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

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Abstract

In a New Keynesian model with asymmetric information we show that publication of macroeconomic projections and of the future interest rate path by the central bank can 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.

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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[1] (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 [2].

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 (Goodhart 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 of more than one member. There is also a

[1] 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*.

[2] See Rudebush and Williams (2007) for a thorough discussion of signalling of policy inclinations.

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 additional 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 then 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.

The gains (and costs) of increasing central bank transparency have been recently widely analysed 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)[3].

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

[3] Comprehensive surveys are provided by Geraats (2002) and van der Cruijsen and Eijfinger (2007).

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. The gains increase with the difficulty to infer the objectives of monetary authorities. 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[4] 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. However, if one assumes that agent's knowledge of the economic model is imperfect[5], 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 banks 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:

$$\pi_t = \gamma\pi_{t-1} + (1-\gamma)\pi^e_{t+1} + \kappa(u^e_t - u^*) + \varepsilon_{\pi,t} \tag{1}$$

$$u_t = \delta u_{t-1} + (1-\delta)u^e_{t+1} + \sigma(i^e_t - \pi^e_{t+1}) + \varepsilon_{u,t} \tag{2}$$

where π 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

[4]See Evans and Honkapohja (2001) and (2007) for introduction and a comprehensive overview of the current literature.

[5]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.

what follows the natural rate of unemployment u^* will be assumed to be zero. The terms ε_π and ε_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 practice of calibrating parameters or even estimating them under the assumption of rational expectations.

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

$$\pi_t = 0.5\pi_{t-1} + 0.5\pi^e_{t+1} - 0.192u^e_t + \varepsilon_{\pi,t} \tag{3}$$

$$u_t = 0.5u_{t-1} + 0.5u^e_{t+1} + 0.036(i^e_t - \pi^e_{t+1}) + \varepsilon_{u,t} \tag{4}$$

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[6]. 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:

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

where ε_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:

$$i_t = 1.5\pi_{t-1} - 2u_{t-1} \tag{6}$$

[6]See Weltz (2006) for derivation and solution of a similar model under this timing assumption.

- 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.

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

In the latter cases the central bank minimizes the discounted sum of losses stemming from variability of inflation, unemployment and interest rates:

$$L_t = \sum_{j=0}^{\infty} \beta^j [\pi_{t+j}^2 + \lambda_u u_{t+j}^2 + \lambda_i (i_{t+j} - i_{t+j-1})^2] \tag{7}$$

For our model we assume $\lambda_u = 4$ and $\lambda_i = 0.25$, which is equivalent to a standard loss function with the weight on inflation and output gap variability being equal and four times higher than the weight on interest rate variability.

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. We thought that it may be unrealistic to assume that agents know the functional form of 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 indeterminancy (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 posses. 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 the true structure of the model driving the economy, the parameters of this model nor the central bank policy rule. Such a setup may be considered to correspond to an opaque central bank who does not share the results of his research on the structure of the economy nor macroeconomic projections with the public. In addition it does not disclose the rule it uses to set interest rates. Like all IT central banks, it reveals to the public the numerical inflation target, and the current policy interest rate. Its projections, models and possible future interest rate paths are kept secret[7].

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 low of motion (PLM):

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

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 80 last observations, i.e. from $t-80$ till $t-1$; the earlier data is simply forgotten by agents.

This VAR is next applied to compute expectations i^e_{t+1}, u^e_{t+1} and π^e_{t+1}. A two period-ahead dynamic forecasts is computed according to:

$$\begin{pmatrix} u^e_t \\ \pi^e_t \\ i^e_t \end{pmatrix} = \mathbf{A} \begin{pmatrix} u_{t-1} \\ \pi_{t-1} \\ i_{t-1} \end{pmatrix} \tag{9}$$

[7]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.

and

$$\begin{pmatrix} u^e_{t+1} \\ \pi^e_{t+1} \\ i^e_{t+1} \end{pmatrix} = \mathbf{A} \begin{pmatrix} u^e_t \\ \pi^e_t \\ i^e_t \end{pmatrix} \tag{10}$$

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^e_t, u^e_t, u^e_{t+1} and π^e_{t+1} 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 π_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 of macroeconomic variables and we refrain from directly using it to construct agents' expectations. In contrast, we consider two alternative solutions:

- the projection can be considered as an additional dataset derived from the central bank's econometric model (which by assumption reflects the ALM of the economy). This dataset may be especially valuable for agents since it is less noisy than macroeconomic data – the only source of variability is the exogenous interest rate path while all shocks are set to zero. Accordingly, we assume that agents append the projection data to the dataset they already possess when estimating the first two equations of the VAR (8) (i.e. with u_t and π_t on the left hand side). Agents do not increase their dataset when estimating the policy rule, since they know that the data for i_t was generated exogenously. Hence, agents act as in **V1** with the only difference that they have a larger dataset. Expectations i^e_t, u^e_t, u^e_{t+1} and π^e_{t+1} are then formed according to (9) and (10),

- in central banking practice, an inherent part of showing macroeconomic projections is the publication of the underlying econometric model. Since these published models usually do not contain monetary policy rules this is equivalent to showing equations 1 and 2 to the agents (at least to those who read central bank working papers). Since agents know the model driving the economy, all they need in addition to build expectations for $t+1$ is the policy rule. Similarly to **V1**, they learn it from past data, which is used to estimate the policy rule:

  $$i_t = \phi_\pi \pi_{t-1} + \phi_u u_{t-1} + v_{i,t} \tag{11}$$

  Estimation is performed by OLS, on an 80-period moving sample in the baseline case.

  Next, agents add the estimated policy rule to the model of the economy published by the central bank ((1) and (2)). Therefore the model (PLM) they use to compute expectations for $t+1$ becomes:

  $$\pi_t = \gamma\pi_{t-1} + (1-\gamma)\pi^e_{t+1} + \kappa u^e_t + \varepsilon_{\pi,t} \tag{12}$$
  $$u_t = \delta u_{t-1} + (1-\delta)u^e_{t+1} + \sigma(i^e_t - \pi^e_{t+1}) + \varepsilon_{u,t} \tag{13}$$
  $$i_t = \hat{\phi}_\pi \pi_{t-1} + \hat{\phi}_u u_{t-1} + \varepsilon_{i,t} \tag{14}$$

where estimates of parameters, obtained through learning, are denoted with hats: $\hat{\phi}_\pi$ and $\hat{\phi}_u$. The model is solved under rational expectations, given the data for period $t-1$, and the solution is used to obtain i_t^e, u_t^e, u_{t+1}^e and π_{t+1}^e.

Obviously, following these two approaches leaves the agents with different forecasts and results in different ALMs. Intuitively publication of the model is more valuable than only increasing the dataset, so the choice of the approach must matter for our results. It seems unlikely that all agents read the central bank's publication, but certainly some do. Moreover, their reading is often shared with the rest of the population in form of private forecasts (e.g. published by commercial banks). Accordingly, we decided to construct the aggregate agents' forecast as a weighted average of forecatst from the two above approaches (as in Muto 2008):

$$x_t^e = px_{p,t}^e + (1-p)x_{m,t}^e \tag{15}$$

where x_t^e is the aggregate private sector forecast of the variable x_t, $x_{p,t}^e$ stands for the forecast based on additional projection data and $x_{m,t}^e$ denotes the forecast based on knowing the model (i.e. (1) and (2)). Having no direct measure of p we decided to take a conservative approach and assumed for our benchmark specification that only 20% of agents know the model while 80% use the projection to augment their dataset (i.e. $p = 0.8$). We check the robustness of our results for different values of p.

The third variant **V3** assumes full knowledge on the side of economic agents. This setup, with no asymmetric information, may be regarded as referring to a central bank publishing its forecasted path of future policy rates together with a macroeconomic forecast conditional on this path. 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**.

As in **V2**, it is assumed that the central bank has full and correct knowledge of the economy and the model it uses and publishes, consisting of equations (1), (2) and (5), indeed depicts the actual law of motion of the economy.

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

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 π, u and i are computed. We take $T_{sim} = 100,000$, and burn the first $b = 1000$ initial, for we consider them being too much dependent on initial conditions.

	V1	**V2**	**V3**
central bank knows:	IS equation Philips curve policy rule	IS equation Philips curve policy rule	IS equation Philips curve policy rule
public knows:	—	Fraction $(1-p)$: IS equation, Philips curve Fraction p: projection (additional data for estimation)	IS equation Philips curve policy rule

Table 1: Information structure applied in the model

We analyse three simulation cases, each with different policy rule coefficients, according to the classification presented in section 2. The first one assumes Taylor rule coefficients at standard values of $\phi_\pi = 1.5$ and $\phi_u = -2$ and is denoted by STR. In the second case, denoted by RETR, the average central bank loss is first minimized subject to policy rule coefficients over the entire simulation span and under the assumption of agents following rational expectations (variant **V3**). The policy rule with optimal coefficients for this variant is next applied in simulations for two remaining variants **V1** and **V2**. In the third case, OTR, the most complex one, Taylor rule coefficients are chosen for each variant separately so that they minimize the average central bank loss.

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 β^h is insignificantly different from zero[8] for higher values of h. So, the central bank loss in period t is computed as:

$$L_t = \sum_{j=1}^{h} \beta^j (\pi_{t+j}^2 + \lambda_u u_{t+j}^2 + \lambda_i (i_{t+j} - i_{t+j-1})^2) \tag{16}$$

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

$$\min_{\phi_u, \phi_\pi} AL = \min_{\phi_u, \phi_\pi} \frac{1}{T_{sim} - b - h} \sum_{t=b+1}^{T_{sim}-h} L_t \tag{17}$$

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

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 *smpl* stretches over 80-periods (20 years), which corresponds[9] to the perpetual learning gain $\kappa = 0.0125$. Orphanides and Williams (2007) find that $\kappa \in (0.01, 0.04)$ perform best in modelling SPF expectations. They also report that this value is in line with Sheridan's (2003) analysis of expectations from the Livingston Survey data. For the sake of robustness, we also analyse different values of *smpl*, ranging from 40 to 160. In the process of learning, the regressions run by agents are tested for stationarity. Should this test be breached,

[8] We take $\beta = 0.99$. Then $\beta^{500} \approx 0.006$

[9] $\kappa = \frac{1}{t}$ under least squares learning with infinite memory

the models' coefficients used to produce expectations 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 summarized in Table 2:

$smpl = 80$	$p = 0.8$	$\gamma = 0.5$
$\kappa = -0.192$	$\delta = 0.5$	$\sigma = 0.036$
$\sigma_{\epsilon_\pi} = 1.11$	$\sigma_{\epsilon_u} = 0.29$	$\sigma_{\epsilon_i} = 0.22$
$\beta = 0.99$	$b = 1000$	$Tsims = 100,000$
$h = 500$	$\lambda_u = 4$	$\lambda_i = 0.25$

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:

$$G_{i/j} = -(\frac{AL_i}{AL_j} - 1) \tag{18}$$

where $G_{i/j}$ stands for gain in 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 while moving from West to East in the Table 3 for any policy rule. This indicates that adopting further transparency stages pays off.
- In all cases, gains for **V2** vs. **V1** are much higher than for **V3** vs. **V2**. 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 optimized policy rule (OTR) publication of conditional forecast improves central bank loss by 17.72 per cent compared to improvement of only 2.61 per cent following the publication of unconditional path of future interest rates.
- Comparison of central bank losses under the rule optimized for rational expectations (RETR) and the optimized rule (OTR) confirms that the central bank can benefit from optimizing the policy rule coefficients subject to the agents' actual information. For example, compare the loss for **V1** under RETR (AL = 121.62) and OTR (AL = 95.81) – applying the rule optimized under the assumption of agents following rational expectations for the asymmetric information case **V1** can end up with disappointing results. Indeed, even the standard Taylor rule STR performs better in this case (AL = 95.85). Thus central banks should consider redefining policy rules they follow when moving along the ladder of transparency stages.

Case	nick	Loss V1	V2	V3	Gain (in per cent) **V2** vs. **V1**	**V3** vs. **V2**
Standard Taylor rule	STR	95.85	82.83	80.92	13.59	2.30
rule optimized for RE (variant V3)	RETR	121.62	78.83	76.77	35.18	2.62
optimized rule	OTR	95.81	78.83	76.77	17.72	2.61

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

- The coefficients on inflation and unemployment in policy rule decrease[10] along the W-E direction for the case of optimized policy (OTR) (Table 4). This can be interpreted as a need to limit the necessary degree of central bank responsiveness once agents get more information on the economy and central bank preferences, ie. when transparency increases. Such a result is consistent with the concept of using the central bank communication channel as support to other transmission channels.

Case	nick	Variant V1	V2	V3
Standard Taylor rule	STR	$\phi_\pi = 1.5$ $\phi_u = -2$	$\phi_\pi = 1.5$ $\phi_u = -2$	$\phi_\pi = 1.5$ $\phi_u = -2$
rule optimized for RE (variant V3)	RETR	$\phi_\pi = 1.16$ $\phi_u = -1.47$	$\phi_\pi = 1.16$ $\phi_u = -1.47$	$\phi_\pi = 1.16$ $\phi_u = -1.47$
optimized rule	OTR	$\phi_\pi = 1.48$ $\phi_u = -1.92$	$\phi_\pi = 1.17$ $\phi_u = -1.45$	$\phi_\pi = 1.16$ $\phi_u = -1.47$

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 Rudebush and Williams (2006)). Our main contribution is the result that gains from disclosing the path of future interest rate by central banks that have already engaged in publishing macroeconomic projections may be lower than those achieved after embarking on disclosing macro-projections and macromodels they are based on. Weighted against fears of revealing future interest rate path, this may explain the reluctance of certain central banks to push their transparency framework that far.

To get an insight about the robustness of our results we also run the simulations for different lengths of the past data span *smpl* that agents use for learning, for different fractions p of agents using macroeconomic projections published by the central to estimate the model and also for different variances of shocks to the interest rate rule σ_{ϵ_i}. 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*, p or σ_{ϵ_i} was altered. The range of *smpl* under analysis spanned from 40 to 160

[10] With the exception of coefficient on unemployment in **V2** vs. **V3**. But the difference between the two is tiny and may stem from random fluctuations in numerical simulations we perform.

with a step of 20. In case of p, the domain stretched from 0 to 1, with a 0.2 step, and for σ_{ϵ_i} we used the values of 0.1, 0.22 (benchmark), 0.3, 0.4 and 0.5.

Results of simulations[11] are depicted in Figures 1, 2 and 3. As the sample length *smpl* used by agents rises the central bank loss tends to be lower. 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. As regards the fraction p, the more agents have to resort to the macroeconomic projections published by the central, the higher the values of central bank loss and the higher the gain from disclosing the interest rate path. On the other hand it is worth noting that showing the IS and PC curves to the agents ($p = 0$) is almost equivalent to V3. The additional gains from publishing the interest rate path become negligible in this case, which reflects the fact the sole estimation of the Taylor rule is relatively unproblematic. A rising variance of the monetary policy shock σ_{ϵ_i} leads to higher values of average central bank loss, which again is consistent with intuition. However, in all cases the difference between V1 and V2 remains substantially larger than the difference between V2 and V3. This confirms our main finding that the gains central banks have reaped publishing macroeconomic projections are very large relative to the remaining gains that can be achieved by additionally showing the interest rate path.

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.

[11] We also 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, these models tended to exhibit indeterminancy during the optimization process in **V2**. This may reflect changes in the Taylor principle under learning as described i.a. by Eusepi and Preston (2007).

This work leaves a number of issues open for further investigation. One relates to the question how to best model the additional knowledge that agents get from the central banks macroeconomic projections. This may require additional studies on the information content of central bank projections.

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Appendix 1

Below we present the results of robustness checks.

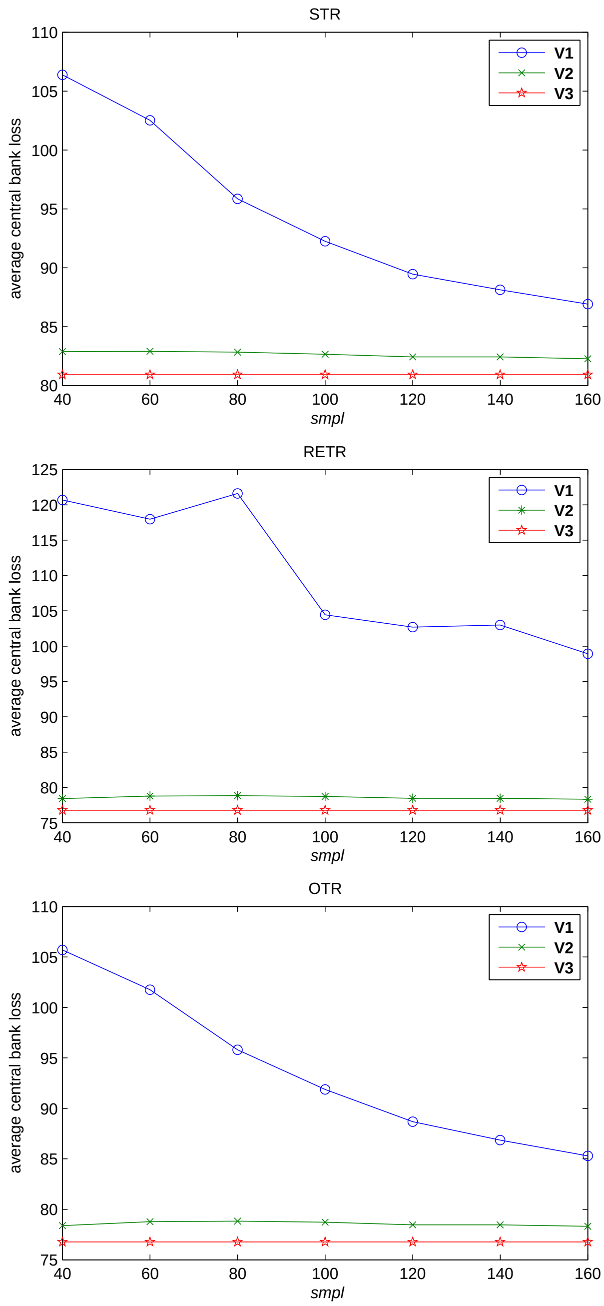

Figure 1: Average central bank loss for different values of *smpl* under various monetary policy rules.

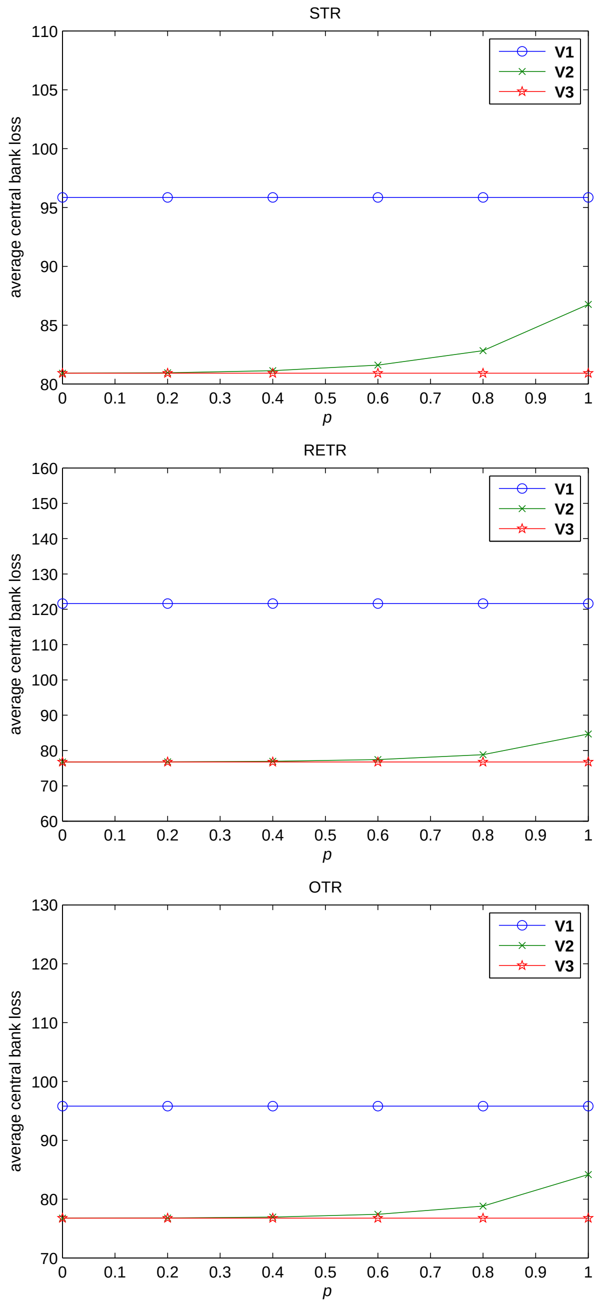

Figure 2: Average central bank loss for different values of p under various monetary policy rules.

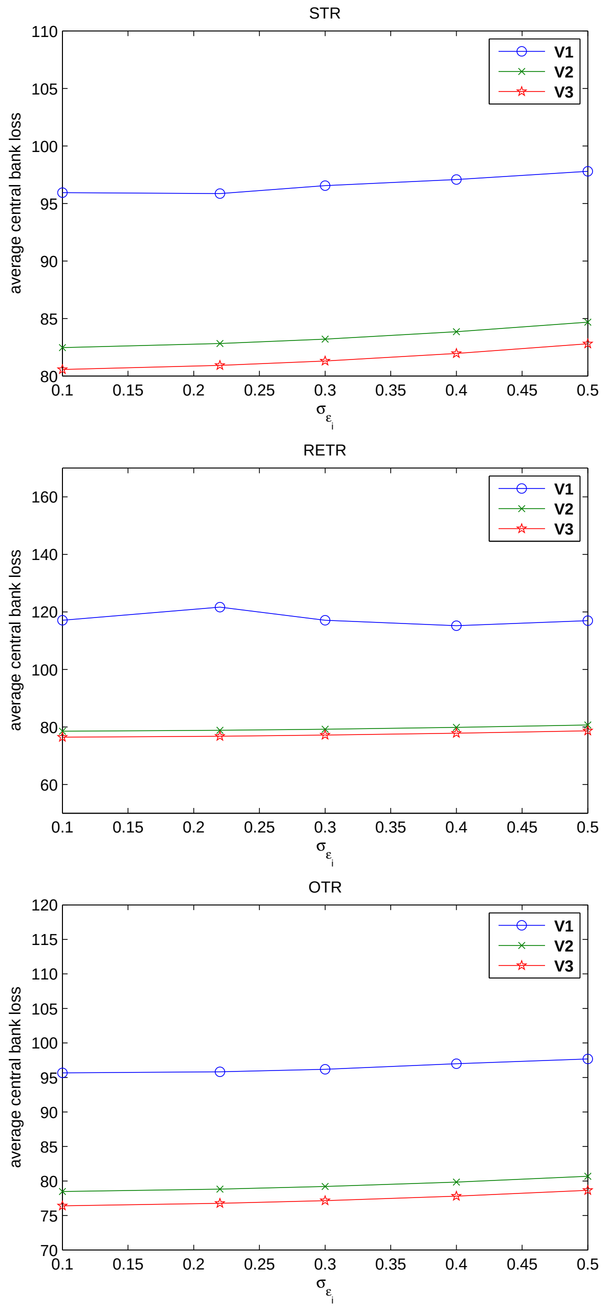

Figure 3: Average central bank loss for different values of σ_{ϵ_i} under various monetary policy rules.

Appendix 2

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

$$\pi_t = \gamma\pi_{t-1} + (1-\gamma)\pi^e_{t+1} + \kappa u^e_t + \varepsilon_{\pi,t}$$

$$u_t = \delta u_{t-1} + (1-\delta)u^e_{t+1} + \sigma(i^e_t - \pi^e_{t+1}) + \varepsilon_{u,t}$$

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

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

The matrix representation of the model is:

$$\Gamma_0 s_t = \Gamma_1 s_{t-1} + \Psi\epsilon_t + \Pi\nu_t \tag{19}$$

where:

- s is the state vector:

  $$s_t = [i_t, \pi_t, u_t, \pi^1_t, u^1_t, \pi^2_t, u^2_t, i^1_t]',$$

  with π^1_t, u^1_t and i^1_t being artificial variables standing for inflation, unemployment and interest rate in period $t+1$ expected at period t ($E_t\pi_{t+1}$, E_tu_{t+1}, E_ti_{t+1}), and π^2_t, u^2_t standing for inflation and unemployment in period $t+2$ expected at period t ($E_t\pi_{t+2}$, E_tu_{t+2}),

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

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

$$\pi_t = \pi^1_{t-1} + \eta^{\pi_1}_t, \qquad \text{where} \qquad \pi^1_t = E_t\pi_{t+1} \tag{20}$$

$$\pi^1_t = \pi^2_{t-1} + \eta^{\pi_2}_t, \qquad \text{where} \qquad \pi^2_t = E_t\pi_{t+2} \tag{21}$$

$$u_t = u^1_{t-1} + \eta^{u_1}_t, \qquad \text{where} \qquad u^1_t = E_tu_{t+1} \tag{22}$$

$$u^1_t = u^2_{t-1} + \eta^{u_2}_t, \qquad \text{where} \qquad u^2_t = E_tu_{t+2} \tag{23}$$

$$i_t = i^1_{t-1} + \eta^{i_1}_t, \qquad \text{where} \qquad i^1_t = E_ti_{t+1} \tag{24}$$

- and the matrices Γ_0, Γ_1, Ψ and Π are defined as follows:

$$\Gamma_0 = \begin{pmatrix} i_t & \pi_t & u_t & \pi^1_t & u^1_t & \pi^2_t & u^2_t & i^1_t \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \tag{25}$$

$$
\Gamma_1 = \begin{pmatrix}
i_{t-1} & \pi_{t-1} & u_{t-1} & \pi^1_{t-1} & u^1_{t-1} & \pi^2_{t-1} & x^2_{t-1} & i^1_{t-1} \\
0 & \phi_\pi & \phi_u & 0 & 0 & 0 & 0 & 0 \\
0 & (1-\gamma) & 0 & 0 & \kappa & \gamma & 0 & 0 \\
0 & 0 & (1-\delta) & 0 & 0 & -\sigma & \delta & \sigma \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
\end{pmatrix} \tag{26}
$$

$$
\Psi = \begin{pmatrix}
\epsilon_{i,t} & \epsilon_{\pi,t} & \epsilon_{u,t} \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
\end{pmatrix} \tag{27}
$$

$$
\Pi = \begin{pmatrix}
\eta_t^{\pi_1} & \eta_t^{\pi_2} & \eta_t^{u_1} & \eta_t^{u_2} & \eta_t^{i_1} \\
0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 1 \\
\end{pmatrix} \tag{28}
$$

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