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Interest Rate Forecasts in Inflation Targeting Open-Economies

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1 Introduction

It is well known that the Central Bank decision on the short term interest rate is of little significance for future inflation and resource utilization. Indeed, this decision fixes the cost of money only for few weeks and therefore has a minor impact on the intertemporal choices of the private sector underlying the aggregate demand, resource utilization and, finally, inflation. What matters, instead, are the expectations of the entire path for the short term interest rate, which determine the long term rate. Forecasting the interest rate path or, equivalently, future policy decisions, is therefore an important task routinely performed by both the private sector and central banks. This is well documented, for example, by the attitude of an increasing number of central banks (Sveriges Riksbank, Norges Bank, Reserve Bank of New Zealand, Czech National Bank) to report on their home pages the expected interest rate path as the key figure.

It is also well known that which inflation index to choose in an inflation targeting economy matters for reasons related to economic determinacy and welfare as argued, among others, by Corsetti-Dedola-Leduc (2010), Gali-Monacelli (2005), Levine-Pearlman (2005), Mankiw-Reis (2003), and Svensson (2000).

Prompted by these observations, this work studies the relation between the forecasting accuracy for the interest rate path and the choice of a target inflation index in a small open-economy. The focus is on the choice between the domestic price index and the consumer price index (CPI). These indexes differ in that the former refers to the goods produced domestically while the latter to both the goods produced domestically and imported. The investigation is framed in a New Keynesian model where the central bank finds the optimal monetary policy minimizing the current and expected variability of inflation and resource utilization. To capture the multisector feature of open economies, the model has two supply sectors: one that produces and retails domestic goods, and the other that imports and retails foreign good. These sectors

are related in that import goods are used in the production of domestic goods, and domestic goods are used to retail foreign goods.

The previous literature examined the choice of the target inflation index mostly from the welfare standpoint and assuming that the central bank knows the model of the economy. Svensson (2000) and Corsetti-Dedola-Leduc (2010), adopting alternative welfare measures and assuming model certainty, provide interesting results which highlights the role played by the Direct Exchange Rate channel in the monetary policy transmission mechanism (i.e. the possibility to affect directly CPI inflation via the exchange rate and therefore the price of the imports in domestic currency), and the role played by the exchange rate pass-through. Letting the welfare measure focusing on output volatility, Mankiw-Reis (2003) consider a static and closed economy with model certainty and establish some criteria that, remarkably, when applied to an open economy question the choice of CPI inflation as a target inflation index.

With respect to the previous literature this paper particularly differs as relaxes the strong assumption of model certainty. Allowing for model uncertainty captures the fact that limited knowledge on the correct model of the economy poses difficult challenges to real-world monetary policy decisions. Importantly, when model uncertainty is considered, the impact of an exogenous shock hitting the economy does no longer lead to a *mean forecast* of the macrovariables, i.e. to an impulse response function. In fact, once model uncertainty is taken on board, the shock gives rise to a *distribution forecast* of the macrovariables; put it differently, at each future point in time, we have a distribution of possible responses to the shock. In the current paper, model uncertainty is introduced in the analysis along with exogenous shocks. This allows measuring forecast accuracy for the interest rate path in terms of the volatility of its distribution forecasts under the two alternative price indexes.

Although the current work does not abstract from welfare considerations, the main contribution to the literature lies in showing that the choice of the target inflation index has an important impact on interest rate forecast accuracy. Forecast accuracy cannot be directly related to welfare, yet plays a key role in the inflation targeting operating procedure in use at central banks (Svensson 2010). Thus, the relation between interest rate forecast accuracy and the choice of the target inflation index appears as a novel further dimension to discuss the choice of the target inflation index. In particular, the main result of the paper that choosing domestic inflation as the target inflation index instead of CPI inflation can increase interest rate forecast accuracy introduces a new consideration in the recent debate on the convenience of publishing the central bank interest rate forecast¹.

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Regarding this debate see for example Svensson (2008) and Holmsen-Qvigstad-Røisland-Solberg-Johansen

Indeed, the possibility to increase the forecasting accuracy for the interest rate through the choice of the inflation index augments the accountability of the central bank if the central bank discloses this important piece of information. More accountability, in turn, can foster the credibility of the central bank if, ex post, forecasts and actual values differ only due to unexpected shocks. Finally, more credibility enhances the central bank ability to shape the expectations of the private sector. Interesting for policy purposes, this suggests that under domestic inflation targeting there are larger benefits associated with the publication of the distribution forecasts for the interest rate and the related distribution forecasts for inflation and resource utilization.

The plan of the paper is as follows. Section 2 presents the model. Section 3 presents and describes the results using impulse distribution forecasts, standard deviations and optimal monetary policies under alternative central bank inflation indexes. Section 4 discusses the paper's findings in relation to transparency in monetary policy and the publication of future policy intentions. Conclusions are in section 5.

2 The model

The model of the economy draws on Flamini (2007) and is based on a continuum of consumers/producers indexed by $j \in [0, 1]$ sharing the same preferences and living forever in a two-sector economy². Intertemporal utility for the representative household is given by

$$(1) \quad E_t \sum_{\tau=0}^{\infty} \delta^{\tau} U(C_{t+\tau}, \check{C}_{t+\tau-1}),$$

where δ is the intertemporal discount factor, C_t is total consumption of household j , and \check{C}_t is the total aggregate consumption. Preferences over total consumption feature habit formation which is modeled as in Abel (1990) by the following instantaneous utility function

$$(2) \quad U(C_{t+\tau}, \check{C}_{t+\tau-1}) = \frac{(C_{t+\tau}/\check{C}_{t+\tau-1}^{\iota})^{1-\frac{1}{\sigma}}}{1 - \frac{1}{\sigma}},$$

where $\iota \geq 0$ captures habit persistence and $\sigma > 0$ is the intertemporal elasticity of substitution. Total consumption, $C_t \equiv C_t^{d(1-w)} C_t^{iw}$, is a Cobb-Douglas function of domestic good consumption (2008).

²A terse description of the private sector behaviour is reported here as it allows a clear presentation of the *model uncertainty* considered by the central bank and modeled in sections 2.2. For details on the derivation of the structural relations see Flamini (2007).

tion, C_t^d , and import good consumption, C_t^i , where w determines the steady state share of imported goods in total consumption and C_t^d, C_t^i are Dixit-Stiglitz aggregates of continuum of differentiated domestic goods and import goods (henceforth indexed with d and i respectively). Domestic and import goods are supplied by a domestic and import sector, respectively, which are described below.

The flow budget constraint for consumer j in any period t is given by

$$\frac{B_t}{1 + I_t} + \frac{B_t^*}{1 + I_t^*} S_t + P_t^c C_t = B_{t-1} + B_{t-1}^* S_t + D_t^d + D_t^i,$$

where B and B^* are two international bonds issued on a discount basis and denominated in domestic and foreign currency with interest rates I_t and I_t^* respectively, S_t is the nominal exchange rate, expressed as home currency per unit of foreign currency. D_t^d and D_t^i are the dividends distributed by the domestic and the import sector and, finally, P^c is the overall Dixit-Stiglitz price index for the minimum cost of a unit of C_t and is given by

$$(3) \quad P_t^c = \frac{P_t^{i^w} P_t^{d^{(1-w)}}}{w^w (1-w)^{(1-w)},}$$

with P^d, P^i denoting, respectively, the Dixit-Stiglitz price index for goods produced in the domestic and import sector.

Utility maximization subject to the budget constraint and the limit on borrowing gives the Euler equation and the uncovered interest rate parity, respectively

$$(4) \quad c_t = \beta c_{t-1} + (1 - \beta) c_{t+1|t} - (1 - \beta) \sigma \left(i_t - \pi_{t+1|t}^c \right), \quad \beta \equiv \frac{\iota(1 - \sigma)}{1 + \iota(1 - \sigma)} < 1,$$

$$(5) \quad i_t - i_t^* = s_{t+1|t} - s_t,$$

where for any variable x , the expression $x_{t+\tau|t}$ stands for the rational expectation of that variable in period $t + \tau$ conditional on the information available in period t and, by means of a log-linearization, the variables c_t, π_t^c, i_t, i_t^* , and $(s_{t+1|t} - s_t)$ are log-deviations from their respective constant steady state values; finally, c_t denotes total aggregate consumption, obtained considering that in equilibrium total consumption for agent j is equal to total aggregate consumption, i.e. $C_t = \check{C}_t$, and π_t^c denotes CPI inflation (measured as the log deviation of gross CPI inflation from the constant CPI inflation target).

Since we have Dixit-Stiglitz aggregate of domestic and import goods, the demand for variety

j is

$$(6) \quad Y_t^h(j) = \widehat{Y}_t^h \left(\frac{P_t^h(j)}{P_t^h} \right)^{-\vartheta}, \quad h = d, i$$

where $P_t^h(j)$ is the nominal price for variety j in sector h and ϑ is the elasticity of substitution between different varieties.

While both supply sectors feature a continuum of unit mass of firms, indexed by j , that produce differentiated goods $Y_t^d(j)$ and $Y_t^i(j)$ in the domestic and import sector respectively, the two sectors differ for the input used: the domestic sector uses a composite input consisting of the domestic (composite) good itself and the (composite) import good provided by the import sector; the import sector uses a composite input consisting of the foreign good Y_t^* and the domestic (composite good). Furthermore, to capture the real-world feature that production inputs tend to be rigid at business cycle frequency, sectors are assumed to use a Leontief technology. Thus, the production functions in the domestic and import sector are given respectively by

$$(7) \quad Y_t^d(j) = f \left[\min \left\{ \frac{Y_t^{d,d}}{1-\mu}, \frac{Y_t^{i,d}}{\mu} \right\} \right], \quad Y_t^i(j) = f \left[\min \left\{ \frac{Y_t^*}{1-\mu^i}, \frac{Y_t^{d,i}}{\mu^i} \right\} \right], \quad \mu, \mu^i \in [0, 1],$$

where f is an increasing, concave, isoelastic function, $Y_t^{d,d}$, $Y_t^{d,i}$ denote the quantity of the (composite) domestic good which is used as an input in the domestic sector, as an input in the import sector and which is demanded by the foreign sector, respectively. $(1-\mu)$ and μ denote, respectively, the shares of the domestic good and import good in the composite input required to produce the differentiated domestic good j , and $(1-\mu^i)$ and μ^i denote, respectively, the shares of the foreign good and domestic good in the composite input required to provide the differentiated import good j . It is worthy of note that μ^i determine the degree of completeness of the pass-through: when $\mu^i = 0$ the exchange rate pass-through is complete as no domestic goods are used to retail the foreign goods and therefore a change in the exchange rate passes completely through to the domestic currency price of the imports. In contrast, when $\mu^i > 0$, μ^i determines the percentage of the price of the imports that depends on the domestic goods and therefore is shielded from exchange rate movements.

Given this production structure, aggregate demand for the good produced in the domestic sector is

$$(8) \quad \widehat{Y}_t^d = C_t^d + Y_t^{d,d} + Y_t^{d,i} + C_t^{*d},$$

where $Y_t^{d,d}$, $Y_t^{d,i}$ and C_t^{*d} denote the quantity of the (composite) domestic good which is used as an input in the domestic sector, as an input in the import sector and which is demanded by

the foreign exogenous sector, respectively. Aggregate demand for import goods is given by

$$(9) \quad \widehat{Y}_t^i = C_t^i + Y_t^{i,d},$$

where $Y_t^{i,d}$ denotes the amount of the import good used as an input in the domestic sector.

Turning to the behaviors of the producers, any firm j at time t finds the price that maximizes the expected discounted flow of profits assuming that this price cannot be changed in the next periods with a probability α according to the Calvo (1983) staggered price model and that in the periods in which the price cannot be updated optimally it is indexed to previous inflation with the indexation rate ζ (Christiano-Eichenbaum-Evans (2005) and Smets-Wouters (2003)). Then, accounting for its own demand function given by (6), each producer solves the following problem

$$(10) \quad \max_{\widetilde{P}_{t+g}^h} E_t \sum_{\tau=0}^{\infty} (\alpha^h \delta)^\tau \widetilde{\lambda}_{t+\tau+g}^h \left\{ \frac{\widetilde{P}_{t+g}^h \left(\frac{P_{t+\tau+g-1}^h}{P_{t+g-1}^h} \right)^\zeta}{P_{t+g+\tau}^h} \widehat{Y}_{t+g+\tau}^h \left[\frac{\widetilde{P}_{t+g}^h \left(\frac{P_{t+\tau+g-1}^h}{P_{t+g-1}^h} \right)^\zeta}{P_{t+g+\tau}^h} \right]^{-\vartheta} - \frac{W_{t+\tau+2}^h}{P_{t+\tau+2}^h} f^{-1} \left[\widehat{Y}_{t+\tau+2}^h \left(\frac{\widetilde{P}_{t+2}^h \left(\frac{P_{t+\tau+g-1}^h}{P_{t+g-1}^h} \right)^\zeta}{P_{t+2+\tau}^h} \right)^{-\vartheta} \right] \right\}, \quad \text{for } h = d, i$$

where δ is set equal to one to ensure the natural-rate hypothesis and $\widetilde{\lambda}_t^h$, W_t^h and \widetilde{P}_{t+g}^h denote, respectively, the marginal utility of h-sector goods, the price of the composite input and the new price chosen in period t for period $t+g$.

In the current model $g = 2$ ($g = 0$) when (10) refers to the domestic (import) sector so that price are predetermined two periods in the domestic sector but not in the import sector. This difference is motivated by the fact that supplying domestic goods involves first producing and then retailing these goods, while supplying import goods consists of importing and retailing foreign goods. Hence, this feature of the actual sectoral supplies is well captured by the assumption that firms in the domestic sector have to decide in the current period the price that will be effective in two-period time, whereas firms in the import sector do not need to set their price before they take effect.

Before moving to the loglinearized version of the model, it is worth noting that α^i in the import sector captures the speed of the pass-through³.

³About the relevance of the speed and the degree of completeness of the pass-through, respectively, α^i and μ^i , in the determination of low exchange rate pass-through found in the industrialized economies, see Devereux-Yetman (2008), Burstein-Neves-Rebelo (2003) and Corsetti-Dedola (2005).

2.1 Loglinearized model for the private sector behavior

Maximizing the preferences of the household leads to three nonlinear structural relations: an aggregate demand, both for the domestic and import sector, and an uncovered interest rate parity condition. Loglinearizing the first two relations around the steady state results in

$$(11) \quad y_{t+1}^d = \beta_y y_t^d - \beta_\rho \rho_{t+1|t} + \beta_q q_{t+1|t} - \beta_{q-1} q_t + \beta_{y^*} y_t^*,$$

$$(12) \quad y_{t+1}^i = \beta_y y_t^i - \beta_\rho^i \rho_{t+1|t} - \beta_q^i q_{t+1|t} + \beta_{q-1}^i q_t + \beta_{y^*}^i y_t^*,$$

which are the aggregate demand in the domestic and import sectors expressed in terms of the output-gap, a natural measure of resource utilization⁴, where lower-case letters denote the log-deviations from steady state values, $\rho_t \equiv \sum_{\tau=0}^{\infty} (i_{t+\tau|t} - \pi_{t+\tau+1|t}^d)$ can be interpreted as the long real interest rate, $q_t \equiv p_t^i - p_t^d$ is the terms of trade, and y_t^* is the foreign good. In (11-12) all the coefficients are positive and functions of the structural parameters of the model. Regarding the uncovered interest rate parity, since it is convenient to express the log-linearized version of this relation in terms of the real price of the input in the import sector, we now move to the production side of the economy and return afterwards to the uncovered parity. Hence, solving the firm's problem described by (10) leads to a nonlinear aggregate supply in both sectors which loglinearized around the steady state results in

$$(13) \quad \pi_{t+2}^d = \phi_\pi \pi_{t+1}^d + (1 - \phi_\pi) \pi_{t+3|t}^d + \phi_y^d y_{t+2|t}^d + \phi_q^d q_{t+2|t} + \varepsilon_{t+2},$$

for the domestic sector, where ε_{t+2} is a zero-mean i.i.d. cost-push shock, and

$$(14) \quad \pi_t^i = \phi_\pi \pi_{t-1}^i + (1 - \phi_\pi) \pi_{t+1|t}^i + \phi_y^i y_t^i + \phi_q^i q_t^i,$$

for the import sector, where q_t^i denotes the real price of the composite input in the import sector and is defined as

$$(15) \quad q_t^i \equiv (1 - \mu^i) (s_t - p_t^*) + \mu^i p_t^d - p_t^i.$$

In (13) and (14) all the implicitly defined coefficients are positive. Finally, having introduced the real price of the composite input in the import sector, the loglinearized version of the uncovered

⁴The output-gap y_t^h is defined as

$$y_t^h \equiv \hat{y}_t^h - y^{h,n}, \quad h = d, i$$

where $y^{h,n}$ denotes the natural output which is assumed to be constant.

interest rate parity can be expressed as

$$(16) \quad q_{t+1|t}^i - q_t^i = \varphi r_t - \varphi \left(i_t^* - \pi_{t+1|t}^* \right) - \left(\pi_{t+1|t}^i - \pi_{t+1|t}^d \right),$$

where r_t is the short term real interest rate defined as $r_t \equiv i_t - \pi_{t+1|t}^d$ and $\varphi \equiv 1 - \mu^i$.

As to the rest of the world, exogenous stationary univariate AR(1) processes describe inflation and the output-gap and monetary policy is conducted according to a Taylor rule⁵.

Having described the private sector behavior, the model is closed with the central bank preferences which are modeled by the following loss function:

$$(17) \quad E_t \sum_{\tau=0}^{\infty} \beta^\tau \left[\mu^c \pi_{t+\tau}^c{}^2 + \mu^d \pi_{t+\tau}^d{}^2 + \lambda y_{t+\tau}^d{}^2 + \nu (i_{t+\tau} - i_{t+\tau-1})^2 \right],$$

where $\pi_t^c = (1 - w) \pi_t^d + w \pi_t^i$ denotes CPI-inflation and μ^c , μ^d , λ and ν are weights that express the preferences of the central bank for the CPI and domestic inflation targets, the output stabilization target, and the instrument smoothing target, respectively⁶. Focusing on the more realistic flexible inflation targeting scenario, the choice of CPI inflation as the target index implies that $\mu^c = 1$, $\mu^d = 0$, $\lambda = 0.5$ while the choice of domestic inflation as the target index implies that $\mu^c = 0$, $\mu^d = 1$, $\lambda = 0.5$; in both cases, $\nu = 0.003$.

It is worth noting that the optimal monetary policy New Keynesian literature describes the central bank loss function either directly in terms of volatility for inflation, output gap and first difference of the interest rate, or in terms of a quadratic approximation of the utility function of the household⁷. The first way bears the advantage to be operational in that does not depend on the specific assumptions of the model (e.g. household preferences, inflation inertia, habit persistence, predetermined pricing decisions) and it is consistent with the inflation targeting operating procedure adopted in several central banks. Describing this procedure, first the staff computes alternative distribution forecasts associated with different interest rate paths minimizing a standard loss function of the type of expression (17). These optimal distribution forecasts are constructed by varying the weights and/or the discount factor in the loss function. Then the Board selects the policy associated with the specific distribution forecast that suits best its preferences. The current work focuses on the accuracy of the interest rate distribution forecasts, which is meant to be important in the central bank decision process just described and, possibly, also in the communication with the private sector if the central bank decides to disclose this information. For this reason central bank preferences are modeled via a standard

⁵Since the analysis focuses on the cost-push shock, it is not necessary to specify the coefficients of the law of motion for the rest of the world.

⁶Regarding the interest rate smoothing component in the loss function see Holmsen-Qvigstad-Røisland-Solberg-Johansen (2008) and Flamini-Fracasso (2011).

⁷See for example Svensson (2000, 2010) for the former and Corsetti-Dedola-Leduc (2010) for the latter.

loss function⁸.

2.2 *Optimal monetary policy with model uncertainty*

Central banks are called to take policy decisions in an uncertain world. A substantial part of this uncertainty stems from a limited knowledge on the structural behavior of the private sector, what is called model uncertainty. A natural approach to capture model uncertainty is to let the central bank have a limited knowledge on the structural parameters of the model⁹. In the New Keynesian literature, the basic structural parameters have been estimated and/or calibrated in several works and for some of them the results exhibit great variation. This happens, in particular, for the degree of habit persistence in the utility of the household, the degree of price stickiness, the level of indexation in pricing decisions, and the speed and incompleteness of the exchange rate pass-through¹⁰. It is worth recalling that the loglinearized aggregate demand and supply (11-14), along with the uncovered interest parity (16), are derived from the optimal conditions that solve the problem of the representative household and firm. This implies that when a parameter in the preferences or the constraints is uncertain, then several coefficients of the loglinearized relations associated to that parameter, in turn, are uncertain. This is shown in Table 1 which reports for each structural parameter the composite coefficients depending on that parameter and indicates the pervasive impact that few uncertain structural parameters have on the loglinearized version of the model.

[INSERT TABLE 1 HERE]

Before turning to the minimization of the central bank loss function subject to the equations that describe the private sector behavior we need to specify the limited knowledge of the central bank on these structural parameters. A conservative assumption is that the central bank knows only the range of the parameters and that the parameters are independent. This assumption is modeled with independent uniform distributions, for example for μ^i a benchmark value is chosen, $\overline{\mu^i}$, and the upper and lower bound of the support of the distribution are set equal to

$$(18) \quad \overline{\mu^i} \pm x\overline{\mu^i},$$

⁸Holmsen-Qvigstad-Røisland-Solberg-Johansen (2008) in section 4.2.2 describe accurately this operating procedure adding at p. 22 that “From the point of view of the staff, the loss function and its relative weights are meant to represent the preferences of the Board. This is in contrast to much of the recent monetary policy literature, where the loss function approximates the utility loss of the representative consumer”.

⁹See, among the others, Estrella-Mishkin (1999), Flamini-Milas (2011), Söderström (2002), and Kimura-Kurozumi (2007).

¹⁰See Kimura-Kurozumi (2007) as to the contrasting results disseminated in the literature; on the variability of the exchange rate pass-through see Cassino-Drew-McCaw (1999), Campa-Goldberg (2005 and 2006), Devereux-Engel (2001), Devereux-Engel-Storgaard (2004), Devereux-Yetman (2008), and Bacchetta-Wincoop (2005).

respectively, where the coefficient x modules the variance of the distribution and therefore the amount of uncertainty.

Since the model cannot be solved analytically and embeds also forward looking variables, I use the Markov-jump-linear-quadratic approach developed by Svensson-Williams (2007) to find the equilibrium in the presence of multiplicative uncertainty. As to the calibration, the choice of the parameters that are known with certainty follows Svensson (2000) and is reported in Table 2, while Table 3 reports the benchmark values of the uncertain parameters along with their specific reference.

[INSERT TABLES 2-3 HERE]

3 Interest rate distribution forecasts

Figure 1 illustrates the unconditional distribution forecasts of the interest rate to a cost push-shock¹¹. Columns 1 and 2 report the distribution forecasts with domestic inflation and CPI inflation as a target respectively. Rows 1-4 report the various uncertainty cases, specifically concerning the pass-through, the private sector persistence, the slope of the domestic aggregate supply, and all the previous sources together (general). Each plot in the figure displays mean (solid line), and quantiles (grey bands), of the distribution where the dark, medium and light grey band show the 30%, 60%, and 90% probability bands, respectively.

[INSERT FIGURE 1 HERE]

Three remarks are in order. First, the uncertainty on the speed and completeness of the exchange rate pass-through stands out as the main source of uncertainty in forecasting the interest rate. Indeed, the distribution forecast for the general case resembles the one for the pass-through case under both domestic and CPI inflation targeting. Second, when the central bank chooses the CPI as the inflation index to stabilize, monetary policy is more aggressive in the initial periods. The reason is that monetary policy can affect directly CPI inflation via the price of the imports in domestic currency, which depends on the exchange rate. This channel, which is called the Direct Exchange Rate Channel, clearly, is not available for the stabilization of the domestic inflation and this explains the different policy action shown in the distribution forecasts. Third, under CPI inflation targeting is much more difficult, in general, to forecast

¹¹ Assuming an uncertainty level of 30% on the uncertain parameters, i.e. setting $x = 0.3$ in (18), these figures have been generated by drawing an initial mode of the Markov chain from its stationary distribution, simulating the chain for a sequence of periods forward, and then repeating this procedure for 1000 simulations runs

the interest rate path. Focusing on the general uncertainty case which best captures the real-world challenges facing central banks, under domestic inflation targeting monetary policy is expected to be tighter than neutral in the initial five periods to get back to neutral afterwards. In contrast, under CPI inflation targeting it is expected to be even tighter than neutral in the first two periods and then equally tighter or easier than neutral afterwards. This result shows that in presence of a cost-push shock it is extremely difficult to forecast the interest rate after the second period under CPI inflation targeting but not under domestic inflation targeting. Interestingly, this theoretical finding related to CPI inflation targeting is consistent with the empirical finding in Goodhart-Bin Lim (2008) showing that interest rate forecasts, in general, do not seem to have any predictive power after the second quarter.

Although the focus of this paper is the relation between the choice of the inflation index and the accuracy of the interest rate distribution forecasts, an interesting question is to what extent if any there is a trade-off between forecast accuracy of the interest rate on the one hand, and the one of the main macrovariables i.e. inflation and the output gap on the other hand¹². Figure 2 and 3 tackle this question presenting the unconditional distribution forecasts of the output gap and CPI inflation to a cost-push shock.

[INSERT FIGURES 2 AND 3 HERE]

Regarding the output gap, Figure 2 shows that, generally, with the CPI inflation target the impact of the shock is stronger and there is no gain at forecasting accuracy. Regarding CPI inflation Figure 3 shows that the only advantage associated with the CPI inflation target is a minor impact of the shock¹³. This analysis then reveals that i. there is no trade off between interest rate forecasting accuracy on the one hand, and output gap and inflation forecasting accuracy, on the other hand; and that ii. with CPI inflation as a target a minor impact of the shock on CPI inflation is associated with a larger one on the output gap.

So far the analysis dealt with forecast accuracy, in line with the main question addressed by this work. Yet there are various factors that matter in the choice of the inflation index to target. From the perspective of maximising stability in economic activity, Mankiw-Reis (2003) provide four criteria to build the ideal price index. Specifically they show that such a price index should weigh more sectors i. whose prices are more responsive to the business cycle, ii. less exposed to idiosyncratic shocks, iii. more predetermined and iv. less important in the CPI. Before discussing these criteria and the current analysis, it is worth noting that the Mankiw and Reis model is static, assumes model certainty and considers only stabilizing

¹²Inflation targeting central banks that disclose distribution forecasts for their policy instruments report also distribution forecasts for inflation and the output gap.

¹³Considering the general uncertainty case and moving from the domestic inflation target to the CPI inflation target, the initial impact of the shock falls of 18.4%.

economic activity. Thus these criteria should be taken with caution to assess the desirability of the alternative target inflation indexes at issue here. With this caveat in mind, we can recall that in the current model the domestic sector produces and retails domestic goods while the import sector only retails foreign goods. Thus the latter has more nature of service sector while the former of manufacturing sector. Since manufacturing sectors generally are more sensitive to the business cycle than services sectors, this implies, according to the first criterion, that the domestic sector price index should receive more weight in the stability price index. Furthermore, the presence of import inflation in CPI inflation implies that CPI inflation is, potentially, more exposed to foreign shocks, and since the import sector only retails foreign goods its price index is not as predetermined as the price index in the domestic sector. Thus, also the second and third criterion suggest that domestic inflation should have more weight in the Mankiw and Reis index. Finally, the last criterion, based on the weight of the sectors in the CPI, is not directly applicable here as both the domestic and import good, which enter the CPI, enter also in the price of the composite inputs and, with respect to the input price in the import sector, with the uncertain coefficient μ^i as shown in equation (15).

Summing up, the Mankiw-Reis (2003) criteria, when applied to an open economy, suggest that the domestic inflation index should be an interesting alternative to the CPI inflation index if the objective is maximising stability in economic activity. To test this conjecture we can focus on the unconditional standard deviation for the output gap reported in Table 4, where for each uncertainty case, the first and second row refer to the choice of the domestic and the CPI inflation index respectively.

[INSERT TABLE 4 HERE]

These statistics show that the CPI inflation index tends to cause equal or larger output gap volatility than the alternative, this supporting the Mankiw and Reis conjecture and contributing to the literature with a useful open-economy application of their criteria.

Table 4 also reports the unconditional standard deviation of CPI and domestic inflation, the terms of trade, and the nominal and real interest rate. Generally, these statistics show that targeting the CPI inflation index leads to more volatility in the economy. This result tends to differ from what found by Svensson (2000) under flexible inflation targeting, where the overall stability tends to be lower choosing the CPI than choosing the domestic price index, the only exception being the output gap.

What determines this difference? two main factors: delayed and incomplete pass through, and model uncertainty. Svensson's results, indeed, are based on two key assumptions which are relaxed here. First, the central bank knows the model of the economy, in particular the speed and degree of completeness of the exchange rate pass-through. Second, the exchange rate

pass-through is not only known with certainty but immediate and complete. These assumptions imply that one of the transmission channels available in an open economy, the Direct Exchange Rate channel, is very efficient. Thus this channel plays a prominent role in the transmission of the monetary policy when the central bank wants to stabilize the CPI inflation index but not when the central bank wants to stabilize the domestic price index. Yet, a key characteristic of real-world small open-economies is that the exchange rate pass-through is delayed and incomplete, and both these features are not known with certainty. Thus, relaxing the assumption of immediate, complete and known exchange rate pass-through, the Direct Exchange Rate channel becomes less efficient in the transmission of the monetary policy. This results in a reduction of the benefits associated with the choice of the CPI inflation index, which is the policy that uses it the most. Thus, choosing the CPI inflation index becomes less attractive than choosing the domestic inflation index in the case of delayed, incomplete and uncertain exchange rate pass-through.

Account being taken of Table 4, the central bank loss function is minimized choosing the domestic price index which, interpreting the central bank preferences as a measure of social welfare, means also maximizing welfare¹⁴. This result can be discussed along with the ones reported in Corsetti-Dedola-Leduc (2010) where the choice of the target inflation index which maximizes welfare depends on the producers price setting behavior. In particular, when producers set the price of the exports in the currency of the country where they are produced (Producer Currency Pricing hypothesis), targeting the domestic price index is welfare maximizing. On the other hand, when the price of the exports is in the currency of the country where they are exported to (Local Currency Pricing hypothesis), assigning a significant role to the stabilization of the CPI index is welfare maximizing.

In the current model the price setting behavior for the foreign goods share features of both hypotheses in Corsetti-Dedola-Leduc (2010) but tends to be closer to the latter. Here, indeed, foreign producers set the price of their exports in foreign currency¹⁵. Then, an import sector kicks in and fixes the price of the foreign goods in terms of domestic currency considering the exchange rate and the cost of the domestic goods used to retail the foreign goods. This implies that changes in the exchange rate pass through to the domestic price of the foreign goods incompletely (as domestic goods are necessary to retail foreign goods), with a delay (as the import sector is monopolistic competitive and features nominal rigidities) and with a certain level of uncertainty (because the central bank has limited information on the speed and degree of completeness of the exchange rate pass-through).

¹⁴Indeed, choosing the domestic price index the volatility of inflation, output gap and interest rate are generally smaller than choosing the CPI. Since the loss function is monotonically increasing in these volatilities, it follows that stabilising the domestic price index leads to a lower loss than stabilizing the CPI.

¹⁵The small open economy assumption adopted in this model implies that the rest of the world is exogenous and this, in turn, implies that foreign producers set the price of the exports in foreign currency.

It should be noted, however, that the current model and the Corsetti et al. model belong to two alternative strands of the New Keynesian literature on optimal monetary policy which adopt different measures of welfare. Hence, results on welfare should be compared with caution. Indeed, in the current model welfare is captured by a central bank loss function in terms of inflation, output gap and degree of smoothing of the interest rate. In the Corsetti et al. model, instead, welfare is captured by the utility function of the household. These two alternative measures of welfare are discussed at the end of section 2.1 with respect to the motivation of the loss function adopted in this work. The reason why the former measure of welfare is used here is that it is consistent with the inflation targeting operating procedure in use at inflation targeting central banks and suits better the analysis of the relation between interest rate forecast accuracy and the choice of the target inflation index.

3.1 *Parameter uncertainty and optimal monetary policy*

Before discussing possible implications related to forecast accuracy and transparency on policy intentions in section 4, the analysis is completed investigating how different is optimal policy from the standard case without parameter uncertainty. For sake of brevity, among the four possible uncertainty cases we focus on the more realistic one, that is general uncertainty. Table 5-6 report the optimal coefficients with and without certainty when the target inflation index is domestic and CPI inflation, respectively.

[INSERT TABLES 5-6 HERE]

Overall, Tables 5-6 show that the size of the coefficients of the optimal policies is very sensitive to the choice of the target inflation index. Indeed, with the CPI inflation as a target, the optimal policy exhibits a sizeable response to several variables, which instead do not play a significant role with the domestic inflation index as a target. These variables are all related to the import sector and the rest of the world. As a result, with the CPI inflation as the target index the optimal policy is more complex than with domestic inflation as the target index. Tables 5-6 also reveals that relaxing the certainty assumption makes the optimal policies differ from the case with uncertainty mostly when the target inflation index is the CPI.

These results matter in that suggests that when the inflation target is the CPI it is more difficult to implement the optimal policy through simple rules. In contrast, when the inflation target is domestic inflation, the optimal policy could be implemented through a simple rule featuring a response to inflation, the output gap and the lagged interest rate. This easy-to-implement rule appears as a Taylor rule, which is appreciated in the literature because able to deliver an outstanding trade-off between simplicity and ability at matching real-world data.

A final point worth investigating is the impact of parameter uncertainty on the centre of the distribution forecast. Interpreting the mean of the distribution as the centre of the distribution, the black curve in Figure 1, shows that after the initial periods, in particular for the Pass-through and General uncertainty cases, the distribution forecast tends to be centred around zero. This raises the question of to what extent assuming no parameter uncertainty the distribution is still centred around zero.

To address this question it is worth noticing that with parameter certainty the distribution at issue boils down to a degenerate distribution which, at a given point in time, is the probability distribution of a random variable with always the same value¹⁶. Thus, in presence of parameters certainty a distribution forecast boils down to a mean forecast. Put it differently we move from an impulse response distribution (i.e. a fan chart) to an impulse response function.

With a degenerate distribution, therefore, at a given point in time we will have a unique value of the distribution, which is also the mean of the distribution and its centre. In other words, with parameters certainty at a given point in time the distribution, its mean and its centre coincide. Hence, keeping in mind that we are dealing with a degenerate distribution, we can still analyse how assuming parameter certainty affect the centre of the distribution. This is done in Figure 4 which focuses on the General uncertainty case and reports the mean of the distribution forecast with parameter uncertainty and the mean of the degenerate distribution forecast with parameter certainty. Figure 4 shows that after the initial periods, the centre of the degenerate distribution is still around zero.

[INSERT FIGURE 4 HERE]

4 Forecast accuracy and transparency on policy intentions

On the basis of the previous results, an inflation targeting central bank that chooses *domestic* instead of *CPI* inflation stabilization can improve the accuracy of the interest rate forecast in presence of a cost-push shock. To appreciate the relevance of this result is worth recalling that the stabilization of resource utilization and inflation - the central bank target variables - do not depend on the short but on the long term interest rate. This means that the central bank periodic decision on the short term rate is of little significance *per se* as it fixes the cost of

¹⁶The degenerate distribution is characterized by a support of only one value, say k_0 , and is localized at a point k_0 on the real line with probability mass function given by

$$f(k; k_0) = \begin{cases} 1 & \text{if } k = k_0 \\ 0 & \text{if } k \neq k_0 \end{cases}$$

Thus, a degenerate distribution does satisfy the definition of random variable and k_0 is the mean of the distribution.

credit for few weeks. What matters, instead, are expected policy inclinations that determine the long term interest rate. Hence, given the importance of the expected path of the interest rate in the economic dynamics, a natural question is what policy implications could arise from improved forecast accuracy achievable *via* the choice of the target inflation index. An interesting one relates to transparency in monetary policy, in particular to transparency on future policy intentions, and to the recent debate on the instrument-rate assumption underlying projections of target variables¹⁷. The debate arises from two alternatives facing inflation targeting economies which imply different levels of transparency: either publishing the optimal instrument-rate plan and the corresponding projections of the economy, or publishing the projections of the economy based on a specific assumption on the interest rate, e.g. the assumption of a constant interest rate or an interest rate path given by market expectations¹⁸. The first alternative has been pioneered by the Reserve Bank of New Zealand and then adopted by the Norges Bank, the Swedish Riksbank, and the Czech National Bank. Yet, most of the inflation targeting central banks has so far opted for the second alternative being reluctant or very cautious in disclosing future policy intentions.

It is worth noting that central banks have an informational advantage on the private sector with respect to interest rate path. First, the sequence of expected policy decisions tends to involve a lot of central bank judgment concerning the information set, in particular the relevance of current events and future contingencies¹⁹. Thus, according to how opaque the central bank is, this judgement will be missed by the private sector leading to forecast for the interest rate path different from the central bank's ones. Second, central banks may have a wider information set than the private sector. This informational advantage suggests that good central banks tend to be better than the private sector at forecasting the interest rate. Furthermore, the private sector and the central bank act strategically so that the paths for the interest rate, resource utilization and inflation are interdependent. This implies that none of the forecasts for these variables can be determined without the others. Thus not disclosing the central bank's interest rate forecast does not only imply making more difficult for the private sector to anticipate future policy intentions and therefore to take appropriate economic decisions. It also means publishing forecasts of inflation and resource utilization not based on the consistent interest rate forecast, which means to provide inferior forecasts.

At this point it is worth noticing that monetary policy is mainly the management of the

¹⁷The last two decades witnessed an increasing trend in central bank transparency. This happened in particular with inflation targeting central banks and an important piece of information disclosed to the private sector has been the central bank forecast for inflation and the output gap. See Geraats (2002 and 2005) for an interesting analysis of central bank transparency and reputation.

¹⁸For a discussion on these alternatives, see Blinder-Wyplosz (2004), Goodhart (2005), Honkapohja-Mitra (2005), Mishkin (2004), Moessner-Nelson (2008), Qvigstad (2006), Rudebusch-Williams (2007), Svensson (2006, 2008), Woodford (2005) and Holmsen-Qvigstad-Røisland-Solberg-Johansen (2008).

¹⁹Regarding policy makers judgment in monetary policy decisions see, for example, Alcidi-Flamini-Fracasso. (2011) and Svensson-Williams (2007).

private sector expectations as extensively argued by Woodford (2003). It is also well accepted that monetary policy transparency proved to be a key ingredient in the central bank capacity to shape the private sector expectations. Transparency, indeed, leads to accountability. Accountability, in turn, generates credibility if forecasts and actual realizations differ, ex post, only due to unforeseen shocks. Finally credibility is what allows central banks shaping the expectations of the private sector if they choose to be transparent²⁰. Interestingly, forecast accuracy in this process acts as a catalyzer. More forecast accuracy in presence of transparency increases central bank's accountability and therefore increases credibility. Thus, the more accurate and reliable the central bank distribution forecasts for the interest rate, the more policymakers can affect the private sector expectations if they choose to disclose this information. Hence, by showing the existence of a relationship between alternative inflation indexes and the quality of the distribution forecasts, this work suggests that the choice of domestic inflation index can increase the benefits associated with transparency on future policy inclinations.

5 Conclusions

This paper argues that by targeting domestic inflation instead of CPI inflation it is possible to obtain more accurate forecasts of the interest rate generally without sacrificing forecast accuracy for the other variables.

This result matters as more accurate forecasts increase the potential accountability of the central bank and therefore its credibility if they are disclosed and the central bank lives up to the announced policy except for unexpected shocks. More credibility, in turn, can lead to an improvement in the central bank ability at shaping the expectations of the private sector, which is an important factor determining monetary policy effectiveness. This suggests that comparing the performance of alternative inflation targets, the relation between interest rate forecast accuracy and policy effectiveness is a further dimension to be considered.

The policy implication is that the choice of the domestic inflation index can increase the benefits associated with transparency on future policy intentions. Thus, under domestic inflation targeting, the paper's result supports the alternative to publish the projections of inflation and resource utilization corresponding to the optimal interest rate path expected by the central bank and the optimal interest rate path as well.

The current investigation could be extended to the real exchange rate. In particular, it would be interesting to study to what extent if any the choice of the target inflation index affects the forecast accuracy of the real exchange rate and its equilibrium value²¹. This is left

²⁰Central bank credibility is a key policy issue extensively debated in the literature and monetary policy practice, see for example Blinder (2000), Lossani-Natale-Tirelli (2001) and for a more recent analysis the papers presented at the Monetary Policy, Transparency, and Credibility 2007 conference organized by the San Francisco FED.

²¹For a recent survey of the empirical alternative approaches to the real equilibrium exchange rate see Belloc-

to future analysis.

A Implementing the Svensson-Williams (2007) approach

The implementation of the Svensson-Williams (2007) approach is carried out in three steps. First the central bank optimization problem is formulated in State-space form. Second, the uncertainty on the structural parameters is mapped in a set of possible modes and in the low of motion for the modes. The latter is specified via an initial distribution and a Markov transition matrix according to the economic assumptions on the central bank information set. Third, the relation between modes and cost-push shock is specified.

Describing these steps, the problem in State-space form is

$$\text{Min}_{\{i_{t+\tau|t}\}_{\tau=0}^{\infty}} E_t \sum_{\tau=0}^{\infty} \beta^{\tau} Y'_{t+\tau} K Y_{t+\tau}$$

subject to

$$\begin{bmatrix} X_{t+1} \\ x_{t+1|t} \end{bmatrix} = \begin{bmatrix} A_{11,t+1} & A_{12,t+1} \\ A_{21,t} & A_{22,t} \end{bmatrix} \begin{bmatrix} X_t \\ x_t \end{bmatrix} + \begin{bmatrix} B_{1,t+1} \\ B_{2,t} \end{bmatrix} i_t + \begin{bmatrix} B_{1,t+1}^1 \\ B_{2,t}^1 \end{bmatrix} i_{t+1|t} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix},$$

$$Y_t \equiv C_{Z,t} \begin{bmatrix} X_t \\ x_t \end{bmatrix} + C_{i,t} i_t,$$

where

$$\begin{aligned} Y_t &= \left(\pi_t^c, \pi_t^d, y_t^d, i_t - i_{t-1} \right)', \\ X_t &= \left(\pi_t^d, \pi_{t+1|t}^d, \pi_{t-1}^i, \pi_t^*, y_t^d, y_t^i, y_t^*, i_t^*, i_{t-1}, q_{t-1} \right)', \\ x_t &= \left(\pi_t^i, q_t^i, \rho_t, \pi_{t+2|t}^d \right)', \end{aligned}$$

and where ε_t is a cost-push shock, K is a diagonal matrix with diagonal $(\mu^c, \mu^d, \lambda, \nu)$ and zero off-diagonal elements.

The matrices

$$(19) \quad A_{11,t}, A_{12,t}, B_{1,t}, B_{1,t}^1, A_{21,t}, A_{22,t}, B_{2,t}, B_{2,t}^1, C_{Z,t}, C_{i,t},$$

are random, each free to take n_j different values in period t corresponding to n_j modes indexed by $j_t \in \{1, 2, \dots, n\}$. This means that, for example, $A_{11,t} = A_{11,j_t}$. Let m be the number of

Federici-Gandolfo (2008).

uncertain parameters and d the number of values that each uncertain parameter can take in any period. Then the number of modes is $n = d^m$. In this work $d = 5$ and m can be either 1 or 2 or 5 depending on the uncertainty cases described below. For each uncertain parameter, say ξ , a benchmark value is chosen, $\bar{\xi}$, and the lower and upper bound of the support of the distribution are set equal to $\bar{\xi} - x\bar{\xi}$ and $\bar{\xi} + x\bar{\xi}$ respectively, where the coefficient x modules the variance of the distribution and therefore the amount of uncertainty. Finally, the support is discretized by d equidistant values.

Modes are drawn initially from a discrete stationary distribution which is assumed to be uniform. After the initial draw from the stationary distribution the modes follow a Markov process with constant transition probabilities given by

$$P_{jk} \equiv \Pr \{j_{t+1} = k | j_t = j\} = \frac{1}{n}, \quad j, k \in \{1, 2, \dots, n\}.$$

Next, the central bank is assumed not to know how the structural parameters co-move together, should they be dependent. So in any period the realization of each parameter is independent of the realizations of the other parameters. Furthermore, model uncertainty and shocks to the economy are assumed to be independent so that modes j_t and cost-push shocks are independently distributed. As to the central bank knowledge before choosing the instrument-plan $\{i_{t+\tau|t}\}_{\tau=0}^{\infty}$ at the beginning of period t , the information set consists of the probability distribution of the cost-push shock, the transition matrix $[P_{jk}]$, the n_j different values that each of the matrices can take in any mode, and finally the realizations of $X_t, j_t, \varepsilon_t, X_{t-1}, j_{t-1}, \varepsilon_{t-1}, x_{t-1}, \dots$.

Since the model cannot be solved analytically and embeds also forward looking variables, I use the numerical methods developed by Svensson-Williams (2007) to find the equilibrium in the presence of multiplicative uncertainty under commitment in a timeless perspective (see Woodford 2003 and Svensson-Woodford 2005).

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Summary

Interest Rate Forecasts in Inflation Targeting Open-Economies

JEL: E52, E58, F41

Can the choice of the target inflation index in an open-economy affect the central bank ability to forecast the interest rate path? Adopting a New Keynesian set up where the central bank

faces real-world model uncertainty, this paper shows that targeting the domestic price index instead of the consumer price index substantially improves the accuracy in the distribution forecast of the interest rate. The policy implication is that adopting the domestic price index may increase the central bank's convenience of publishing the expected interest rate path.

Tables and Figures

TABLE 1 Uncertain structural parameters and corresponding uncertain composite coefficients

ι	Degree of habit persistence	$\beta_y, \beta_\rho, \beta_\rho^i, \beta_q, \beta_q^i, \beta_{q-1}$ $\beta_{q-1}^i, \beta_{y^*}, \beta_{y^*}^i, \beta_{y^n}, \beta_{y^n}^i$
ζ	Degree of inflation indexation	$\phi_\pi, \phi_y^d, \phi_q^d, \phi_y^i, \phi_q^i$
α	Degree of price stickiness in domestic sector	ϕ_y^d, ϕ_q^d
α^i	Speed of exchange rate pass-through	ϕ_y^i, ϕ_q^i
μ^i	Degree of completeness of exch. rate pass-through	ϕ_q^i, φ

TABLE 2 Parameters known with certainty

ω	0.8	w	0.3
ϑ	1.25	σ_π^2	1
σ	0.5	$\gamma_y^{d,n}, \gamma_y^{i,n}$	0.96
μ	0.1		

TABLE 3 Benchmark values of the uncertain parameters

$\bar{\iota}$	0.8	Banerjee and Batini (2003)
$\bar{\zeta}$	0.66	Smets and Wouters (2005)
$\bar{\alpha}, \bar{\alpha}^i$	0.5	Svensson (2000)
$\bar{\mu}^i$	0.35	Flamini (2007)

TABLE 4 Unconditional standard deviations

Uncertainty case		π^c	π^d	y^d	q	i	r
Pass-through	D	0.105	0.045	0.095	0.245	0.437	0.436
	CPI	0.145	0.071	0.148	0.308	0.785	0.785
Domestic AS	D	0.179	0.190	0.138	0.202	0.200	0.207
	CPI	0.182	0.195	0.145	0.207	0.268	0.298
Private sector persistence	D	0.105	0.114	0.152	0.167	0.295	0.316
	CPI	0.114	0.126	0.152	0.164	0.281	0.302
General	D	0.187	0.192	0.170	0.349	0.451	0.458
	CPI	0.202	0.210	0.205	0.431	0.777	0.784

D= Domestic Inflation Index, CPI = CPI Inflation Index

TABLE 5 Optimal policies with domestic inflation as target inflation index

	π_t^d	$\pi_{t+1 t}^d$	π_{t-1}^i	π_t^*	y_t^d	y_t^i	y_t^*	i_t^*	i_{t-1}	q_{t-1}
Certainty	0.01	0.30	0.01	0.03	0.40	0.01	0.04	0.00	0.52	-0.01
Uncertainty	0.02	0.28	0.01	0.07	0.33	0.04	0.09	0.03	0.50	-0.02

TABLE 6 Optimal policies with CPI inflation as target inflation index

	π_t^d	$\pi_{t+1 t}^d$	π_{t-1}^i	π_t^*	y_t^d	y_t^i	y_t^*	i_t^*	i_{t-1}	q_{t-1}
Certainty	1.33	0.01	0.42	0.24	0.26	0.16	0.21	0.08	0.48	-0.19
Uncertainty	1.36	-0.24	0.41	0.33	0.12	0.24	0.33	0.17	0.42	-0.19

Figure 1. Interest rate distribution forecasts

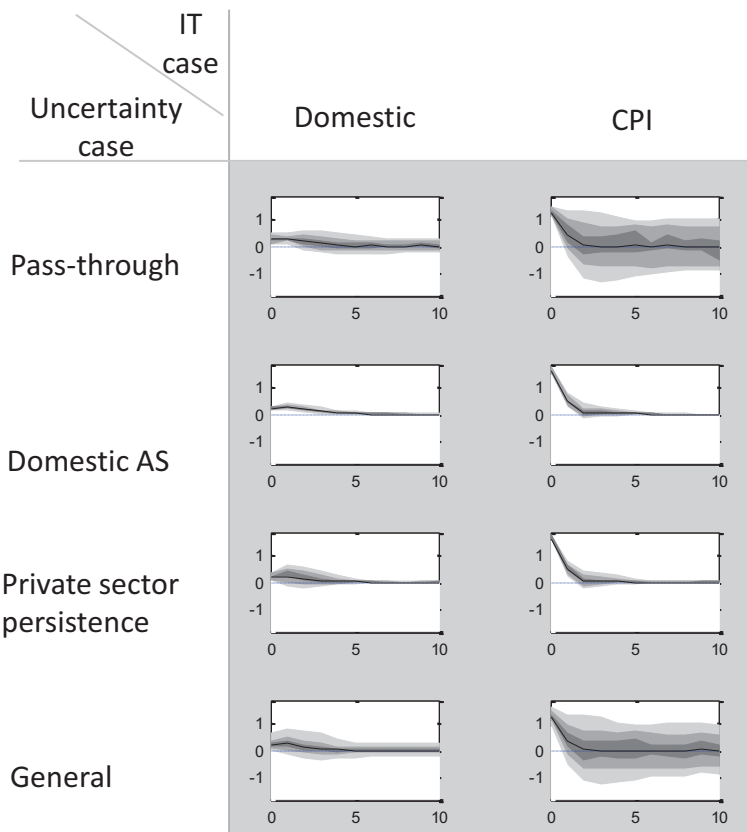


Figure 2. Output gap distribution forecasts

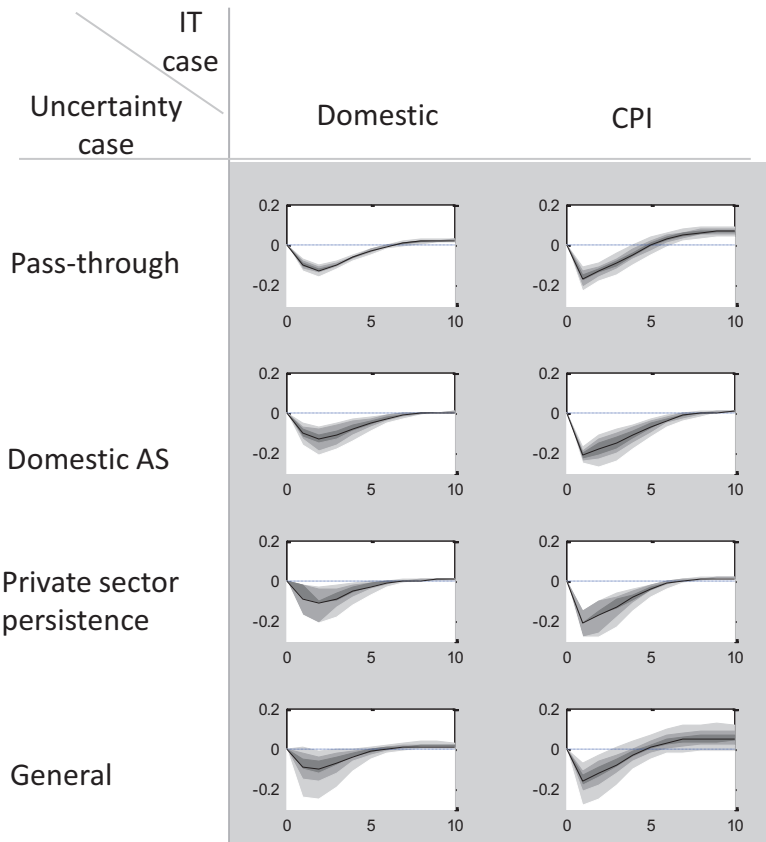


Figure 3. CPI inflation distribution forecasts

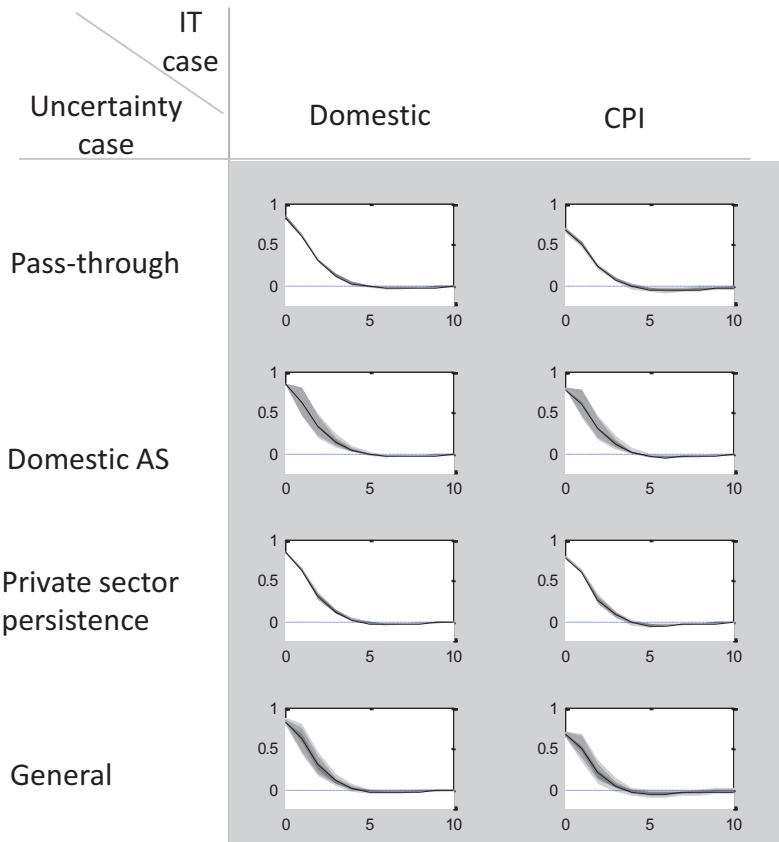
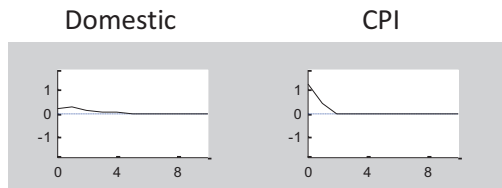


Figure 4. Mean of the interest rate distribution forecast

Panel a: Uncertainty



Panel b: Certainty

