<sup>‡</sup>Bank Pekao (Unicredit Group) and Warsaw School of Economics, e-mail: [akot@sgh.waw.pl](mailto:akot@sgh.waw.pl)

# 1 Introduction

The last two decades have witnessed a substantial increase in transparency about actions of monetary authorities. Central bankers widely share the view that their main impact on the economy is not via short-term interest rates they control, but via expectations of future policy actions. It is fairly easy to show, within standard microfounded models used for monetary policy analysis (e.g. Woodford 2003) that what matters for economic agents when they make decisions about current prices, investment and consumption is the whole path of future expected interest rates. Taking this into account, central bankers have made a great effort to, at least indirectly, guide these expectations. All inflation targeters<sup>1</sup> (IT) set publicly a numerical target for inflation. Most publish reports, where they explain their monetary policies. Several central banks decided to publish minutes from meetings of their decision making bodies. Last but not least a vast majority decided to show their inflation and GDP projections. On the other hand, however, only a limited number of central banks decided to do — what on the first view seems the most efficient way of guiding expectations on future interest rates — to publish their view on the most likely path for interest rates. Currently only New Zealand, Norway, Sweden and the Czech Republic show explicitly expected interest rate paths. Other banks prefer to guide the markets indirectly<sup>2</sup>.

The last two examples of increasing central bank transparency will be explicitly analysed in this paper. We wonder why most central banks decided to publish macroeconomic projections but only few started to show future interest rate paths. Obviously both decisions bring costs and benefits. Central banks were reluctant to show macroeconomic forecasts because i.a. of possible reputational costs related to being wrong. Moreover they feared that the conditional nature of projections could be misunderstood — high inflation projected under a constant interest rate assumption could fuel inflation expectations instead of showing that monetary policy would be tightened in order to bring inflation back to target. On the other hand, central bankers' intuition as well as formal models suggested that publishing projections and showing the model of the economy could improve macroeconomic outcomes. Taking these arguments (and possibly other, like peer pressure (e.g. Fracasso et al. 2003)) into consideration most inflation targeting central banks decided to follow the path paved by the Bank of England in 1996 and started to publish their macroeconomic projections in the form of fan-charts.

Similar arguments are raised in the debate whether or not to publish interest rate forecasts (Good-

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<sup>1</sup>We use the term *inflation targeters* for convenience. Obviously the analysis applies equally likely to central banks who, like the ECB or the FED follow similar monetary policy strategies, without calling them explicitly *inflation targeting*.

<sup>2</sup>See Rudebush and Williams (2007) or Blinder et al (2008) for a thorough discussion of signalling of policy inclinations.

hart 2001, King 2007, Weber 2007, Rudebusch 2008). On the one hand there are costs related to reputation and misunderstandings. Central banks fear that showing an interest rate path may be taken by the public for commitment to follow this path. This could negatively affect the bank's reputation once it deviates from the announced path. Additionally this could lead to sub-optimal allocations if the conditional nature of these paths were not understood properly. Further, it is difficult to embed interest rates paths into the monetary policy decision making process, especially when decisions are taken by committees comprising more than one member. There is also a risk that revealing interest rates paths could constrain the monetary authority by narrowing the spectrum of its possible future choices, thus undermining policy effectiveness. On the other hand there are potential gains related to better guiding expectations and, as a results, leading to lower volatility of output and inflation.

One possible explanation, why despite potentially similar costs central banks were much more keen to publish macroeconomic projections than interest rate paths is that formally or intuitively they know that the majority of attainable benefits has already been reaped by publishing the macroeconomic projection (Kahn 2007). In other words, it is relatively difficult for agents to model the economy and make forecasts of output and inflation. In fact only few analysts do so, the majority of the population does not build econometric models. So, improvement in understanding the economy from showing projections can be huge. However, once agents have the projection and observe the behaviour of output and inflation relative to target they can relatively easily show the likely direction in which interest rates will move. Hence, the informational gains from additionally publishing the interest rate path may be minor.

In this paper we treat this problem formally. On the basis of a simple three-equation model of the economy we calculate the potential gains from publishing a macroeconomic projection and compare them to the benefits that can be achieved by additionally publishing an interest rate path. In our model there is an asymmetry of information between the central bank and the public which can be reduced either by learning on the side of the public or by publishing forecasts by the central bank. Our results confirm the intuition: the gains from showing the projection are substantially bigger than those from additionally showing the interest rate path. This means that most gains from increased central bank transparency in this area may already have been reaped when central banks started to publish projections. The remaining gains are relatively small what, given the aforementioned costs and fears, may explain why banks are relatively reluctant to show future interest rate paths. It should be noted that these results come up despite a modelling framework relatively favourable for publishing interest rate forecasts. Information asymmetry guarantees welfare improvements of increased transparency, something not so obvious in other modelling frameworks, as shown below.

The gains (and costs) of increasing central bank transparency have been recently widely anal-

ysed in the literature. The literature on the relationship between central bank transparency and macroeconomic outcomes goes back to the 1980's and the contributions of Cukierman and Meltzer (1986) and Goodfriend (1986)<sup>3</sup>.

The issue of publishing macroeconomic projections and interest rate paths constitutes only a small subset of this literature. Tarkka and Mayes (1999) show on the basis of a Barro-Gordon model that publishing forecasts improves macroeconomic performance, even if the forecast is imprecise. Chortareas, Stasavage and Sterne (2002) show on empirical grounds that publishing central bank forecasts is associated with lower inflation (though endogeneity issues cannot be fully ruled out). Geraats (2005) uses a game theoretic approach to show that publishing macroeconomic forecasts lowers the inflation bias. It must be however noted that the literature also describes negative consequences of central bank transparency. For example in Cukierman's (2000) model the central bank reveals information about upcoming shocks and thus impedes its own ability to stabilise the economy by surprising agents. Similar arguments are given by Gersbach (2003).

The issue of publishing interest rate paths has been taken up in the literature as well. Faust and Leeper (2005) analyse data from macroeconomic projections of the Bank of England, the Fed and the Riksbank. They conclude that the conditional forecasts published by these institutions were of little value to market participants. Instead, they argue, central banks should show unconditional forecasts, based on the most likely path of interest rates. Ferrero and Secchi (2007) review quantitative and qualitative interest rate forecasts of four central banks and conclude that their publication improves the ability of market operators to predict monetary policy decisions. Euseppi and Preston (2007) show that when the central bank does not have full knowledge about the economy communicating details about monetary policy rules helps restore stability. Rudebush and Williams (2006) use a standard New Keynesian model with learning to show that publishing the interest rate path lowers the variability of output and inflation. Gosselin et al. (2008) use a model with heterogeneous information to show that the publication of an interest rate path may increase or reduce welfare depending on the relative quality of signals received by the central bank and the public. To our knowledge no study attempted to compare the gains from publishing macroeconomic projections and the interest rate path. Our paper tries to fill this gap.

On technical grounds our paper is directly linked to an increasing literature on learning<sup>4</sup> and its adaptation to monetary policy. Learning is a natural framework for analysing the gains from increased central bank transparency. Under rational expectations agents know the economic model and hence, there is no room for the central bank to improve their forecasts by revealing projections.

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<sup>3</sup>Important recent contributions include i.a. Moris and Shin (2002), Ehrman and Fratscher (2005) or Walsh (2008). Comprehensive surveys are provided by Geraats (2002) and van der Cruijsen and Eijffinger (2007).

<sup>4</sup>See Evans and Honkapohja (2001) and (2007) for introduction and a comprehensive overview of the current literature.

However, if one assumes that agent's knowledge of the economic model is imperfect<sup>5</sup>, central banks (assumed to know the model perfectly) can share their knowledge, hence improve private forecasts and the overall macroeconomic outcome. On the other hand, if a central bank chooses not to disclose its information, agents can be assumed to follow a learning process, i.e. use past data to estimate the parameters of the underlying model.

The rest of the paper is structured as follows. In section 2 we present the model. In section 3 we describe the issues related to expectation formation. Section 4 presents the simulation results and section 5 concludes.

## 2 The Model

Our model consists of three equations: a Phillips curve linking inflation and unemployment, an IS curve linking real interest rates and unemployment and a monetary policy rule driving the nominal interest rate. The first two equations are:

$$\pi_t = \gamma\pi_{t-1} + (1 - \gamma)\pi_{t+1}^e + \kappa(u_t^e - u^*) + \varepsilon_{\pi,t} \quad (1)$$

$$u_t = \delta u_{t-1} + (1 - \delta)u_{t+1}^e + \sigma(i_t^e - \pi_{t+1}^e) + \varepsilon_{u,t} \quad (2)$$

where  $\pi$  denotes inflation,  $u$  unemployment,  $i$  the nominal interest rate and the superscript  $e$  stands for (possibly non-rational) expectations. For convenience, without loss of generality, in what follows the natural rate of unemployment  $u^*$  will be assumed to be zero. The terms  $\varepsilon_{\pi}$  and  $\varepsilon_u$  denote *iid* shocks, being respectively  $N(0, \sigma_{\varepsilon_{\pi}})$  and  $N(0, \sigma_{\varepsilon_u})$ .

This model is closely related to the hybrid version of the standard New Keynesian closed economy model as presented in Giannoni and Woodford (2005). The main difference between our approach and the New Keynesian model is the presence of the unemployment gap instead of the output gap. This however is only a minor technical issue, since these concepts are closely linked by the Okun law. The main advantage of such specification is that its parameters have been recently estimated for the US economy taking explicitly into consideration forecasts of inflation and unemployment from the Survey of Professional Forecasters – SPF (Orphanides and Williams (2007)). We believe that, in the context of a model used for analysing systems under learning, such an approach to fixing model parameters is superior to the usual practise of calibrating parameters or even estimating them under the assumption of rational expectations.

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<sup>5</sup>This assumption seems justified as empirical studies like Romer and Romer (2000) and Peek et al. (1998) show that the Fed has an informational advantage over the public when creating forecasts.

Our benchmark calibration is equivalent to that of Orphanides and Williams (2007):

$$\pi_t = 0.5\pi_{t-1} + 0.5\pi_{t+1}^e - 0.192u_t^e + \varepsilon_{\pi,t} \quad (3)$$

$$u_t = 0.5u_{t-1} + 0.5u_{t+1}^e + 0.036(i_t^e - \pi_{t+1}^e) + \varepsilon_{u,t} \quad (4)$$

with  $\sigma_{\varepsilon_{\pi}} = 1.11$ ,  $\sigma_{\varepsilon_u} = 0.29$ . This model was estimated under the assumption that expectations are formed at period  $t - 1$  and we stick to this assumption throughout the paper regardless of whether they are formed under RE or under learning<sup>6</sup>. The state space representation of our model is presented in Appendix 2.

Monetary policy is modelled as a Taylor rule, linking the interest rate to previous period unemployment and inflation:

$$i_t = \phi_{\pi}\pi_{t-1} + \phi_u u_{t-1} + \varepsilon_{i,t}, \quad (5)$$

where  $\varepsilon_i$  denotes a monetary policy shock, which is assumed *iid*  $N(0, \sigma_{\varepsilon_i})$ . This reflects the fact that the behaviour of monetary authorities cannot be described precisely by a simple (or even complicated) rule. Central bankers take various information into account; moreover, given voting procedures, their decision cannot be treated as a linear function of the underlying economic factors. We model these issues in form of a monetary policy shock. Following the estimation in Smets and Wouters (2007) and deWalque and Wouters (2004) we set its standard deviation to  $\sigma_{\varepsilon_i} = 0.22$ .

We consider three variants of determination of the Taylor rule's parameters:

- Standard parameters as suggested by Taylor (1993) corrected for the fact that instead of the output gap we use the unemployment gap. Taking into account that the variability of unemployment is about 1/4 of the variability of output, our Taylor rule becomes:

$$i_t = 1.5\pi_{t-1} - 2u_{t-1} \quad (6)$$

- Optimal parameters derived from minimization of the central bank's loss function under the assumption of agents following rational expectations. Under this rule the central bank follows the same policy regardless of whether agents' expectations are formed rationally or under learning.
- Optimal parameters derived from minimization of the central bank's loss function, whereas this time the central bank takes into account the way agents' expectations are formed.

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<sup>6</sup>See Wetz (2006) for derivation and solution of a similar model under this timing assumption.

In what follows, these policy variants will be denoted respectively as STR, RETR and OTR.

In the latter cases the central bank minimises the discounted sum of losses stemming from variability of inflation and unemployment:

$$L_t = \sum_{j=0}^{\infty} \beta^j [\pi_{t+j}^2 + \lambda_u u_{t+j}^2] \quad (7)$$

For our benchmark model we assume  $\lambda_u = 4$ , which is equivalent to a standard loss function with equal weights on inflation and output gap variability. We also conduct robustness checks with respect to this parameter.

We decided to restrict our attention to the functional form of a Taylor rule and ignore fully optimal (discretionary or commitment-based) policies for the following reasons:

- First, the functional form of such policies depends crucially on the underlying model. It may be unrealistic to assume that agents know the functional form of a complicated, model-specific reaction function. On the other hand assuming that the functional form estimated by agents differs from the true reaction function may result in non-convergence to the rational expectations equilibrium (Evans and Honkapohja 2001).
- Second, the literature shows that introducing optimal policies to models with learning may result in indeterminacy (e.g. Evans and McGough 2005, 2006, Evans and Honkapohja 2006, Dennis and Ravenna 2007). This stream of research seems to be still developing and we decided, at least as a first approach to avoid it. Nevertheless, we think that an attempt to introduce fully optimal policy may be an interesting extension for future research.

In contrast to a number of recent studies (e.g. Orphanides and Williams (2007) and Rudebusch and Williams (2007)) we do not introduce into our model variable natural rates (of unemployment or interest) nor variable inflation targets. This decision comes from our preference to treat various parts of the modelled economy symmetrically as regards the easiness of parameter estimation by learning agents. For instance a variable natural rate of unemployment makes it more difficult to estimate properly the Phillips curve and, hence, increases the potential gains from publication of a macroeconomic projection. On the other hand a variable inflation target makes it more difficult to estimate the monetary policy reaction function, increasing the potential gains from showing the interest rate path.

As a first approximation to how this affects our results we think that variable natural rates of unemployment or interest are contemporaneously probably more confusing than variable inflation targets. Central banks (in particular inflation targeters) have recently been very open as regards

publication of inflation targets while a substantial literature documents the difficulties related to estimating natural rates of unemployment and interest. Thus, by omitting these elements we are likely erring on the upside when assessing the relative gains from publishing inflation rate paths and macroeconomic projections. Hence, inclusion of variable rates and targets would probably reinforce our conclusions.

### 3 Expectations

We consider three variants of private agents expectations formation, depending on the information on the economy and central bank preferences they possess. This information is assumed to be conditional on what the central bank reveals.

The first variant, denoted by **V1** refers to a situation when agents do not know neither the central bank projection nor interest rate forecast. Such a setup corresponds to an opaque central bank who does not share his expectations with the public<sup>7</sup>.

Having no knowledge about the true model of the economy nor the central bank policy rule, agents learn them on the basis of past data. To do so, they estimate a three-variable VAR(1), reflecting their perceived law of motion (PLM):

$$\begin{pmatrix} u_t \\ \pi_t \\ i_t \end{pmatrix} = \mathbf{A} \begin{pmatrix} u_{t-1} \\ \pi_{t-1} \\ i_{t-1} \end{pmatrix} + \begin{pmatrix} v_{u,t} \\ v_{\pi,t} \\ v_{i,t} \end{pmatrix} \quad (8)$$

Estimation of the coefficient matrix  $\mathbf{A}$  is performed equation by equation with standard OLS. The estimation sample is a moving window and in the baseline scenario it covers 50 last observations, i.e. from  $t - 50$  till  $t - 1$ ; the earlier data is simply forgotten by agents.

This VAR is next applied to compute expectations  $i_{t+1}^e$ ,  $u_{t+1}^e$  and  $\pi_{t+1}^e$ . A two period-ahead dynamic forecasts is computed according to:

$$\begin{pmatrix} u_t^e \\ \pi_t^e \\ i_t^e \end{pmatrix} = \mathbf{A} \begin{pmatrix} u_{t-1} \\ \pi_{t-1} \\ i_{t-1} \end{pmatrix} \quad (9)$$

and

$$\begin{pmatrix} u_{t+1}^e \\ \pi_{t+1}^e \\ i_{t+1}^e \end{pmatrix} = \mathbf{A} \begin{pmatrix} u_t^e \\ \pi_t^e \\ i_t^e \end{pmatrix} \quad (10)$$

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<sup>7</sup>Examples of central banks operating under such a setup are usually new IT-adopters, who commit to an inflation target but are not yet ready or fully convinced to disclose more out of their policy analysis systems. For instance Poland used to operate under such a setup for almost 6 years after formal adoption of IT in 1998.



Shocks  $\varepsilon_{\pi,t}$ ,  $\varepsilon_{u,t}$  and  $\varepsilon_{i,t}$  at periods  $t$  and  $t + 1$  are assumed to be unknown to the agents. The expectations  $i_t^e$ ,  $u_t^e$ ,  $u_{t+1}^e$  and  $\pi_{t+1}^e$  are then plugged into the true model of the economy, consisting of (1), (2) and (5), to obtain the actual law of motion (ALM). When shocks  $\varepsilon_{\pi,t}$ ,  $\varepsilon_{u,t}$  and  $\varepsilon_{i,t}$  arrive this can be used to generate  $i_t$ ,  $u_t$  and  $\pi_t$ .

The second variant **V2** differs from **V1** in that economic agents are assumed to know the macroeconomic projection of the central bank. Modelling this formally poses the question what it means to agents to know a projection. Central banks usually show the projected paths for inflation and output based on an exogenous (e.g. constant or market expectations based) interest rate path. Due to the interest rate assumption, such a projection cannot formally be considered as an unconditional forecast. However, in practice the projections are relatively similar to unconditional forecasts, and we assume that agents treat them so. Following central banking practice we consider two projection variants: projections based on a constant interest rate path and on an interest rate path expected by the agents (financial markets in the real world).

- **V2cons**: the constant interest rate projection is constructed by the central bank on the basis of (1), (2) and a constant, period  $t - 1$  interest rate. It is assumed that no shocks occur during the projection horizon.
- **V2mkt**: the market interest rate based projection is constructed by the central bank on the basis of (1), (2) and the unconditional interest rate forecast of the agents. This means that agents first run a VAR and make a forecast as described in **V1**. Then the central bank applies the agents' interest rate forecast as exogenous in its projection. Again, it is assumed that no shocks occur in the projection horizon.

It seems natural to assume that apart from the projection agents also can use the knowledge based on learning as in **V1**. In what follows we assume that they combine their VAR based forecast (9) and (10) with the projection provided by the central bank. In doing so they weight the two forecasts according to a simple rule based on their past performance:

$$f_v = (1 - \mu_v)f_v^{CB} + \mu_v f_v^{VAR} \quad (11)$$

for  $v = i, u, \pi$ , where  $f_v$  denotes the combined forecast,  $f_v^{CB}$  the central bank's projection and  $f_v^{VAR}$  the VAR forecast of variable  $v$ . The parameter  $\mu_v$  weights the two forecasts as suggested in Newbold and Harvey (2002):

$$\mu_v = \frac{\sigma_{v,CB}^2}{\sigma_{v,CB}^2 + \sigma_{v,VAR}^2} \quad (12)$$

Here  $\sigma_{v,CB}^2$  and  $\sigma_{v,VAR}^2$  denote the variances of the past forecast errors of central bank projections and private VAR forecasts respectively<sup>8</sup>. When calculating  $\mu_v$  from past errors we assume that agents have a history of forecasts of length equal to their learning sample *simpl*. This procedure leaves us with a full set of agent's expectations for periods  $t$  and  $t + 1$ .

As before, these expectations are then plugged into the true model of the economy, consisting of (1), (2) and (5), to obtain the actual law of motion (ALM). When shocks  $\varepsilon_{\pi,t}$ ,  $\varepsilon_{u,t}$  and  $\varepsilon_{i,t}$  arrive this can be used to generate  $i_t$ ,  $u_t$  and  $\pi_t$ .

The third variant **V3** assumes that agents know an internally consistent forecast of the central bank (i.e. future paths for inflation, unemployment and the interest rate). This reflects the practise of central banks that decided to publish the interest rate path - they show the macroeconomic forecast consistent with this path. As a result, the public can then use directly the central bank forecast as its own. Technically, (1), (2) and (5) are solved under rational expectations with the same timing assumptions as in **V1** and **V2**.

The information structure of the variants described above is summarised in Table 1. We interpret the gains from going from V1 to V2 as corresponding to publishing a macroeconomic projection and the gains from going from V2 to V3 as corresponding to additionally showing an interest rate path.

	<b>V1</b>	<b>V2</b>	<b>V3</b>
<b>central bank knows:</b>	IS equation Philips curve policy rule	IS equation Philips curve policy rule	IS equation Philips curve policy rule
<b>public knows:</b>	Past data used to estimate VAR and make forecast	Past data used to estimate VAR + central bank's projections and combines the forecasts	Complete, consistent central bank forecast

**Table 1:** Information structure applied in the model

<sup>8</sup>As noted by Newbold and Harvey (2002) this weighting scheme performs in practice often better than the more appropriate choice based on minimisation of the combined forecast error  $\mu_v = \frac{\sigma_{v,CB}^2 - cov_{CB,VAR}}{\sigma_{v,CB}^2 + \sigma_{v,VAR}^2 - 2cov_{CB,VAR}}$ . This was also our experience, the latter weight being extremely variable for small learning samples.

## 4 Simulations and results

### 4.1 Simulations

We run stochastic simulations in order to compare central bank losses under different stages of transparency discussed above. Each simulation run spans over  $T_{sim}$  periods, for which the values of  $\pi$ ,  $u$  and  $i$  are computed. We take  $T_{sim} = 100,000$ , and burn the first  $b = 10,000$  to make the results independent of initial conditions.

We analyse three simulation cases, each with different policy rule coefficients, according to the classification presented in section 2. In a theoretical setup, according to (7), central bank loss is computed over the infinite horizon. In simulations we restrict the horizon to  $h = 500$  periods ahead since  $\beta^h$  is insignificantly different from zero<sup>9</sup> for higher values of  $h$ . So, the central bank loss in period  $t$  is computed as:

$$L_t = \sum_{j=1}^h \beta^j (\pi_{t+j}^2 + \lambda_u u_{t+j}^2) \quad (13)$$

Minimization of the average central bank loss (AL) to pick the policy rule coefficients follows:

$$\min_{\phi_u, \phi_\pi} AL = \min_{\phi_u, \phi_\pi} \frac{1}{T_{sim} - b - h} \sum_{t=b+1}^{T_{sim}-h} L_t \quad (14)$$

The minimization is performed numerically. The initial vector for **V3** is  $[\phi_u, \phi_\pi] = [-2, 1.5]$ . The initial vector for **V1** and **V2** is the *argmin* reached for **V3**.

Agents can choose different sample lengths of past data for the purpose of learning. In the baseline scenario it is assumed that the learning sample *simpl* stretches over 50-periods (12.5 years), which corresponds<sup>10</sup> to the perpetual learning gain  $\kappa = 0.02$ . Orphanides and Williams (2007) find that  $\kappa \in (0.01, 0.04)$  perform best in modelling SPF expectations. For the sake of robustness, we also analyse different values of *simpl*. In the process of learning, the regressions run by agents are tested for stationarity. Should this test be breached, the models' coefficients are set equal to the average of parameters applied in the previous periods. In practise, we found this restriction binding only with negligible frequency.

The main parameters applied in the baseline scenario are summarised in Table 2:

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<sup>9</sup>We take  $\beta = 0.99$ . Then  $\beta^{500} \approx 0.006$

<sup>10</sup> $\kappa = \frac{1}{\bar{t}}$  under least squares learning with infinite memory

$simpl = 50$	$\gamma = 0.5$	$\kappa = -0.192$
$\delta = 0.5$	$\sigma = 0.036$	$\lambda_u = 4$
$\sigma_{\varepsilon_\pi} = 1.11$	$\sigma_{\varepsilon_u} = 0.29$	$\sigma_{\varepsilon_i} = 0.22$
$\beta = 0.99$	$b = 10,000$	$Tsim_s = 100,000$
$h = 500$		

**Table 2:** Baseline scenario parametrization.

## 4.2 Results

The results for the baseline scenario are summarised in Tables 3 and 4. In order to easily compare the gains from publishing the macroeconomic model and from publishing the policy rule we calculate gains defined as:

$$G_{i/j} = 1 - \frac{AL_i}{AL_j} \quad (15)$$

where  $G_{i/j}$  stands for gain of variant  $i$  versus variant  $j$ , and  $AL_i$  denotes average central bank loss in variant  $i$ .

The following findings stem from the baseline scenario simulations:

- Central bank loss decreases with increased transparency for any policy rule. This is an inherent feature of our modelling framework.
- In all cases, gains for **V2cons** or **V2mkt** vs. **V1** are much higher than for **V3** vs. **V2cons** or **V2mkt**. This points to benefits from publishing macroeconomic projections being substantially higher than gains from additionally showing the future interest rate path. For instance, under the optimised policy rule (OTR) publication of forecasts conditional upon constant interest rates improves central bank loss by 12.89 per cent compared to 4.03 from additionally revealing the interest rate path. Publication of the projection based on market-expected interest rates lowers the loss by 14.54 per cent while adding the interest rate path adds only 2.17 per cent
- Comparison of central bank losses under the rule optimised for rational expectations (RETR) and the optimised rule (OTR) confirms that the central bank can benefit from optimising the policy rule coefficients subject to the agents' actual information. For example, comparing the loss for **V1** under RETR ( $AL = 381.38$ ) and OTR ( $AL = 375.55$ ) shows that applying the rule optimised under the (wrong) assumption of agents following rational expectations instead of adaptive learning the central bank can end up with suboptimal results. This shows that central banks should redefine policy rules when moving along the ladder of transparency stages.

- The improvement in central bank loss after the disclosure of the future interest rates path is still higher when the central bank publishes its projections based on the constant interest rate **V2cons** (e.g. 4.03 per cent for OTR) compared to the market expected interest rates **V2mkt** (e.g. 2.17 per cent for OTR). This shows that projections based on market interest rates are more informative than constant interest rate projections. Moreover, publishing projections based on the market interest rate expectations is a close substitute to revealing an unconditional forecast based on the future interest rate path.
- The coefficients in the optimised Taylor rules are relatively high, compared to the standard case. One should, however remember two things. First, it is a standard finding in the literature (e.g. Rudebusch and Svensson 1999) that Taylor rule coefficients optimal with respect to a standard loss function (based on inflation and output variability) are substantially higher than those found by Taylor (1993). By adding inertia, learning probably further increases these coefficients. Second, the coefficient on unemployment should be divided by -4 to correspond to the coefficients on output gaps.

Case	nick	Loss				Gain (in per cent)			
		V1	V2cons	V2mkt	V3	V2cons vs V1	V2mkt vs V1	V3 vs V2cons	V3 vs V2mkt
Standard Taylor rule	STR	448.20	337.71	332.11	324.42	24.65	25.90	3.93	2.32
rule optimized for RE (variant V3)	RETR	381.38	326.68	320.11	313.13	14.34	16.06	4.15	2.18
optimized rule	OTR	374.55	326.28	320.08	313.13	12.89	14.54	4.03	2.17

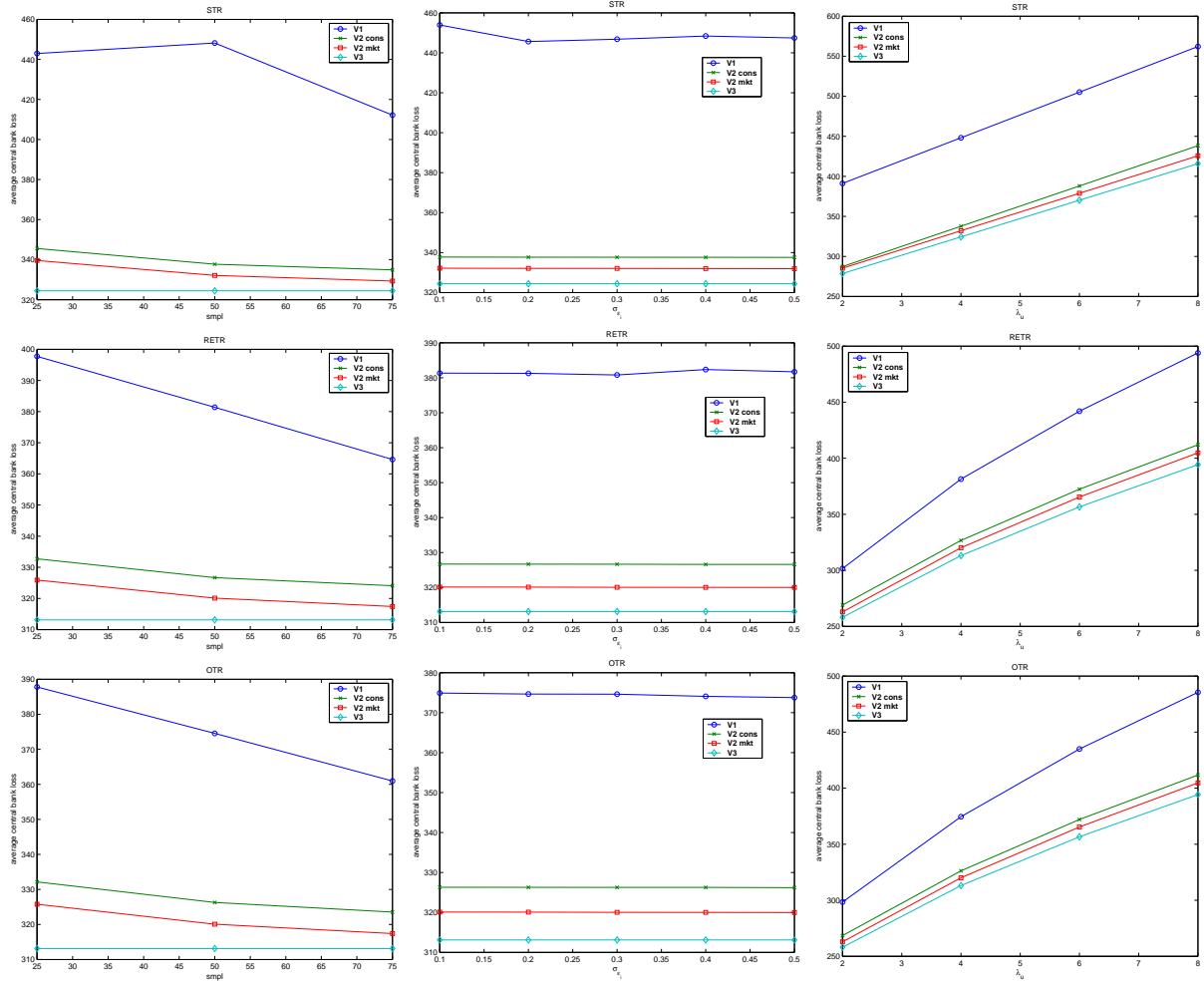
**Table 3:** Average central bank loss and gains in the baseline scenario.

Case	nick	Variant			
		V1	V2cons	V2mkt	V3
Standard Taylor rule	STR	$\phi_\pi = 1.5$	$\phi_\pi = 1.5$	$\phi_\pi = 1.5$	$\phi_\pi = 1.5$
		$\phi_u = -2$	$\phi_u = -2$	$\phi_u = -2$	$\phi_u = -2$
rule optimized for RE (variant V3)	RETR	$\phi_\pi = 2.62$	$\phi_\pi = 2.62$	$\phi_\pi = 2.62$	$\phi_\pi = 2.62$
		$\phi_u = -4.53$	$\phi_u = -4.53$	$\phi_u = -4.53$	$\phi_u = -4.53$
optimized rule	OTR	$\phi_\pi = 3.45$	$\phi_\pi = 2.48$	$\phi_\pi = 2.62$	$\phi_\pi = 2.62$
		$\phi_u = -5.40$	$\phi_u = -4.55$	$\phi_u = -4.38$	$\phi_u = -4.53$

**Table 4:** Taylor rule coefficients in the baseline scenario.

Some of these results simply confirm the results obtained in other studies (e.g. Orphanides and Williams (2007) or Rudebusch and Williams (2006)). Our main contribution is the result that gains from disclosing the path of future interest rates may be substantially lower than those

achieved earlier, when embarking on disclosing macroeconomic projections. Weighted against fears of revealing the future interest rate path, this may explain the reluctance of certain central banks to push their transparency framework that far.



**Figure 1:** Average central bank loss for different values of  $smpl$ ,  $\sigma_{\epsilon_i}$  and  $\lambda_u$

In order to get an insight into the robustness of our results we also run the simulations for different lengths of the past data span  $smpl$  that agents use for learning, different variances of shocks to the interest rate rule  $\sigma_{\epsilon_i}$  and for different weights on unemployment in the central bank loss function  $\lambda_u$ . To enable comparisons, all the remaining parameters were left unchanged at the benchmark scenario values, i.e. during each simulation only the value of  $smpl$ ,  $\sigma_{\epsilon_i}$  or  $\lambda_u$  was altered. The range of  $\sigma_{\epsilon_i}$  spanned from 0.1 to 0.5 with a step of 0.1. In the case of  $\lambda_u$  the domain stretched from 2 to 8 with the step of 2. The  $smpl$  values tested were 25, 50 and 75.

Results of the robustness simulations are presented in Figure 1. In all cases the difference in loss

between **V2cons** or **V2mkt** and **V1** is markedly higher than that between **V3** and **V2cons** or **V2mkt**. This confirms our main finding that the gains central banks have reaped publishing macroeconomic projections are large relative to the remaining gains that can be achieved by additionally showing the interest rate path.

Altering the variance of the monetary policy shock barely changes the value of the loss function. Increasing the sample length *smp* used by agents lowers the central bank loss. This is in line with the intuition that using larger data sets by agents enables them to better approximate the true law of motion of the economy and thus lower central bank loss. Increasing the weight on unemployment in the loss function raises the absolute value of loss but again does not change our main conclusions.

Additionally we checked two alternative Taylor rule settings with the central bank responding to period  $t$  or period  $t+1$  inflation and unemployment. The results remained close to those presented in the text. However, the model with central bank responding to  $t+1$  inflation and unemployment tended to exhibit indeterminacy during the optimisation process in **V2cons**. This may reflect changes in the Taylor principle under learning as described i.a. by Eusepi and Preston (2007).

## 5 Conclusions

In this paper we examined the relative gains from publishing macroeconomic projections and interest rate paths by central banks. Our results were based on a simple three-equation model developed under the assumption of information asymmetry between the public and the central bank. This information gap can be filled either by learning on the side of the public or by publishing forecasts (macroeconomic or interest rate) by the central bank. Our model shows that the gains from publishing the macroeconomic projection dominate the gains from additionally publishing the interest rate path. This, in our opinion, reflects the intuition that it is relatively hard for agents to forecast economic developments. However, once they have a hint on how the economy is expected to move, they can relatively easily guess what will happen to interest rates in the near future.

We think that this may be one of the reasons for why inflation targeting central banks, of which most already publish macroeconomic projections, are relatively reluctant to start publishing interest rate paths. Although we strongly believe that most banks will sooner or later follow the path paved by the Reserve Bank of New Zealand and the Norges Bank and start publishing interest rate projections, this reluctance seems symptomatic to us. It may be a sign that central banks intuitively know what we show formally – that most gains from showing forecast have already been reaped by publishing macroeconomic projections.

Finally, our results show that publishing a macroeconomic projection based on exogenous interest rates expected by the agents (financial markets in the real world) is a better choice than publishing a constant interest rate projection. Consequently, this solution could be adopted by central banks that for some reason do not want to publish their own interest rate forecast.

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## Appendix 1

This appendix presents the state space representation of the model used in the paper:

$$\begin{aligned}\pi_t &= \gamma\pi_{t-1} + (1 - \gamma)\pi_{t+1}^e + \kappa u_t^e + \varepsilon_{\pi,t} \\ u_t &= \delta u_{t-1} + (1 - \delta)u_{t+1}^e + \sigma(i_t^e - \pi_{t+1}^e) + \varepsilon_{u,t} \\ i_t &= \phi_\pi \pi_{t-1} + \phi_u u_{t-1} + \varepsilon_{i,t},\end{aligned}$$

where expectations are assumed to be formed at  $t - 1$ .

The matrix representation of the model is:

$$\Gamma_0 s_t = \Gamma_1 s_{t-1} + \Psi \epsilon_t + \Pi \nu_t \quad (16)$$

where:

- $s$  is the state vector:

$$s_t = [i_t, \pi_t, u_t, \pi_t^1, u_t^1, \pi_t^2, u_t^2, i_t^1]'$$

with  $\pi_t^1$ ,  $u_t^1$  and  $i_t^1$  being artificial variables standing for inflation, unemployment and interest rate in period  $t + 1$  expected at period  $t$  ( $E_t \pi_{t+1}$ ,  $E_t u_{t+1}$ ,  $E_t i_{t+1}$ ), and  $\pi_t^2$ ,  $u_t^2$  standing for inflation and unemployment in period  $t + 2$  expected at period  $t$  ( $E_t \pi_{t+2}$ ,  $E_t u_{t+2}$ ),

- $\epsilon_t = [\epsilon_{i,t}, \epsilon_{\pi,t}, \epsilon_{u,t}]'$  is a vector of shocks,

- $\eta_t = [\eta_t^{\pi_1}, \eta_t^{\pi_2}, \eta_t^{u_1}, \eta_t^{u_2}, \eta_t^{i_1}]'$  is a vector of endogenous expectational errors, as introduced by Sims (2002):

$$\pi_t = \pi_{t-1}^1 + \eta_t^{\pi_1}, \quad \text{where} \quad \pi_t^1 = E_t \pi_{t+1} \quad (17)$$

$$\pi_t^1 = \pi_{t-1}^2 + \eta_t^{\pi_2}, \quad \text{where} \quad \pi_t^2 = E_t \pi_{t+2} \quad (18)$$

$$u_t = u_{t-1}^1 + \eta_t^{u_1}, \quad \text{where} \quad u_t^1 = E_t u_{t+1} \quad (19)$$

$$u_t^1 = u_{t-1}^2 + \eta_t^{u_2}, \quad \text{where} \quad u_t^2 = E_t u_{t+2} \quad (20)$$

$$i_t = i_{t-1}^1 + \eta_t^{i_1}, \quad \text{where} \quad i_t^1 = E_t i_{t+1} \quad (21)$$

- and the matrices  $\Gamma_0$ ,  $\Gamma_1$ ,  $\Psi$  and  $\Pi$  are defined as follows:

$$\Gamma_0 = \begin{pmatrix} i_t & \pi_t & u_t & \pi_t^1 & u_t^1 & \pi_t^2 & u_t^2 & i_t^1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \quad (22)$$

$$\Gamma_1 = \begin{pmatrix} i_{t-1} & \pi_{t-1} & u_{t-1} & \pi_{t-1}^1 & u_{t-1}^1 & \pi_{t-1}^2 & x_{t-1}^2 & i_{t-1}^1 \\ 0 & \phi_\pi & \phi_u & 0 & 0 & 0 & 0 & 0 \\ 0 & (1-\gamma) & 0 & 0 & \kappa & \gamma & 0 & 0 \\ 0 & 0 & (1-\delta) & 0 & 0 & -\sigma & \delta & \sigma \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \quad (23)$$

$$\Psi = \begin{pmatrix} \epsilon_{i,t} & \epsilon_{\pi,t} & \epsilon_{u,t} \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad (24)$$

$$\Pi = \begin{pmatrix} \eta_t^{\pi_1} & \eta_t^{\pi_2} & \eta_t^{u_1} & \eta_t^{u_2} & \eta_t^{i_1} \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \quad (25)$$

This model representation is equivalent to that described by Sims (2002) and can be solved using his algorithm.