# Working Paper Series

Sebastian Schmidt

Time-consistent monetary policy, terms of trade manipulation and welfare in open economies

**Abstract**

A key insight from the open economy literature is that domestic price stability is in general not optimal for countries that exert some market power over their terms of trade. Under commitment, a national benevolent monetary policymaker improves upon the allocation associated with stable domestic prices by manipulating the terms of trade to her own country's advantage. In this paper, I study optimal monetary policy in a sticky-price small open economy model when the policymaker lacks a commitment device. Without commitment, the benevolent policymaker's attempt to improve national welfare by manipulating the terms of trade can be self-defeating. By steering international relative prices the discretionary policymaker induces fluctuations in domestic prices, the costs of which she is unable to fully internalize in her decision-making. Society may thus be better off if it appoints an inward-looking policymaker who aims for domestic price stability and resists the temptation to exploit the country's monopoly power in trade. Accounting for the effective lower bound on nominal interest rates further strengthens the case for the inward-looking policy objective.

# Non-technical summary

A key insight from the open economy literature is that domestic price stability is in general not optimal from a national perspective. This is particular apparent in small open economy (SOE) models which abstract from any cross-country strategic interactions among policymakers. A monetary policymaker of a SOE that acts under full credibility ('policy commitment') and aims to maximize national welfare can improve upon the allocation associated with stable domestic prices by exploiting the SOE's market power over its terms of trade. In so doing, the national policymaker trades off the welfare cost from giving up domestic price stability against the welfare gain from stabilizing international relative prices. Little is known, however, about the role of policy credibility for the policymaker's ability to improve upon a policy of strict domestic price stability. The issue is addressed in this paper.

I study optimal monetary policy in a textbook SOE model when the policymaker lacks a commitment device ('discretionary policy'). The model features complete financial markets and complete exchange rate pass-through. Firms act under monopolistic competition and are subject to quadratic price adjustment costs. Imported foreign goods and domestically produced goods are imperfect substitutes. This configuration grants the SOE some power to influence its terms of trade.

The main result of the paper is that without commitment, the policymaker's attempt to improve national welfare by manipulating the terms of trade can be self-defeating. By steering international relative prices the discretionary policymaker induces fluctuations in domestic prices, the cost of which she is unable to fully internalize in her decision-making. This reflects the fact that, unlike in the case of policy commitment, a policymaker acting under discretion takes agents' future decision rules as given. In equilibrium, the gain from improved terms of trade conditions can therefore be more than outweighed by the cost from fluctuations in domestic prices. If this is the case, society is better off if it appoints a policymaker who aims for domestic price stability and resists the temptation to engage in policies that aim to influence international relative prices.

# 1 Introduction

An important policy question for open economies is whether their central banks should focus on the stabilization of domestic prices or whether they should also pay attention to international relative prices. The New Keynesian open economy literature tends to find support for the latter policy prescription. In particular, under commitment, the benevolent policymaker of an open economy in general deviates from domestic price stability and improves national welfare by exploiting the country's monopoly power in trade.[1] This paper addresses the following question. Does the benevolent policymaker of an open economy also improve upon the allocation associated with stable domestic prices when she lacks a commitment device?

I work with a non-linear version of the textbook New Keynesian model of a small open economy (SOE). Using a SOE setup has the advantage that one can abstract from cross-border strategic interactions among policymakers, and the potentially welfare-reducing effects of foreign policymakers' reaction to national policies. The model features complete financial markets and complete exchange rate pass-through. Firms act under monopolistic competition and are subject to quadratic price adjustment costs. Imported foreign goods and domestically produced goods are imperfect substitutes. This configuration grants the SOE the power to steer its terms of trade. I consider two types of exogenous disturbances, preference shocks and technology shocks, and solve the stochastic model using global methods. In the model, a monetary policy regime that stabilizes domestic prices at all times and in all states replicates the flexible-price allocation. The flexible-price allocation is, however, in general inefficient from the viewpoint of the SOE. This holds true even if fiscal subsidies ensure that the flexible-price steady state is efficient, as is assumed throughout the paper. At the same time, the presence of price adjustment costs renders the efficient allocation unattainable outside of the deterministic steady state.

I first show that the benevolent discretionary policymaker of the SOE deviates from

---

[1]See Corsetti et al. (2010) for a recent review of the literature on optimal monetary policy in open economies.

the flexible-price allocation towards the efficient allocation. That is, if the terms of trade are inefficiently volatile in the flexible-price equilibrium then the discretionary policymaker stabilizes the terms of trade relative to the flexible-price equilibrium. In this regard, the optimal discretionary monetary policy resembles the optimal commitment policy. Like the benevolent policymaker acting under commitment, the benevolent policymaker acting under discretion internalizes the terms of trade externality in her decision making. However, I find that without commitment, the benevolent policymaker's attempt to improve national welfare by manipulating the terms of trade can be self-defeating. That is, national welfare under the benevolent discretionary policymaker can be lower than in the flexible-price equilibrium. Policy credibility is therefore an important ingredient for the ability of a national policymaker to improve upon the flexible-price allocation.

In the sticky-price model, openness creates a trade-off for monetary policy between stabilization of domestic prices and stabilization of international relative prices that is absent in the closed economy.[2] When assessing this trade-off, the discretionary policymaker is unable to fully internalize the costs associated with fluctuations in domestic prices since, unlike a policymaker that acts under commitment, she takes agents' future decision rules as given.[3] In equilibrium, the gains from improved terms of trade conditions can be more than outweighed by the resource costs from domestic price adjustments. If this is the case, society can make itself better off by assigning a strict domestic inflation objective to the monetary policymaker in the spirit of the policy-delegation literature.[4] A discretionary policymaker with a strict domestic inflation objective resists the temptation to exploit the SOE's monopoly power in trade and replicates the flexible-price allocation.

---

[2]The relation to the closed economy literature on optimal discretionary monetary policy is discussed further below.

[3]Under commitment, the optimal monetary policy response to exogenous disturbances features endogenous inertia in the policy rate. The time-inconsistent policy inertia improves the stabilization trade-off between domestic prices and international relative prices.

[4]A central result of the literature on the policy delegation approach is that discretionary equilibria can often be improved by modifying the policymaker's objective function or by putting additional constraints on the policymaker's optimization problem. Prominent early examples from the closed economy literature include Rogoff (1985), Persson and Tabellini (1993), Walsh (1995) and Svensson (1997).

When is the SOE's welfare higher under the domestic inflation-targeting policymaker than under the benevolent policymaker? A key parameter is the elasticity of substitution between home and foreign goods, henceforth referred to as the trade elasticity. The larger the trade-elasticity parameter the stronger is the expenditure-switching effect associated with a given change in international relative prices and the bigger the potential gains from manipulating the terms of trade. Hence, for the strict domestic inflation-targeting policymaker to be welfare-improving upon the benevolent policymaker the trade elasticity has to be smaller than some numerically-determined threshold value.[5] In contrast, the welfare-improving nature of the strict domestic inflation-targeting regime is surprisingly insensitive to the degree of price stickiness. Even for very low degrees of price stickiness, national welfare turns out to be lower under the benevolent policymaker than under the domestic inflation-targeting policymaker.

How is the main result of the paper affected if the model accounts for the existence of an effective lower bound on nominal interest rates? I find that accounting for the lower bound strengthens the case for assigning a strict domestic inflation objective to the discretionary monetary policymaker. The reason is that the lower bound constraint is most likely to bind for realizations of the preference shock that render households more patient. These are exactly the states of nature in which the benevolent policymaker has an incentive to engineer an appreciation of the terms of trade relative to the flexible-price equilibrium. When the lower bound constraint is binding, the relative appreciation of the terms of trade and the real exchange rate get amplified and domestic inflation drops sharply. In contrast, if the monetary policymaker has a domestic price stability objective, then accounting for the lower bound constraint may increase national welfare. This is the case when the gains from reduced terms of trade volatility induced by the lower bound constraint outweigh the resource costs resulting from the policymaker's inability to fully stabilize domestic prices in those

---

[5]This suggests that a more general remedy to the time inconsistency problem of monetary policy in the SOE consists of augmenting (rather than replacing) the benevolent policymaker's objective function—i.e. household lifetime utility—with an optimally-weighted additional term that punishes deviations from domestic price stability.

states where the constraint is binding.

The paper contributes to the literature on optimal monetary policy in open economies. Corsetti and Pesenti (2001) show how national welfare in open economies may depend on a terms of trade externality, using a two-country model with monopolistic competition and one-period wage contracts.[6] Benigno and Benigno (2003) analyze optimal monetary policy in a two-country model with imperfect competition and price stickiness. They find that even from a cooperative perspective, the allocation achieved under the optimal commitment policy in general deviates from and improves upon the flexible-price allocation. Faia and Monacelli (2008) and De Paoli (2009) study how the terms of trade externality affects optimal monetary policy under commitment in New Keynesian SOE models similar to the one considered here. They show that a national benevolent policymaker who acts under commitment improves upon the flexible-price allocation by exploiting the SOE's monopoly power in trade. Their work builds on Galí and Monacelli (2005) who uncover conditions under which it is optimal for monetary policy to replicate the flexible-price allocation. Bhattarai and Egorov (2016) compare optimal monetary (and fiscal) policy under commitment and under discretion in a non-linear New Keynesian SOE model with perfect foresight. Using a two-country New Keynesian open economy model, Groll and Monacelli (2016) show that lack of monetary policy commitment can make it desirable for a country to become part of a monetary union. None of these papers, however, considers the question addressed in this paper, i.e. whether the benevolent policymaker's attempt to improve upon the flexible-price allocation raises or lowers national welfare when she lacks a commitment device.

The paper is also related to the literature on optimal time-consistent monetary policy in closed economy sticky-price models, and the potential desirability of "inflation conservatism" in these models. In particular, Clarida et al. (1999) show how in a New Keynesian closed economy model, the presence of a persistent, exogenous disturbance to firms' desired markup over nominal marginal costs can make it desirable for the

---

[6]Subsequent extensions of their framework that relax the assumption of a unit elasticity of substitution between home and foreign goods include Tille (2001) and Sutherland (2006).

economy to appoint a monetary policymaker who is more concerned with inflation stabilization relative to output gap stabilization than society as a whole. An important feature that the open economy model used here has in common with the closed economy framework is the inability of discretionary policymakers to fully internalize the costs associated with systematic deviations from (domestic) price stability when prices are set in a forward-looking way. The main differences are twofold. First, the monetary policy trade-off arising in the closed economy model of Clarida et al. (1999) is between inflation and output gap stabilization. Instead, in the open economy model considered here, the trade-off is between stabilization of domestic and international relative prices. This trade-off between inward-looking and outward-looking policy objectives is specific to the open economy. Indeed, the type of exogenous disturbances considered in my model, i.e. preference and technology shocks, would not create any stabilization trade-off for monetary policy in the closed economy limit of that model.[7] Second, Clarida et al. (1999) show that society may be able to improve welfare in a closed economy by replacing the discretionary benevolent policymaker with a policymaker who puts more weight on inflation stabilization relative to other objectives than society does. I find that in an open economy it might be welfare-improving to replace the discretionary benevolent policymaker with a policymaker who cares only about domestic inflation stabilization and puts zero weight on any other objective.

Finally, the part of the paper that extends the analysis to a model with a lower bound constraint on nominal interest rates is related to some recent studies that reconsider the desirability of alternative monetary policy regimes for open economies in the presence of the lower bound. Cook and Devereux (2016) and Corsetti et al. (2017) analyze the desirability of fixed versus flexible exchange rate systems and how this depends on the origin of the shock that drives the economy to the lower bound. The paper by Bhattarai and Egorov (2016) mentioned before also accounts for the lower bound and shows that the trade elasticity plays an important role for stabilization outcomes and policies, both under commitment and under discretion. In

---

[7]The paper intentionally limits the analysis to disturbances with this property to highlight the difference to the closed economy setup.

their analysis, however, the policymaker is always benevolent. A technical contribution of my paper compared to these studies is that it solves the non-linear stochastic New Keynesian SOE model using projection methods and therefore accounts for economic uncertainty and its interactions with the lower bound constraint.[8] Nakata and Schmidt (2014) show that in a New Keynesian closed economy model with an occasionally binding lower bound constraint and a discretionary monetary policymaker, the anticipation of future lower bound episodes creates a trade-off for monetary policy between inflation and output stabilization in those states where the lower bound constraint is not binding. This trade-off can be improved by appointing a policymaker who is more concerned with inflation stabilization relative to output gap stabilization than society as a whole.

The remainder of the paper is organized as follows. Section 2 describes the model and defines the private sector equilibrium. Section 3 recapitulates how the terms of trade externality renders the flexible-price allocation inefficient. Section 4 analyses optimal time-consistent monetary policy in the sticky-price model and presents the welfare results. Section 5 discusses the time inconsistency problem of monetary policy in the SOE that prevents the benevolent discretionary policymaker from replicating the optimal commitment policy. Section 6 presents additional results, including on the role of the effective lower bound, and Section 7 concludes.

## 2 The model

The model consists of two economies, a SOE and the rest of the world. The SOE is assumed to be infinitesimally small so that the rest of the world operates like a closed economy. Each economy is inhabited by a continuum of identical households, a continuum of goods-producing firms acting under monopolistic competition and facing quadratic price adjustment costs, and a monetary authority.[9] The model features complete financial markets and complete exchange rate pass-through, as prices are set in

---

[8]Nakata (2016) solves a non-linear closed economy model with occasionally binding nominal interest rate bound under optimal monetary policy with and without policy commitment.

[9]Fiscal policy is assumed to be Ricardian.

producers' currency. Time is discrete and indexed by $t$. In the following, the private sector of the SOE is described in more detail. Reflecting the numerical nature of the analysis, functional forms for preferences, technology and price adjustment costs are imposed from the beginning.

## 2.1 Representative household

The representative household in the SOE maximizes expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \delta_t \left( \frac{C_t^{1-\sigma} - 1}{1 - \sigma} - \chi \frac{N_t^{1+\phi}}{1 + \phi} \right) \tag{1}$$

subject to a sequence of budget constraints

$$P_t C_t + E_t Q_{t,t+1} D_{t+1} \leq W_t N_t + D_t - T_t \tag{2}$$

and a no-Ponzi game condition. The household obtains utility from private consumption $C_t$ bought at price $P_t$ and dislikes labor $N_t$. $E_t$ is the rational expectations operator conditional on information available in period $t$, $\beta \in (0,1)$ is the subjective discount factor and $\delta_t$ is an exogenous preference shifter. The preference parameters satisfy $\sigma, \phi, \chi > 0$. $D_{t+1}$ is the nominal payoff in period $t+1$ of the asset portfolio held at the end of period $t$ and $Q_{t,t+1}$ is the stochastic discount factor for one-period-ahead nominal payoffs. The household earns labor income $W_t N_t$, where $W_t$ is the nominal wage rate, and pays lump-sum taxes $T_t$.

The consumption index $C_t$ is defined as

$$C_t \equiv \left( (1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{1-\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{1-\frac{1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{3}$$

where $C_{H,t}$ is a CES aggregator of consumption goods produced in the SOE, $C_{H,t} = \left( \int_0^{\infty} C_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$, and $C_{F,t}$ is a CES aggregator of imported consumption goods $C_{F,t} = \left( \int_0^{\infty} C_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$. Parameter $\eta > 0$ measures the degree of substitutability

between domestic and foreign goods, henceforth referred to as the trade elasticity.[10] Parameter $\alpha \in [0, 1]$ is a measure of openness, and parameter $\epsilon > 1$ denotes the elasticity of substitution between differentiated goods produced in the same jurisdiction.

The consumer price index $P_t$ is defined as

$$P_t \equiv \left( (1 - \alpha) P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right)^{\frac{1}{1-\eta}}, \tag{4}$$

where $P_{H,t} = \left( \int_0^1 P_{H,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$ is the domestic price index, with $P_{H,t}(i)$ denoting the price of variety $i$, and $P_{F,t} = \left( \int_0^1 P_{F,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$ is the price index for imported goods in domestic currency, with $P_{F,t}(i)$ denoting the price of foreign variety $i$.

It can be shown that the optimal allocation of expenditures between domestic and imported goods is given by

$$C_{H,t} = (1 - \alpha) \left( \frac{P_{H,t}}{P_t} \right)^{-\eta} C_t, \quad C_{F,t} = \alpha \left( \frac{P_{F,t}}{P_t} \right)^{-\eta} C_t, \tag{5}$$

and the optimal allocation of a given amount of expenditures on domestic and imported goods across varieties satisfies

$$C_{H,t}(i) = \left( \frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\epsilon} C_{H,t}, \quad C_{F,t}(i) = \left( \frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\epsilon} C_{F,t} \tag{6}$$

for all $i$.

The first-order necessary conditions to the representative household's optimization problem are given by

$$w_t = \chi C_t^\sigma N_t^\phi, \tag{7}$$

$$Q_{t,t+1} = \beta \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \pi_{t+1}^{-1}, \tag{8}$$

where $\pi_t = P_t / P_{t-1}$ is the gross consumer price inflation rate between periods $t - 1$ and $t$, and $w_t = W_t / P_t$ is the real wage rate. Taking conditional expectations on both

---

[10]Domestic and foreign goods are substitutes if and only if $\eta\sigma > 1$.

sides of equation (8), one obtains the consumption Euler equation

$$\frac{1}{R_t} = \beta E_t \frac{\delta_{t+1}}{\delta_t} \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \pi_{t+1}^{-1},$$ (9)

where $1/R_t \equiv E_t Q_{t,t+1}$ is the inverse of the one-period nominal interest rate.

Finally, the transversality condition has to be satisfied

$$\lim_{T \to \infty} E_t(Q_{t,T} D_T) = 0.$$ (10)

## 2.2 International relative prices and risk sharing

The terms of trade is defined as the price of foreign goods relative to domestic goods

$$S_t \equiv \frac{P_{F,t}}{P_{H,t}}.$$ (11)

The law of one price is assumed to hold for all individual goods. Hence, we have $P_{F,t} = \mathcal{E}_t P_t^*$ where $\mathcal{E}_t$ is the nominal exchange rate and $P_t^*$ is the price of foreign goods expressed in foreign currency. Since the rest of the world is essentially a closed economy, $P_t^*$ is also the consumer price index of the rest of the world.

The real exchange rate is defined as the ratio between the consumer price indexes of the rest of the world and the SOE, expressed in domestic currency

$$\mathcal{Q}_t \equiv \frac{\mathcal{E}_t P_t^*}{P_t} = \frac{P_{F,t}}{P_t} = S_t \frac{P_{H,t}}{P_t}.$$ (12)

It is also useful to relate the ratio between the consumer price index of the SOE and the domestic price index to the terms of trade

$$g(S_t) \equiv \frac{P_t}{P_{H,t}} = \left(1 - \alpha + \alpha S_t^{1-\eta}\right)^{\frac{1}{1-\eta}}.$$ (13)

We can then rewrite the real exchange rate as

$$\mathcal{Q}_t = \frac{S_t}{g(S_t)}.$$ (14)

Finally, under complete financial markets, the following international risk sharing condition holds

$$(C_t^*)^{-\sigma} = \kappa \delta_t \mathcal{Q}_t C_t^{-\sigma}, \tag{15}$$

where I have abstracted from foreign preference shocks. The parameter $\kappa$ depends on the initial relative net asset positions. Assuming symmetric initial conditions, we have $\kappa = 1$.

## 2.3 Firms

Each monopolistic firm in the SOE produces a differentiated good using domestic labor, subject to a common technology shock $A_t$

$$Y_t(j) = A_t N_t(j) \tag{16}$$

for all $j$.

The domestic firms are owned by the households and face quadratic price adjustment costs. In period $t$, firm $j$ chooses the price of good $j$, $P_{H,t}(j)$, to maximize expected discounted profits

$$E_t \sum_{l=0}^{\infty} Q_{t,t+l} \left[ Y_{t+l}(j) \left( (1+v) P_{H,t+l}(j) - \frac{W_{t+l}}{A_{t+l}} \right) - \frac{\omega}{2} \left( \frac{P_{H,t+l}(j)}{P_{H,t+l-1}(j)} - 1 \right)^2 P_{H,t+l} \right] \tag{17}$$

subject to $Y_{t+l}(j) = \left( \frac{P_{H,t+l}(j)}{P_{H,t+l}} \right)^{-\epsilon} Y_{t+l}$, where $Y_{t+l}$ denotes aggregate output of the SOE in period $t+l$, and $Q_{t,t} \equiv 1$. The parameter $v$ denotes a constant production subsidy.

The first-order necessary condition for the optimization problem of firm $j$ in period $t$ is

$$(1 - \epsilon)(1 + v)Y_t(j) + \epsilon \frac{w_t}{A_t} g(S_t)Y_t(j) - \omega \left( \frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1 \right) \frac{P_{H,t}}{P_{H,t-1}(j)}$$

$$+ \omega E_t \left( Q_{t,t+1} \left( \frac{P_{H,t+1}(j)}{P_{H,t}(j)} - 1 \right) \frac{P_{H,t+1}(j)P_{H,t+1}}{P_{h,t}(j)^2} \right) = 0. \tag{18}$$

I assume that all firms are symmetric, $P_{H,t}(j) = P_{H,t}$ for all $j$. Hence, $Y_t(j) = Y_t$ for all $j$. Equation (18) can then be written as a New Keynesian Phillips curve

$$\epsilon Y_t \left( \chi C_t^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) - \frac{\epsilon - 1}{\epsilon}(1 + v) \right)$$

$$= \omega \left[ (\pi_{H,t} - 1)\pi_{H,t} - \beta E_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{g(S_t)}{g(S_{t+1})} (\pi_{H,t+1} - 1)\pi_{H,t+1} \right], \tag{19}$$

where I used (7) and (8) to substitute out the real wage rate and the stochastic discount factor.

Finally, the aggregate resource constraint of the economy is given by

$$Y_t = (1 - \alpha) g(S_t)^\eta C_t + \alpha S_t^\eta C_t^* + \frac{\omega}{2} (\pi_{H,t} - 1)^2. \tag{20}$$

## 2.4 Private sector equilibrium

A private sector equilibrium consists of four stochastic processes $\{C_t, Y_t, S_t, \pi_{H,t}\}$, for all $t \geq 0$, that satisfy the following system of equations

$$\frac{1}{R_t} = \beta E_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \pi_{H,t+1}^{-1} \frac{g(S_t)}{g(S_{t+1})} \tag{21}$$

$$(C_t^*)^{-\sigma} = \delta_t \frac{S_t}{g(S_t)} C_t^{-\sigma} \tag{22}$$

$$\epsilon Y_t \left( \chi C_t^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) - \frac{\epsilon - 1}{\epsilon} (1 + \nu) \right)$$
$$= \omega \left[ (\pi_{H,t} - 1) \pi_{H,t} - \beta E_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{g(S_t)}{g(S_{t+1})} (\pi_{H,t+1} - 1) \pi_{H,t+1} \right] \tag{23}$$

$$Y_t = (1 - \alpha) g(S_t)^\eta C_t + \alpha S_t^\eta C_t^* + \frac{\omega}{2} (\pi_{H,t} - 1)^2 \tag{24}$$

given monetary policy $\{R_t\}$ and the exogenous processes $\{\delta_t, A_t, C_t^*\}$, where $g(S_t)$ is defined in (13).

## 2.5 Baseline calibration and model solution

The baseline calibration follows Faia and Monacelli (2008) and is documented in Table 1.[11] Note that under the baseline calibration, the composite domestic consumption

Table 1: Baseline calibration

| Parameters | Description | Values |
|---|---|---|
| $\beta$ | Discount factor | 0.99 |
| $\sigma$ | Inverse of intertemporal elasticity of substitution | 1 |
| $\phi$ | Inverse of labor supply elasticity | 1 |
| $\chi$ | Preference parameter | 1 |
| $\epsilon$ | Elasticity of substitution between domestic goods | 7.5 |
| $\eta$ | Trade elasticity | 1.5 |
| $\alpha$ | Share of imported goods in domestic consumption basket | 0.4 |
| $\omega$ | Price adjustment costs | 75 |

good $C_{H,t}$ and the composite imported foreign consumption good $C_{F,t}$ are substitutes. The production subsidy $\nu$ is chosen such that the deterministic steady state associated

---

[11]The only exception is the labor supply elasticity which is set equal to one. The sensitivity analysis in Section 6.3 presents results when $\phi$ is set to 3 as in Faia and Monacelli.

with a particular policy regime coincides with the steady state of the efficient equilibrium. Furthermore, I impose symmetric steady states across countries, i.e. $C^* = C$ and $S = 1$. For the baseline variant of the model, the preference shock $\delta_t$ is assumed to be the only source of uncertainty, and follows a stationary AR(1) process

$$\delta_t = \rho_\delta \delta_{t-1} + (1 - \rho_\delta)\delta + \epsilon_t^\delta, \tag{25}$$

where $\epsilon_t^\delta$ is an i.i.d. normally distributed random variable with zero mean and variance $\sigma_\delta^2$. Parameter values are $\delta = 1$, $\rho_\delta = 0.85$ and $\sigma_\delta = 0.025$.[12] The technology shock $A_t$ and the world consumption index $C_t^*$ are held constant at their deterministic steady states.

I solve the model using projection methods. The numerical algorithm is described in the Appendix.

# 3 The terms of trade externality when prices are flexible

Before considering optimal policy in the sticky-price model, it is useful to briefly recapitulate how the presence of the terms of trade externality creates an incentive for the social planner of the SOE to deviate from the flexible-price allocation.

## 3.1 The flexible-price equilibrium

In the absence of price adjustment costs, the equilibrium condition for aggregate price-setting behavior (23) simplifies to

$$\chi C_t^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) = \frac{\epsilon - 1}{\epsilon}(1 + \nu). \tag{26}$$

The competitive flexible-price equilibrium then consists of a sequence of allocations $\{C_t, Y_t\}$ and a sequence of prices $\{S_t\}$, for all $t \geq 0$, that satisfy equations (22), (26) and the resource constraint $Y_t = (1 - \alpha) g(S_t)^\eta C_t + \alpha S_t^\eta C_t^*$, given the exogenous

---

[12]See Basu and Bundick (2015).

processes $\{\delta_t, A_t, C_t^*\}$. Equation (26) implies that in the flexible-price equilibrium, firms' real marginal costs and similarly firms' markup over nominal marginal costs, are constant over time and across states.

## 3.2 The efficient equilibrium

The social planner of the SOE maximizes the representative household's utility subject to the production technology, the international risk-sharing condition and the resource constraint

$$\max_{C_t, Y_t, S_t} \delta_t \left( \frac{C_t^{1-\sigma} - 1}{1-\sigma} - \chi \frac{(Y_t / A_t)^{1+\phi}}{1+\phi} \right) \tag{27}$$

subject to

$$(C_t^*)^{-\sigma} = \delta_t \frac{S_t}{g(S_t)} C_t^{-\sigma}, \tag{28}$$

$$Y_t = (1-\alpha) g(S_t)^\eta C_t + \alpha S_t^\eta C_t^*. \tag{29}$$

An important characteristic of the social planner's optimization problem is that, in contrast to the individual household, she internalizes the terms of trade externality. The resulting optimality conditions can be combined to an equation for the SOE's real marginal costs[13]

$$\chi C^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) = \frac{1-\alpha}{(1-\alpha) \left[ 1 + (\sigma\eta - 1)\alpha \left( \frac{S_t}{g(S_t)} \right)^{1-\eta} \right] + \alpha\sigma\eta \delta_t^{-\frac{1}{\sigma}} \left( \frac{S_t}{g(S_t)} \right)^{\eta-\frac{1}{\sigma}}}. \tag{30}$$

The efficient equilibrium is then made up of stochastic processes $\{C_t, Y_t, S_t\}$, for all $t \geq 0$, that satisfy equations (28)-(30) given the exogenous processes $\{\delta_t, A_t, C_t^*\}$.

Equation (30) shows that unlike in the flexible-price equilibrium, real marginal

---

[13]See also Faia and Monacelli (2008). They derive a similar condition for the case without preference shocks.

costs are time-varying in the efficient equilibrium. Hence, the flexible-price equilibrium is inefficient. Interestingly, in the presence of the preference shifter $\delta_t$, this holds true even if the model is parameterized such that $\sigma\eta = 1$, a condition that has been shown to render the flexible-price allocation efficient if the economy is only buffeted by technology shocks and the subsidy $\nu$ is chosen appropriately.[14]

The next subsection contrasts the policy functions of the flexible-price equilibrium and the efficient equilibrium using the baseline calibration summarized in Table 1.

## 3.3   Equilibrium responses

Figure 1 shows the policy functions for consumption, output/labor, the terms of trade and the real exchange rate.[15] Since the baseline model features only one state variable, the policy functions are fully characterized by the equilibrium responses to the exogenous state $\delta_t$. Blue dashed lines represent optimal responses in the flexible-price equilibrium and red dash-dotted lines represent optimal responses in the efficient equilibrium.

The smaller $\delta_t$, the more the SOE's representative household appreciates future felicity relative to current felicity. Hence, in response to a decline in $\delta_t$, the household would like to save more and consume less. According to the international risk-sharing condition (15), a drop in $\delta_t$ has a direct negative effect on aggregate consumption in the SOE. At the same time, with home bias in consumption, the terms of trade and the real exchange rate depreciate. On the one hand, the depreciation of the real exchange rate mitigates the decline in aggregate consumption via the risk-sharing condition. On the other hand, the depreciation of the terms of trade leads consumers in the SOE and in the rest of the world to reallocate part of their consumption expenditures towards goods produced in the SOE. This is the expenditure-switching effect comprised in the aggregate resource constraint (20). Therefore, in our numerical example, equilibrium output/labor increases in response to a decline in $\delta_t$ and vice versa.

---

[14]See Galí and Monacelli (2005).

[15]Having approximated the policy function for the terms of trade, we obtain the policy function for the real exchange rate using equation (14).

Figure 1: Equilibrium responses: Efficient vs flexible-price equilibrium
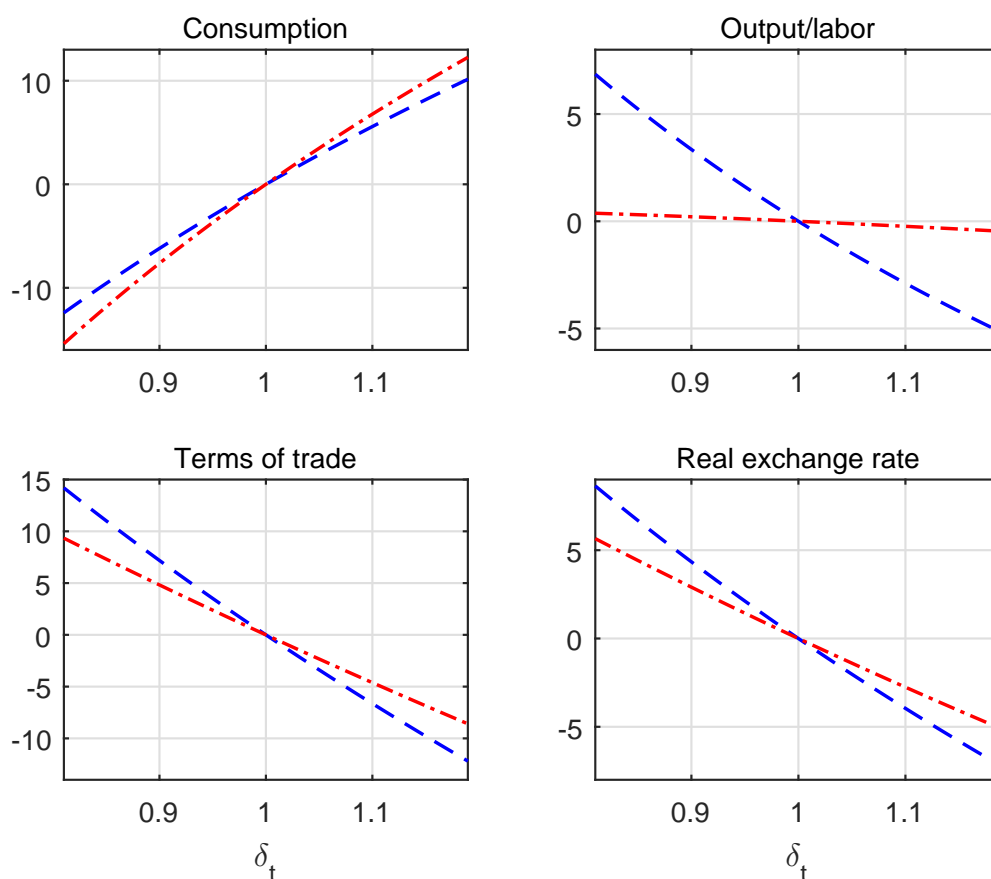


Note: Flexible-price equilibrium (blue dashed lines), Efficient equilibrium (red dash-dotted lines). Equilibrium responses are expressed in percentage deviations from the deterministic steady state.

The social planner internalizes this terms of trade externality in her decision making. By stabilizing the terms of trade relative to the flexible-price equilibrium, she substantially mitigates the increase in output/labor in response to a decline in $\delta_t$. At the same time, private consumption falls only slightly more than in the flexible-price equilibrium. This favorable trade-off arises due to the presence of perfect international risk-sharing, which weakens the otherwise tight link between labor income and consumption.

The efficient allocation and the flexible-price allocation are useful benchmarks for the analysis of discretionary equilibria in the sticky-price model considered next.

# 4 Optimal time-consistent monetary policy

This section analyses how the terms of trade externality affects equilibrium behavior and welfare of the SOE under optimal time-consistent monetary policies in the sticky-price model. I consider two alternative monetary policy regimes, that both act under discretion: (i) a policymaker who aims to maximize household welfare, also referred to as the benevolent policymaker, and (ii) a policymaker who aims to stabilize domestic price inflation. The analysis focuses on Markov-Perfect equilibria. Since the two policymakers do not possess a commitment device, they decide about policy at the time of implementation. In so doing, they take the decision rules of agents as given when evaluating alternative policies.

I first state the optimization problems of the two alternative monetary policy regimes and then present results on equilibrium dynamics and welfare.

## 4.1 The benevolent monetary policy regime

The benevolent policymaker solves a sequence of static optimization problems.[16] Specifically, each period $t$, she solves

$$\max_{C_t, Y_t, S_t, \pi_{H,t}, R_t} \delta_t \left( \frac{C_t^{1-\sigma} - 1}{1 - \sigma} - \chi \frac{(Y_t/A_t)^{1+\phi}}{1 + \phi} \right) \tag{31}$$

subject to the private sector equilibrium conditions (21) - (24), given $\mathbb{S}_t = [\delta_t, A_t, C_t^*]$, and taking as given $\{C_{t+j}, Y_{t+j}, S_{t+j}, \pi_{H,t+j}, R_{t+j}\}$ for all $j \geq 1$. The first order conditions are shown in the Appendix.

## 4.2 The domestic inflation-targeting monetary policy regime

Next, we consider the discretionary policymaker with a domestic inflation-targeting objective. Each period $t$, she solves

---

[16]Note that the baseline model can be described by a system of equations that features only exogenous state variables.

$$\max_{C_t,Y_t,S_t,\pi_{H,t},R_t} \quad -\frac{1}{2}\left(\pi_{H,t}-1\right)^2 \tag{32}$$

subject to the private sector equilibrium conditions (21) - (24), given $S_t$, and taking as given $\{C_{t+j}, Y_{t+j}, S_{t+j}, \pi_{H,t+j}, R_{t+j}\}$ for all $j \geq 1$.[17] In the baseline model without an effective lower bound on nominal interest rates, the authority is able to achieve its target criterion $\pi_{H,t} = 1$ for all $t$ and in all states, and replicates the flexible-price allocation.
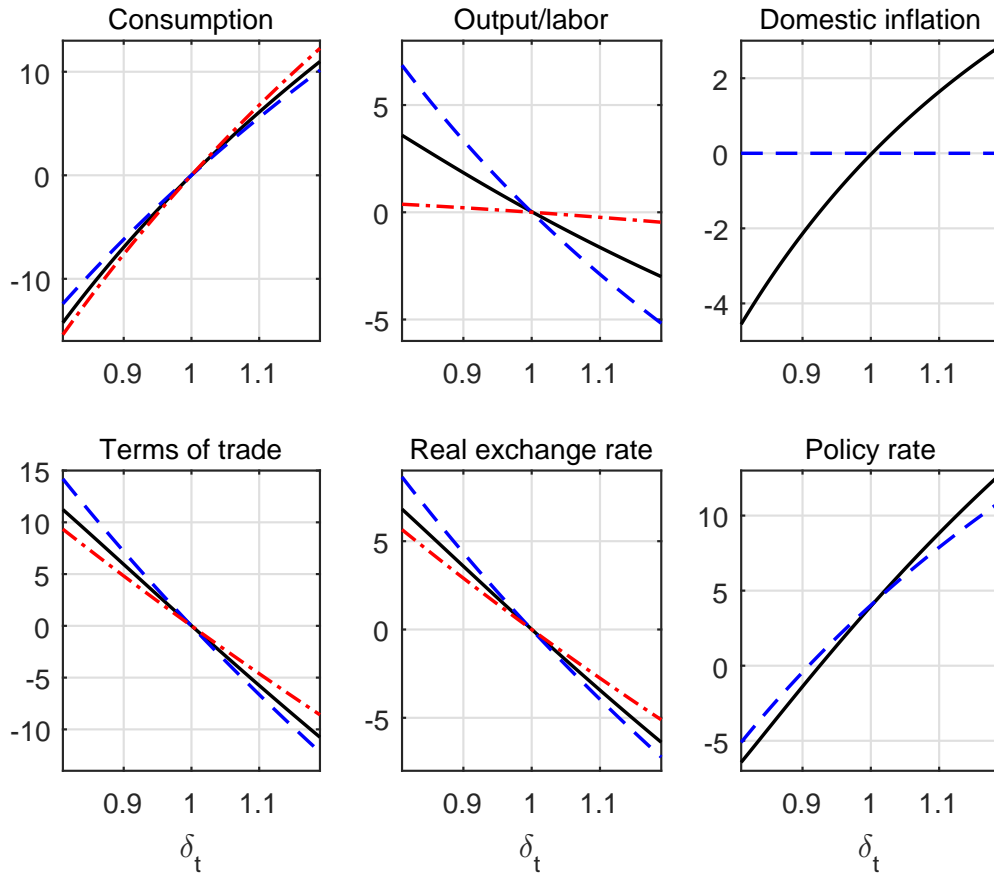
## 4.3 Equilibrium responses

Figure 2 shows equilibrium responses of consumption, output/labor, domestic price inflation, the terms of trade, the real exchange rate, and the one-period nominal interest rate to the discount factor shock, using again the baseline calibration summarized in Table 1. Optimal responses for the case where monetary policy is conducted by the benevolent policymaker are represented by black solid lines and optimal responses for the case where the monetary policymaker has a strict domestic inflation objective are represented by blue dashed lines. As a benchmark case I also plot the optimal responses associated with the efficient equilibrium, as represented by the red dash-dotted lines.

The benevolent policymaker in the sticky-price model deviates from the flexible-price allocation—which is implemented by the policymaker with a strict domestic inflation objective—towards the efficient allocation. While the terms of trade are more stable than in the flexible-price equilibrium they are more volatile than in the efficient equilibrium. This is because by deviating from the flexible-price allocation, the benevolent policymaker has to give up on domestic price stability, which in turn reduces the amount of resources available for consumption. The implementation of the efficient allocation is therefore not feasible, and the benevolent policymaker is confronted with a trade-off between stabilization of international relative prices to

---

[17]Here I have again made use of the fact that in the absence of an endogenous state variable, the policymaker solves a sequence of static optimization problems.

Figure 2: Equilibrium responses: Sticky-price model

Note: Benevolent discretionary policymaker (black solid lines), Discretionary policymaker with strict domestic inflation-targeting objective (blue dashed lines), Social planner (red dash-dotted lines). Equilibrium responses are expressed in percentage deviations from the deterministic steady state, and have been annualized for the inflation rate. The policy rate is expressed in annualized percentage points.

exploit the economy's market power in trade and stabilization of domestic prices to minimize the resource costs associated with domestic price adjustments.

Next, we will explore how the presence of this trade-off affects welfare of the SOE under the two discretionary monetary policy regimes.

## 4.4 Welfare

I assess the SOE's welfare associated with a particular monetary policy regime $p$ relative to the SOE's welfare in the efficient equilibrium, denoted by $EFF$. Here, $p \in \{BP, DIT\}$, where $BP$ denotes the benevolent policymaker and $DIT$ denotes

the strict domestic inflation-targeting policymaker. The SOE's welfare in period 0 associated with the efficient equilibrium conditional on the state of the economy is defined as

$$V^{EFF}(\mathbb{S}_0) = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \delta_t \left( \frac{C^{EFF}(\mathbb{S}_t)^{1-\sigma} - 1}{1-\sigma} - \chi \frac{(Y^{EFF}(\mathbb{S}_t)/A_t)^{1+\phi}}{1+\phi} \right), \qquad (33)$$

where $C^{EFF}(\mathbb{S}_t)$ and $Y^{EFF}(\mathbb{S}_t)$ are the optimal decision rules for consumption and output in the efficient equilibrium.

Similarly, I define the conditional welfare in period 0 associated with monetary policy regime $p \in \{BP, DIT\}$ as

$$V^p(\mathbb{S}_0) = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \delta_t \left( \frac{C^p(\mathbb{S}_t)^{1-\sigma} - 1}{1-\sigma} - \chi \frac{(Y^p(\mathbb{S}_t)/A_t)^{1+\phi}}{1+\phi} \right). \qquad (34)$$

Following Schmitt-Grohé and Uribe (2006), I express the welfare cost associated with monetary policy regime $p$ relative to the efficient equilibrium in terms of the share $\tau^p$ by which consumption in the efficient equilibrium would have to be reduced in order to equalize conditional welfare in the efficient equilibrium and in the discretionary equilibrium associated with policy regime $p$. Formally, $\tau^p$ is implicitly defined by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \delta_t \left( \frac{((1-\tau^p)C^{EFF}(\mathbb{S}_t))^{1-\sigma} - 1}{1-\sigma} - \chi \frac{(Y^{EFF}(\mathbb{S}_t)/A_t)^{1+\phi}}{1+\phi} \right) = V^p(\mathbb{S}_0). \qquad (35)$$

The solution for $\tau^p$ is derived in the Appendix.

Figure 3 plots the SOE's welfare costs associated with the benevolent monetary policymaker $\tau^{BP}$ (solid black line) and the strict domestic inflation-targeting policymaker $\tau^{DIT}$ (blue dashed line) for the baseline variant of the model with the preference shock.

For all considered states, the SOE's welfare cost is lower if the monetary policymaker is assigned a strict domestic inflation stabilization objective than if the poli-

Figure 3: Welfare cost for the SOE
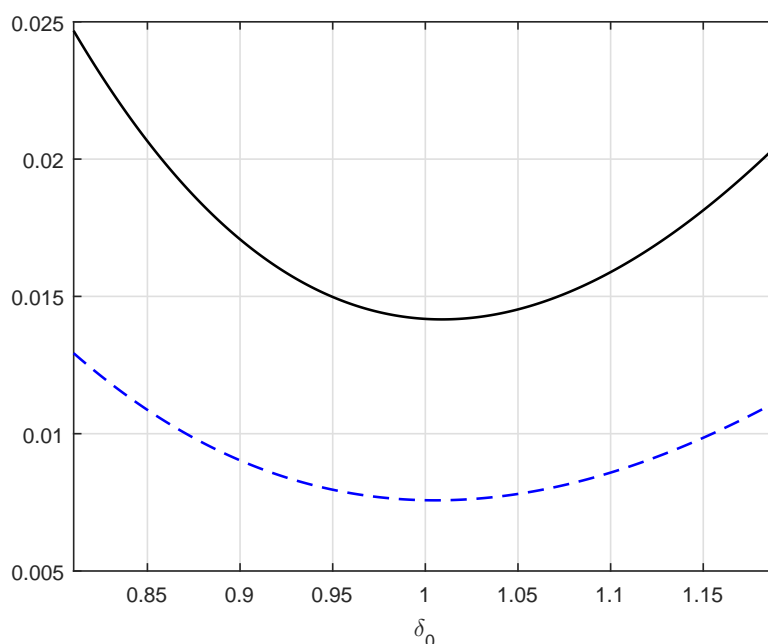


Note: Welfare costs associated with the optimal benevolent discretionary policymaker (solid black line) and the discretionary policymaker with a strict domestic inflation-targeting objective (blue dashed line). The welfare-cost measure $\tau^p$ is defined by equation (35) and expressed in percent.

cymaker aims to maximize household welfare.[18] Under a discretionary policymaker that aims to maximize household welfare, the gains from manipulating international relative prices are more than outweighed by the costs associated with fluctuations in domestic prices. Without policy commitment, the benevolent policymaker is unable to fully internalize these costs in the sense that there is no mechanism that prevents the policymaker in the future from treating the effects of her future policy decisions via expectations upon current economic decisions as bygones. By constraining the discretionary policymaker to focus on domestic inflation stabilization, society can eliminate the benevolent policymaker's temptation to exploit the SOE's monopoly power in trade.

The flexible-price allocation is, however, not optimal. Whether or not the appointment of a strict domestic inflation-targeting policymaker in place of the benevolent

---

[18]A common feature of the type of model considered here is that welfare costs are typically rather small in absolute terms if steady state inefficiencies have been eliminated. Also, here only one type of exogenous disturbance is considered at a time.

policymaker is welfare-improving depends on the relative importance of the terms of trade externality vis-a-vis the resource costs of domestic price adjustments. Figure 4 shows the average welfare costs for the SOE associated with the two monetary policy regimes for different values of the trade elasticity $\eta$.[19]

Figure 4: Average welfare cost as a function of the trade elasticity
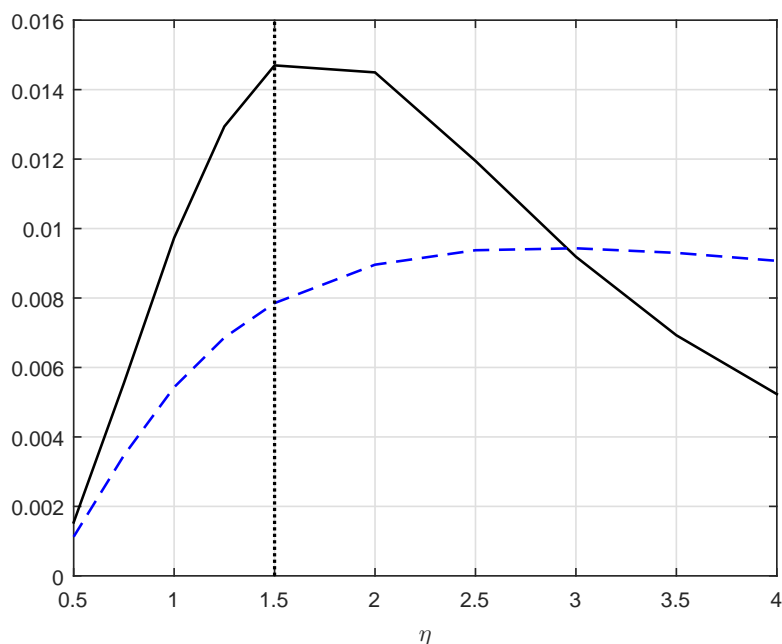


Note: Average welfare costs associated with the benevolent discretionary policymaker (solid black line) and the discretionary policymaker with a strict domestic inflation-targeting objective (blue dashed line) for different values of the trade elasticity $\eta \in [0.5, 4]$. The baseline value for the trade elasticity is indicated by the vertical dotted line. The welfare-cost measure $\tau^p$ is defined by equation (35) and expressed in percent. For average welfare costs, the unconditional expectations operator is applied to equation (35).

The baseline value of $\eta$ is indicated by the vertical dotted line. For values of the trade elasticity between 0.5 and about 3, the average welfare cost is lower under the domestic inflation-targeting policymaker (blue dashed line). For values of the trade elasticity higher than 3, the average welfare cost is lower under the benevolent policymaker (solid black line). The higher the trade elasticity, the stronger the expenditure-switching effect of a given change in relative prices and, hence, the larger the gain from a marginal deviation from domestic price stability.

---

[19]Average welfare costs are obtained from three million simulations.

To summarize, whether the benevolent policymaker can improve upon the flexible-price allocation when she lacks a commitment device is an empirical question. In particular, the numerical analysis suggests that for values of the trade elasticity commonly estimated in the New Keynesian open economy literature, the benevolent policymaker's terms of trade manipulations deteriorate national welfare if she acts under discretion.[20]

# 5   The time inconsistency problem

The welfare analysis presented in the previous section raises the question how policy under the discretionary benevolent policymaker differs from the Ramsey policy, i.e. the policy chosen by a benevolent policymaker that acts under commitment. After all, previous work has shown that with commitment the benevolent policymaker in general improves upon the flexible-price allocation and never implements an allocation inferior to the flexible-price allocation. Put differently, what is the time inconsistency problem of monetary policy in the SOE that prevents the discretionary policymaker from replicating the Ramsey policy? The question is addressed in this section. To do so, I first recapitulate the Ramsey problem, and then compare equilibrium dynamics under policy discretion and commitment in a preference shock scenario. A comparison of the welfare cost is presented in the Appendix.

## 5.1   The Ramsey problem

The Ramsey policymaker acts under commitment. In period 0, she chooses state-contingent paths for consumption, output, the terms of trade, and the domestic inflation rate to maximize conditional welfare subject to the sequence of constraints (22) -

---

[20]Christoffel et al. (2008) estimate a medium-scale SOE model of the euro area with a posterior mode for the trade elasticity parameter close to 2. Rabanal and Tuesta (2010) estimate a two-country model using data for the United States and the euro area, and find a trade elasticity parameter close to 1 for both countries. Justiniano and Preston (2010) estimate SOE models for Australia, Canada, and New Zealand. For all three countries, their median estimate of the trade elasticity parameter is below 1. However, the micro-empirical trade literature typically finds higher values.

(24). The details are relegated to the Appendix.[21] Unlike a discretionary policymaker, the Ramsey policymaker does not take decision rules characterizing future behavior as given, but fully internalizes how his policies affect the decision rules of the private sector. The Ramsey equilibrium can be characterized by a set of time-invariant policy functions $\left[C(\tilde{\mathbb{S}}_t), Y(\tilde{\mathbb{S}}_t), S(\tilde{\mathbb{S}}_t), \pi_H(\tilde{\mathbb{S}}_t)\right]$, where $\tilde{\mathbb{S}}_t = \left[\mathbb{S}_t, \lambda_{t-1}^{PC}\right]$, given $\lambda_{-1}^{PC} = 0$. The variable $\lambda_t^{PC}$ denotes the Lagrange multiplier associated with the Phillips curve constraint in period $t$. One can then infer the policy function for the nominal interest rate $R_t$ from the consumption Euler equation (21).

## 5.2 Commitment vs discretion: A preference shock scenario

We are now equipped to compare optimal benevolent policies under discretion and under commitment. Consider the following preference shock scenario. The economy is initially in the deterministic steady state. In the first period, $t = 0$, the preference shifter $\delta_t$ falls by one unconditional standard deviation. In the second period, it unexpectedly jumps back to its steady state. This scenario might appear rather extreme given the autoregressive process for the preference shock, but it is useful in cleanly illustrating the role of policy commitment. Importantly, in the initial period when the shock hits the economy, the Ramsey policymaker is not constrained by any promises made in the past, that is, $\lambda_{-1}^{PC} = 0$.

Figure 5 compares equilibrium dynamics associated with the benevolent discretionary policymaker (black lines with circles) and the Ramsey policymaker (magenta lines with crosses). On impact, domestic inflation drops less under the Ramsey policymaker than under the discretionary policymaker. At the same time, the initial depreciation of the terms of trade associated with the Ramsey policy is smaller. Hence, in the initial period, the Ramsey policymaker faces an improved trade-off between stabilization of domestic prices and stabilization of international relative prices compared to the discretionary policymaker. Both, the smaller drop in domestic inflation and the smaller depreciation of the terms of trade mitigate the initial increase in output/labor

---

[21]See also Faia and Monacelli (2008).

Figure 5: Discretion vs commitment: A preference shock scenario
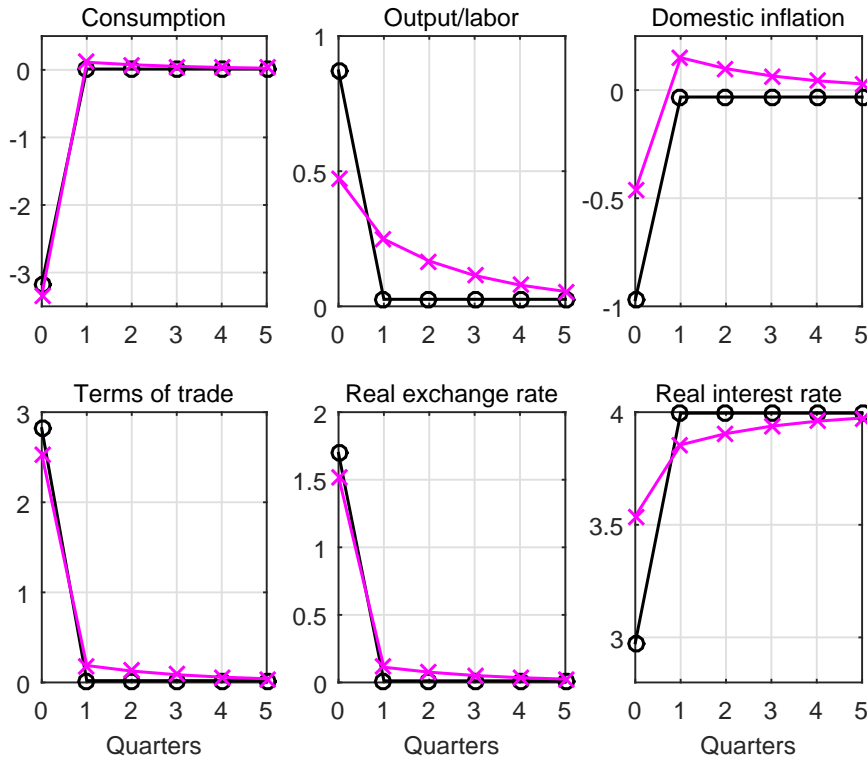


Note: Benevolent discretionary policymaker (solid lines with circles), Ramsey policymaker (magenta lines with crosses). Responses are expressed in percentage deviations from the deterministic steady state, and have been annualized for the inflation rate. The real interest rate is expressed in annualized percentage points.

relative to the case where the policymaker acts under discretion. The improved stabilization trade-off between domestic prices and international relative prices is a result of the Ramsey policies in subsequent periods. In particular, even so the shock returns to steady state in the second period, the Ramsey policymaker raises the real interest rate only gradually. In so doing, she engineers a temporary overshooting in future consumption and domestic inflation, that mitigate the initial drop in the two variables through expectations. Inheriting the inertia in the interest rate response, output/labor, the terms of trade and the real exchange rate adjust only gradually towards the risky steady state.

The response of the Ramsey policymaker is, however, time inconsistent, rendering the Ramsey allocation unattainable under policy discretion. Consider the discre-

tionary benevolent policymaker in the first period. Clearly, she would like the private sector to expect a gradual response of the policy rate, and therefore the real interest rate, conditional on the preference shock returning to its steady state in the next period. However, when the preference shock has disappeared in the second period, the discretionary policymaker has an incentive to renege on her earlier promise since from the perspective of the second period it is optimal to raise the policy rate immediately to its risky steady state. Doing so allows the policymaker to closely replicate the efficient allocation.[22] Without commitment, a policy announcement to adjust policy rates only gradually is therefore not credible, leaving the discretionary policymaker with an inferior stabilization trade-off compared to the Ramsey policymaker.

# 6 Additional results

This section presents some additional results. The first part explores how accounting for an effective lower bound on nominal interest rates affects the conclusions obtained in the baseline model. I find that, if anything, the effective lower bound strengthens the case for the appointment of a strict domestic inflation-targeting policymaker. The second part shows that the main conclusions from the baseline model continue to hold true if the SOE is buffeted by technology shocks instead of preference shocks. The final part explores the robustness of the welfare results with respect to selected parameter values.

## 6.1 The effective lower bound

So far, the analysis abstracted from the existence of an effective lower bound on nominal interest rates. This subsection compares the SOE's equilibrium behavior and welfare under the two discretionary monetary policy regimes when the lower bound is taken into account.

---

[22]Due to the presence of the optimized production subsidy $\nu$, the efficient allocation is attainable in the deterministic steady state. However, since certainty equivalence fails, there is a small wedge between the risky steady state and the deterministic steady state so that, strictly speaking, the discretionary policymaker can only approximately replicate the efficient allocation in the state where $\delta_t = 1$.

In the model with an effective lower bound, the optimization problems of the benevolent policymaker and the strict domestic inflation-targeting policymaker are augmented with an additional constraint

$$R_t \geq 1, \tag{36}$$

where, without loss of generality, I have set the lower bound on the gross nominal interest rate equal to 1. The first order conditions to the optimization problems of the two monetary policy regimes are shown in the Appendix. I use again the baseline calibration summarized in Table 1, except that I have to lower the standard deviation of the preference shock innovation $\sigma_\delta$ from 0.025 to 0.02 to ensure convergence of the solution algorithm.

Figure 6 shows equilibrium responses to the discount factor shock in the model with the lower bound. To focus on the optimal responses at and close to the lower bound, the plotted responses are truncated to the right at $\delta_t = 1$. For low realizations of the preference shifter, the lower bound becomes binding in the sticky-price model.

To better understand how the effective lower bound affects the optimal response functions under the two monetary policy regimes, Figure 7 plots the difference between the equilibrium responses in the model with the lower bound (as shown in Figure 6) and the responses in the model without the lower bound. In those states where the lower bound is binding, private consumption and domestic inflation is lower and the terms of trade and the real exchange are more appreciated than in the model without the lower bound. This is true for both policy regimes. However, the effect of the lower bound on the optimal responses is more pronounced in case of the benevolent policymaker (solid black lines) than under the domestic inflation-targeting policymaker (blue dashed lines). The benevolent policymaker's attempt to dampen the terms of trade depreciation relative to the flexible-price equilibrium in states where the preference shifter is low interacts with the effective lower bound constraint and exacerbates the relative appreciation of the terms of trade and the real exchange rate as well as the decline in domestic inflation in these states. Note also

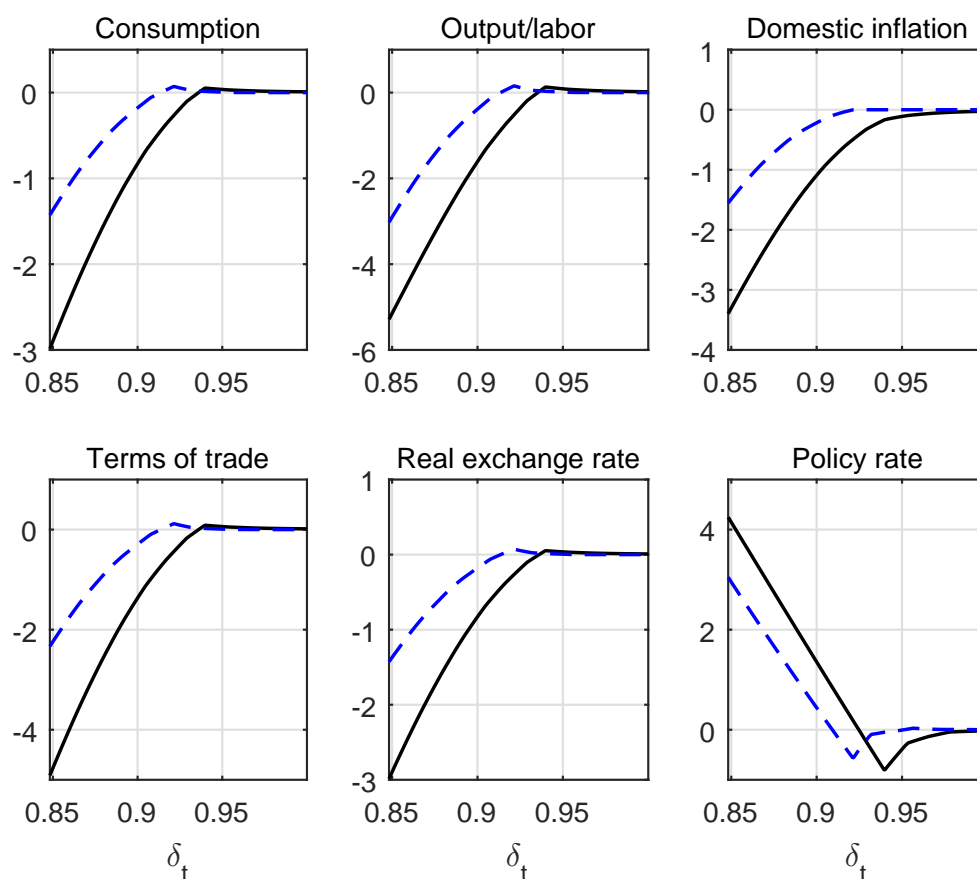## Figure 6: Equilibrium responses in the model with effective lower bound
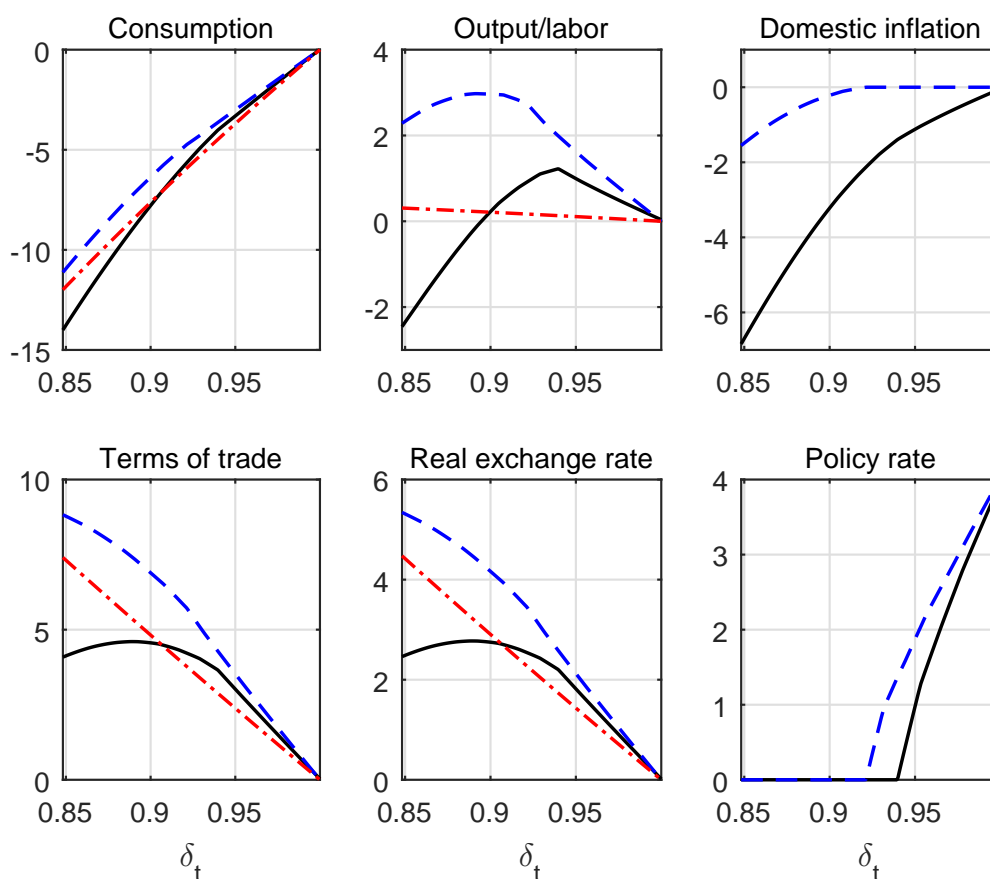


Note: Benevolent discretionary policymaker (black solid lines), Discretionary policymaker with strict domestic inflation-targeting objective (blue dashed lines), Social planner (red dash-dotted lines). Equilibrium responses are expressed in percentage deviations from the deterministic steady state, and have been annualized for the inflation rate. The policy rate is expressed in annualized percentage points.

that the threshold value for the preference shifter below which the lower bound becomes binding is lower for the domestic inflation-targeting policymaker than for the benevolent policymaker, and hence the frequency of effective lower bound events is lower under the policymaker that aims for domestic inflation stabilization (2% vs 6%).

Next, we consider how the effective lower bound constraint affects welfare of the SOE under the two monetary policy regimes. Figure 8 plots the welfare costs associated with the two regimes in the model with the lower bound constraint (dashed lines) and in the model without the constraint (solid lines).

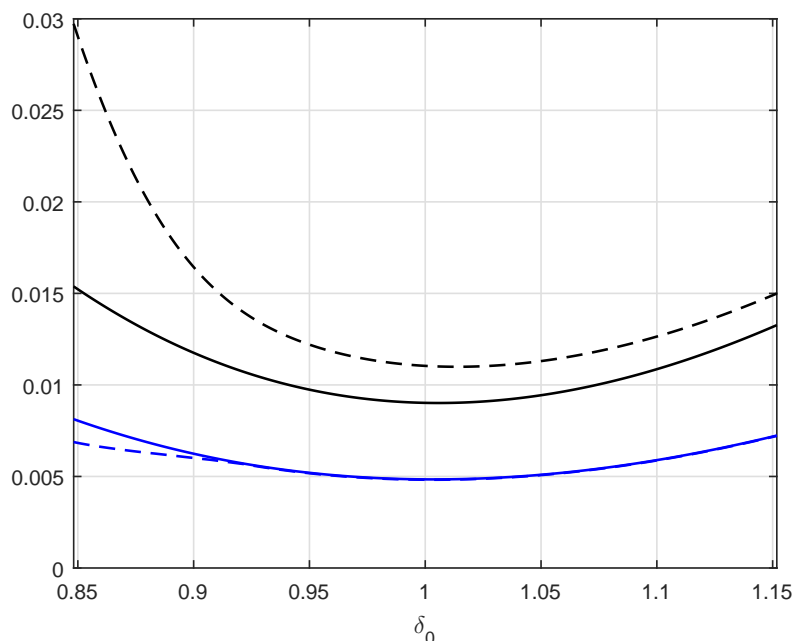In case of the benevolent policymaker (black lines), accounting for the effective

Figure 7: Equilibrium responses: Relative effect of the lower bound constraint



Note: Benevolent discretionary policymaker (black solid lines), Discretionary policymaker with strict domestic inflation-targeting objective (blue dashed lines). Shown is the difference between equilibrium responses in the model with lower bound and the responses in the model without lower bound.

lower bound constraint raises the conditional welfare cost in all states. In contrast, when a strict domestic inflation-targeting policymaker (blue lines) is in charge of monetary policy, accounting for the lower bound constraint reduces the welfare cost in some states. This is because in the flexible-price equilibrium—which is replicated by the domestic inflation-targeting policymaker in the model without the lower bound— the terms of trade are inefficiently volatile. In particular, in states where the preference shock is low, the terms of trade are more depreciated than in the efficient equilibrium. In the model with the lower bound constraint and a strict domestic inflation-targeting policymaker, the lower bound helps to stabilize the terms of trade since the constraint binds exactly in those states where the terms of trade are (otherwise) too depreciated.

Figure 8: Welfare cost with and without effective lower bound



Note: Welfare costs associated with the optimal benevolent discretionary policymaker (black lines) and the discretionary policymaker with a strict domestic inflation-targeting objective (blue lines) in the model without lower bound (solid lines) and in the model with lower bound (dashed lines). The welfare-cost measure $\tau^p$ is defined by equation (35) and expressed in percent.

In the numerical example, the gains from more stable international relative prices outweigh the higher resource costs from domestic price deflation under the domestic inflation-targeting regime.

## 6.2 Technology shocks

The baseline analysis focused on disturbances to the preference shifter $\delta_t$ while keeping the technology shock $A_t$ constant. We now consider the case where the SOE is buffeted by technology shocks instead of preference shocks. Following Faia and Monacelli (2008), the logarithm of $A_t$ is assumed to follow an AR(1) process

$$\log(A_t) = \rho_A \log(A_{t-1}) + \epsilon_t^A, \tag{37}$$

with $\rho_A = 0.95$, and a standard deviation of the i.i.d. innovation $\epsilon_t^A$ of $\sigma_A = 0.0056$.

Figure 9 shows the SOE's average welfare costs associated with the two discretionary monetary policy regimes for different values of the trade elasticity $\eta$.[23] As before, the solid black line represents the average welfare cost associated with the benevolent monetary policymaker and the blue dashed line represents the average welfare cost associated with the strict domestic inflation-targeting policymaker.

Figure 9: Average welfare cost: Model with technology shocks
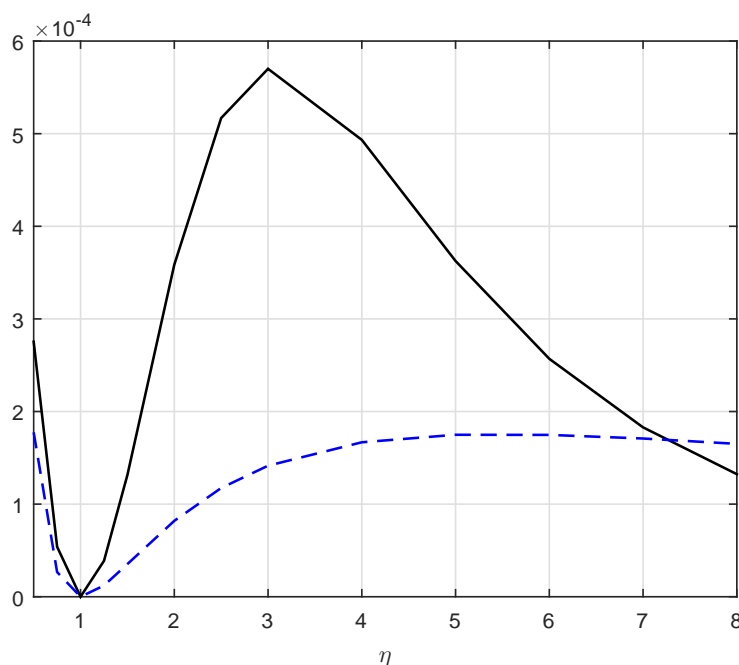


Note: Average welfare costs associated with the benevolent discretionary policymaker (solid black line) and the discretionary policymaker with a strict domestic inflation-targeting objective (blue dashed line) for different values of the trade elasticity $\eta \in [0.5, 8]$. The welfare-cost measure $\tau^p$ is defined by equation (35) and expressed in percent. For average welfare costs, the unconditional expectations operator is applied to equation (35).

For a wide range of parameter values, the discretionary policymaker with a domestic inflation objective leads to higher national welfare than the benevolent discretionary policymaker. The main result from the baseline analysis is thus robust to the incorporation of technology shocks into the model. A prominent special case arises if $\eta = 1$. Since the baseline calibration assumes log-utility in consumption, when $\eta = 1$ (and the lower bound on nominal interest rates is ignored), the flexible-price alloca-

---

[23]Average welfare costs are obtained from three million simulations as in the baseline analysis.

tion is not only attainable but also optimal, and both discretionary monetary policy regimes replicate the efficient allocation.

## 6.3 Sensitivity with respect to parameter values

Section 4.4 showed how the welfare ranking of the two discretionary monetary policy regimes depends on the value of the trade elasticity $\eta$. This subsection explores how the SOE's welfare depends on the calibration of a few other model parameters. The analysis is based on the baseline model with the stochastic preference shifter and without a lower bound on nominal interest rates.

Figure 10 shows how the SOE's average welfare cost associated with the benevolent policymaker (solid black lines) and the average welfare cost associated with the strict domestic inflation-targeting policymaker (blue dashed lines) varies with the price adjustment cost parameter $\omega$ (left panel), the openness parameter $\alpha$ (middle panel), and the inverse of the labor supply elasticity $\phi$ (right panel). All other parameters are kept fixed at their baseline values, respectively.

Figure 10: Average welfare cost: The role of selected parameters
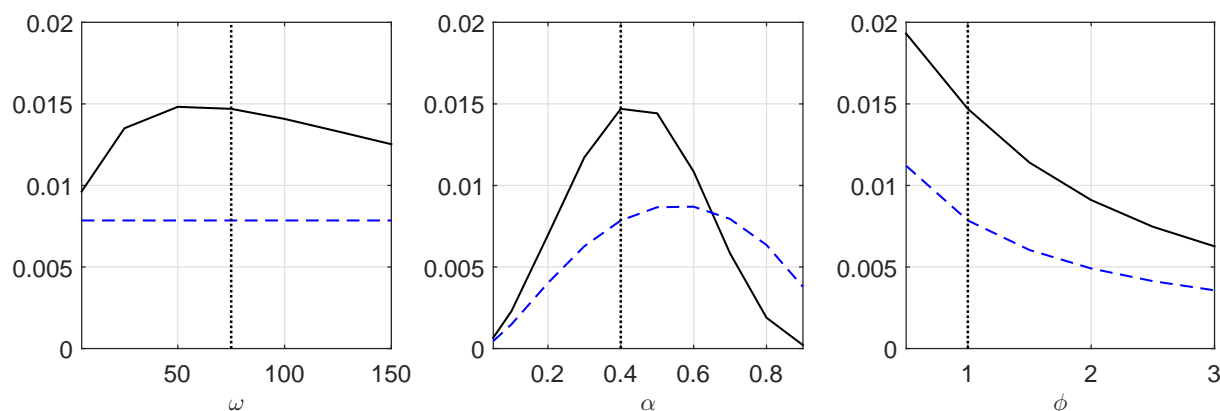


Note: Average welfare costs associated with the benevolent discretionary policymaker (solid black lines) and the discretionary policymaker with a strict domestic inflation-targeting objective (blue dashed lines) for different parameter values. The baseline value for the respective parameter is indicated by a vertical dotted line. The welfare-cost measure $\tau^p$ is defined by equation (35) and expressed in percent. For average welfare costs, the unconditional expectations operator is applied to equation (35).

For the price adjustment cost parameter, I consider values between 5 and 150.

In the absence of the lower bound on nominal interest rates, the domestic inflation-targeting policymaker always achieves her objective. Hence, the degree of price stickiness does not affect the welfare cost associated with the domestic inflation-targeting policymaker. Under the benevolent policymaker, the average welfare cost is a hump-shaped function of $\omega$. On the one hand, a higher value of $\omega$ translates into larger resource costs for a given amount of domestic price inflation. On the other hand, a higher value of $\omega$ reduces the sensitivity of domestic inflation with respect to changes in firms' real marginal costs, as can be seen from equation (19). The overall effect of a marginal increase in $\omega$ on the welfare cost thus depends on the relative strength of these two channels. Interestingly, the welfare ranking obtained under the baseline calibration holds up even when the price adjustment cost parameter is lowered to a value close to zero.

For the openness parameter $\alpha$, I consider values between 0.05 and 0.9. Under both policy regimes, the welfare cost are a hump-shaped function of $\alpha$. When $\alpha$ is close to zero, the SOE exhibits almost full home bias and the economy becomes very similar to a closed economy. Since the flexible-price allocation is efficient in the analogous closed economy model and attainable in the open economy model, the welfare costs associated with the two regimes converge to zero as $\alpha$ converges to zero. For intermediate values of $\alpha$, including the baseline calibration $\alpha = 0.4$, the domestic inflation-targeting policymaker leads to lower welfare cost than the benevolent policymaker, for the reasons discussed in Section 4.4. For high degrees of openness, however, there is a reversal in the welfare ranking of the two monetary policy regimes. The more open the economy, the smaller the effect of a change in the domestic preference shifter on international relative prices in the flexible-price equilibrium. This property is inherited by the equilibrium associated with the benevolent policymaker, but the volatility of the terms of trade is declining more rapidly in $\alpha$ than under the domestic inflation-targeting policymaker. This reflects the fact that, all else equal, the effect of a change in the terms of trade on domestic production is larger the more open the SOE. At the same time, ceteris paribus the effect on consumption is smaller the more

open the SOE.[24] Hence, the incentive for the benevolent policymaker to stabilize the terms of trade relative to the flexible-price equilibrium is increasing in $\alpha$. Crucially, however, the volatility of real marginal costs is a hump-shaped function of $\alpha$. Hence, for high degrees of openness, the benevolent policymaker faces a more benign trade-off between stabilization of domestic prices and stabilization of international relative prices than for intermediate degrees of openness.

Finally, for the considered range of parameter values, welfare cost are decreasing in the inverse of the labor supply elasticity $\phi$. While this holds true for both discretionary policymakers, welfare cost are lower under the domestic inflation-targeting policymaker than under the benevolent policymaker.

All in all, the main result from the baseline analysis that without commitment the benevolent policymaker's attempt to improve upon the flexible-price allocation can be self-defeating is thus quite robust with respect to the calibration of the model parameters. Only if domestically-produced goods and imported foreign goods are strong substitutes, or if the SOE exhibits a very high degree of openness, the gains from improved stabilization of international relative prices have been shown to outweigh the costs from bigger fluctuations in domestic prices.

# 7 Conclusion

Using a standard New Keynesian model of a SOE, I have shown that without commitment, the benevolent policymaker's attempt to improve national welfare by exploiting her country's monopoly power in trade can be self-defeating. This holds true even so I abstract from potential cross-border strategic interactions in policy making. The result has implications for the long-standing debate over the desirability of inward-looking versus outward-looking monetary policy objectives in open economies. In particular, while the optimal plan under commitment in the New Keynesian SOE framework considered here is, in general, outward-looking in the sense that there is a role for stabilizing international relative prices, the analysis in this paper shows that it can be

---

[24]See resource constraint (24) and the international risk sharing condition (22), respectively.

desirable to assign an inward-looking objective to the monetary policymaker if she lacks a commitment device.

In future work, the present analysis could be extended by relaxing the assumptions of perfect international risk sharing and complete exchange rate pass-through.

# References

**Basu, Susanto and Brent Bundick**, "Endogenous Volatility at the Zero Lower Bound: Implications for Stabilization Policy," Working Paper 21838, National Bureau of Economic Research December 2015.

**Benigno, Gianluca and Pierpaolo Benigno**, "Price Stability in Open Economies," *Review of Economic Studies*, 2003, *70* (4), 743–764.

**Bhattarai, Saroj and Konstantin Egorov**, "Optimal monetary and fiscal policy at the zero lower bound in a small open economy," Globalization and Monetary Policy Institute Working Paper 260, Federal Reserve Bank of Dallas January 2016.

**Christoffel, Kai, Guenter Coenen, and Anders Warne**, "The new area-wide model of the euro area: a micro-founded open-economy model for forecasting and policy analysis," Working Paper Series 944, European Central Bank October 2008.

**Clarida, Richard, Mark Gertler, and Jordi Galí**, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, December 1999, *37* (4), 1661–1707.

**Cook, David and Michael B Devereux**, "Exchange rate flexibility under the zero lower bound," *Journal of International Economics*, 2016, *101*, 52 – 69.

**Corsetti, Giancarlo and Paolo Pesenti**, "Welfare and Macroeconomic Interdependence," *The Quarterly Journal of Economics*, 2001, *116* (2), 421–445.

— , **Keith Kuester, and Gernot Mueller**, "Fixed to flexible: Rethinking Exchange Rate Regimes after the Great Recession," *IMF Economic Review*, 2017, *forthcoming.*

—, **Luca Dedola, and Sylvain Leduc**, "Optimal Monetary Policy in Open Economies," in Benjamin M. Friedman and Michael Woodford, eds., *Handbook of Monetary Economics*, Vol. 3 of *Handbook of Monetary Economics*, Elsevier, 2010, chapter 16, pp. 861–933.

**De Paoli, Bianca**, "Monetary policy and welfare in a small open economy," *Journal of International Economics*, February 2009, *77* (1), 11–22.

**Faia, Ester and Tommaso Monacelli**, "Optimal Monetary Policy in a Small Open Economy with Home Bias," *Journal of Money, Credit and Banking*, 06 2008, *40* (4), 721–750.

**Galí, Jordi and Tommaso Monacelli**, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 2005, *72* (3), 707–734.

**Groll, Dominik and Tommaso Monacelli**, "The Inherent Benefit of Monetary Unions," CEPR Discussion Papers 11416, C.E.P.R. Discussion Papers July 2016.

**Justiniano, Alejandro and Bruce Preston**, "Monetary policy and uncertainty in an empirical small open-economy model," *Journal of Applied Econometrics*, 2010, *25* (1), 93–128.

**Miranda, Mario J. and Paul L. Fackler**, *Applied Computational Economics and Finance*, The MIT Press, 2002.

**Nakata, Taisuke**, "Optimal fiscal and monetary policy with occasionally binding zero bound constraints," *Journal of Economic Dynamics and Control*, 2016, *73*, 220 – 240.

— **and Sebastian Schmidt**, "Conservatism and Liquidity Traps," Finance and Economics Discussion Series 2014-105, Board of Governors of the Federal Reserve System (U.S.) 2014.

**Persson, Torsten and Guido Tabellini**, "Designing Institutions for Monetary Stability," *Carnegie-Rochester Conference Series on Public Policy*, December 1993, *39* (1), 53–84.

**Rabanal, Pau and Vicente Tuesta**, "Euro-dollar real exchange rate dynamics in an estimated two-country model: An assessment," *Journal of Economic Dynamics and Control*, April 2010, *34* (4), 780–797.

**Rogoff, Kenneth**, "The Optimal Degree of Commitment to an Intermediate Monetary Target," *The Quarterly Journal of Economics*, November 1985, *100* (4), 1169–89.

**Schmitt-Grohé, Stephanie and Martín Uribe**, "Optimal Simple and Implementable Monetary and Fiscal Rules: Expanded Version," NBER Working Papers 12402, National Bureau of Economic Research, Inc August 2006.

**Sutherland, Alan**, "The expenditure switching effect, welfare and monetary policy in a small open economy," *Journal of Economic Dynamics and Control*, July 2006, *30* (7), 1159–1182.

**Svensson, Lars E O**, "Optimal Inflation Targets, 'Conservative' Central Banks, and Linear Inflation Contracts," *American Economic Review*, March 1997, *87* (1), 98–114.

**Tille, Cedric**, "The role of consumption substitutability in the international transmission of monetary shocks," *Journal of International Economics*, April 2001, *53* (2), 421–444.

**Walsh, Carl E**, "Optimal Contracts for Central Bankers," *American Economic Review*, March 1995, *85* (1), 150–67.

# A  Appendix

## Discretionary monetary policy regimes

This section presents the optimization problems and first order conditions associated with the two discretionary monetary policy regimes considered in the sticky-price model. We first consider the benevolent policymaker and then the policymaker with a strict domestic inflation-targeting objective.

### The benevolent monetary policy regime

Each period $t$, the benevolent policymaker solves

$$
\begin{aligned}
\max \quad & \delta_t \left( \frac{C_t^{1-\sigma} - 1}{1 - \sigma} - \chi \frac{(Y_t / A_t)^{1+\phi}}{1 + \phi} \right) \\
& + \lambda_t^{EE} \left[ \frac{1}{R_t} - \beta \mathrm{E}_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \pi_{H,t+1}^{-1} \frac{g(S_t)}{g(S_{t+1})} \right] \\
& + \lambda_t^{RS} \left[ \delta_t \frac{S_t}{g(S_t)} C_t^{-\sigma} - (C_t^*)^{-\sigma} \right] \\
& + \lambda_t^{RC} \left[ Y_t - (1-\alpha) \, g(S_t)^\eta C_t - \alpha S_t^\eta C_t^* - \frac{\omega}{2} \left( \pi_{H,t} - 1 \right)^2 \right] \\
& + \lambda_t^{PC} \left[ \epsilon Y_t \left( \chi C_t^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) - \frac{\epsilon - 1}{\epsilon} (1 + \nu) \right) - \omega (\pi_{H,t} - 1) \pi_{H,t} \right. \\
& \qquad \left. + \beta \omega \mathrm{E}_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{g(S_t)}{g(S_{t+1})} (\pi_{H,t+1} - 1) \pi_{H,t+1} \right] \\
& + \lambda_t^{ELB} \left[ R_t - 1 \right].
\end{aligned}
$$

The first order conditions are

$$\delta_t C_t^{-\sigma} - \sigma \frac{C_t^{-\sigma-1}}{R_t g(S_t)} \lambda_t^{EE} + \sigma C_t^{\sigma-1} \frac{g(S_t)}{S_t} \lambda_t^{RS} - (1-\alpha) g(S_t)^\eta \lambda_t^{RC} + \left[ \sigma \epsilon \chi C_t^{\sigma-1} \left( \frac{Y_t}{A_t} \right)^{1+\phi} g(S_t) \right.$$

$$\left. + \beta \omega \sigma E_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} C_t^{-1} \frac{g(S_t)}{g(S_{t+1})} (\pi_{H,t+1} - 1) \pi_{H,t+1} \right] \lambda_t^{PC} = 0,$$

$$-\chi \delta_t \frac{Y_t^\phi}{A_t^{1+\phi}} + \lambda_t^{RC} + \left[ \epsilon \left( \chi C_t^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) - \frac{\epsilon-1}{\epsilon} (1+\nu) \right) + \epsilon \phi \chi C_t^\sigma \frac{Y_t^\phi}{A_t^{1+\phi}} g(S_t) \right] \lambda_t^{PC} = 0,$$

$$(\pi_{H,t} - 1) \lambda_t^{RC} + (2\pi_{H,t} - 1) \lambda_t^{PC} = 0,$$

$$\frac{g'(S_t)}{g(s_t)^2} \frac{C_t^{-\sigma}}{R_t} \lambda_t^{EE} - \frac{(1-\alpha) g(S_t)^\eta}{S_t^2} C_t^\sigma \lambda_t^{RS} - \left[ (1-\alpha) \eta g(S_t)^{\eta-1} g'(S_t) C_t + \alpha \eta S_t^{\eta-1} C_t^* \right] \lambda_t^{RC}$$

$$+ \left[ \epsilon \chi C_t^\sigma \left( \frac{Y_t}{A_t} \right)^{1+\phi} g'(S_t) + \beta \omega E_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{g'(S_t)}{g(S_{t+1})} (\pi_{H,t+1} - 1) \pi_{H,t+1} \right] \lambda_t^{PC} = 0,$$

$$\lambda_t^{ELB} - \frac{C_t^{-\sigma}}{R_t^2 g(S_t)} \lambda_t^{EE} = 0,$$

as well as the complementary slackness conditions $R_t \geq 1$, $\lambda_t^{ELB} \geq 0$, $\lambda_t^{ELB}(R_t - 1) = 0$ and the private sector equilibrium conditions. Here, $g'(S_t) \equiv \alpha \left( \frac{S_t}{g(S_t)} \right)^{-\eta}$.

In the baseline model variant without the effective lower bound constraint, $\lambda_t^{ELB}, \lambda_t^{EE} = 0$ for all $t$.

### The domestic inflation-targeting regime

The monetary policymaker with a domestic inflation objective solves

$$
\max \quad -\frac{1}{2}\left(\pi_{H,t}-1\right)^2
$$

$$
+\lambda_t^{EE}\left[\frac{1}{R_t}-\beta\mathrm{E}_t\frac{\delta_{t+1}}{\delta_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\pi_{H,t+1}^{-1}\frac{g(S_t)}{g(S_{t+1})}\right]
$$

$$
+\lambda_t^{RS}\left[\delta_t\frac{S_t}{g(S_t)}C_t^{-\sigma}-\left(C_t^*\right)^{-\sigma}\right]
$$

$$
+\lambda_t^{RC}\left[Y_t-(1-\alpha)\,g(S_t)^\eta C_t-\alpha S_t^\eta C_t^*-\frac{\omega}{2}\left(\pi_{H,t}-1\right)^2\right]
$$

$$
+\lambda_t^{PC}\left[\epsilon Y_t\left(\chi C_t^\sigma\frac{Y_t^\phi}{A_t^{1+\phi}}g(S_t)-\frac{\epsilon-1}{\epsilon}(1+\nu)\right)-\omega(\pi_{H,t}-1)\pi_{H,t}\right.
$$

$$
\left.+\beta\omega\mathrm{E}_t\frac{\delta_{t+1}}{\delta_t}\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{g(S_t)}{g(S_{t+1})}(\pi_{H,t+1}-1)\pi_{H,t+1}\right]
$$

$$
+\lambda_t^{ELB}\left[R_t-1\right].
$$

The first order conditions imply

$$
\pi_{H,t}\leq 1,\quad R_t\geq 1,
$$

where $\pi_{H,t}=1$ if and only if $R_t>1$.

## The Ramsey policy regime

This section presents the optimization problem and the first order conditions associated with the Ramsey policymaker, i.e. the benevolent policymaker of the SOE with a commitment device. In period 0, the Ramsey policymaker chooses the state-contingent plan that maximizes welfare conditional on the state of the economy in period 0.

$$\max \quad \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \delta_t \left( \frac{C_t^{1-\sigma}-1}{1-\sigma} - \chi \frac{(Y_t/A_t)^{1+\phi}}{1+\phi} \right) \right.$$

$$+ \lambda_t^{RS} \left[ \delta_t \frac{S_t}{g(S_t)} C_t^{-\sigma} - (C_t^*)^{-\sigma} \right]$$

$$+ \lambda_t^{RC} \left[ Y_t - (1-\alpha)g(S_t)^\eta C_t - \alpha S_t^\eta C_t^* - \frac{\omega}{2}(\pi_{H,t}-1)^2 \right]$$

$$+ \lambda_t^{PC} \left[ \epsilon Y_t \left( \chi \delta_t \frac{Y_t^\phi}{A_t^{1+\phi}} - \frac{\epsilon-1}{\epsilon}(1+\nu)\delta_t C_t^{-\sigma} g(S_t)^{-1} \right) \right.$$

$$- \omega(\pi_{H,t}-1)\pi_{H,t}\delta_t C_t^{-\sigma}g(S_t)^{-1}$$

$$\left. \left. + \beta\omega\mathrm{E}_t\delta_{t+1}C_{t+1}^{-\sigma}g(S_{t+1})^{-1}(\pi_{H,t+1}-1)\pi_{H,t+1} \right] \right\}.$$

The first order conditions are

$$\delta_t C_t^{-\sigma} + \sigma C_t^{\sigma-1}\frac{g(S_t)}{S_t}\lambda_t^{RS} - (1-\alpha)g(S_t)^\eta\lambda_t^{RC} + \epsilon\frac{\epsilon-1}{\epsilon}(1+\nu)\sigma\delta_t C_t^{-\sigma-1}g(S_t)^{-1}Y_t\lambda_t^{PC}$$

$$+ \omega\sigma\delta_t C_t^{-\sigma-1}g(S_t)^{-1}(\pi_{H,t}-1)\pi_{H,t}\left(\lambda_t^{PC}-\lambda_{t-1}^{PC}\right) = 0,$$

$$(\pi_{H,t}-1)\lambda_t^{RC} + \delta_t C_t^{-\sigma}g(S_t)^{-1}(2\pi_{H,t}-1)\left(\lambda_t^{PC}-\lambda_{t-1}^{PC}\right) = 0,$$

$$-\chi\delta_t\frac{Y_t^\phi}{A_t^{1+\phi}} + \lambda_t^{RC} + \epsilon\delta_t\left(\chi\frac{Y_t^\phi}{A_t^{1+\phi}} - \frac{\epsilon-1}{\epsilon}(1+\nu)C_t^{-\sigma}g(S_t)^{-1} + \phi\chi\frac{Y_t^\phi}{A_t^{1+\phi}}\right)\lambda_t^{PC} = 0,$$

$$-\frac{(1-\alpha)g(S_t)^\eta}{S_t^2}C_t^\sigma\lambda_t^{RS} - \left[(1-\alpha)\alpha\eta g(S_t)^{2\eta-1}S_t^{-\eta}C_t + \alpha\eta S_t^{\eta-1}C_t^*\right]\lambda_t^{RC}$$

$$+ \alpha\epsilon\frac{\epsilon-1}{\epsilon}(1+\nu)\delta_t Y_t C_t^{-\sigma}g(S_t)^{\eta-2}S_t^{-\eta}\lambda_t^{PC} + \alpha\omega\delta_t C_t^{-\sigma}(\pi_{H,t}-1)\pi_{H,t}g(S_t)^{\eta-2}S_t^{-\eta}\left(\lambda_t^{PC}-\lambda_{t-1}^{PC}\right) = 0,$$

as well as the private sector equilibrium conditions, where $\lambda_{-1}^{PC}=0$.

## Measuring welfare costs

The conditional welfare cost associated with monetary policy regime $p$ relative to the efficient equilibrium is expressed in terms of the share $\tau^p$ by which consumption in the efficient equilibrium would have to be reduced in order to equalize con-

ditional welfare in the efficient equilibrium and in the equilibrium associated with policy regime $p$. Formally, $\tau^p$ is implicitly defined by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \delta_t \left( \frac{((1-\tau^p)C^{EFF}(\mathbb{S}_t))^{1-\sigma} - 1}{1-\sigma} - \chi \frac{(Y^{EFF}(\mathbb{S}_t)/A_t)^{1+\phi}}{1+\phi} \right) = V^p(\mathbb{S}_0). \quad \text{(A.1)}$$

Making use of the assumption that $\sigma = 1$, one can rewrite (A.1) as

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \delta_t \log(1-\tau^p) = V^p(\mathbb{S}_0) - V^{EFF}(\mathbb{S}_0). \quad \text{(A.2)}$$

Solving for the welfare cost measure $\tau^p$, one obtains

$$\tau^p = \exp\left[ \frac{(1-\beta)(1-\beta\rho_\delta)}{(1-\beta)\delta_0 + \beta(1-\rho_\delta)} \left( V^p(\mathbb{S}_0) - V^{EFF}(\mathbb{S}_0) \right) \right]. \quad \text{(A.3)}$$

When reporting average welfare costs, $\tau^p$ is instead calculated as follows

$$\tau^p = \exp\left[ (1-\beta) \left( \mathrm{E}V^p(\mathbb{S}_0) - \mathrm{E}V^{EFF}(\mathbb{S}_0) \right) \right], \quad \text{(A.4)}$$

where the unconditional expectations operator E is taken with respect to the unconditional distribution of the exogenous state variables.

## Welfare cost under commitment and under discretion

This section compares the welfare cost for the SOE under the Ramsey policy regime (i.e. policy commitment) with those under the two discretionary monetary policy regimes. The welfare-cost measure $\tau^p$ is defined in equation (35) of Section 4.4, where now $p \in \{BP, DIT, RAM\}$ with $RAM$ denoting the Ramsey policymaker. Figure 11 plots the SOE's welfare costs under the three regimes for the baseline variant of the model conditional on the initial state $\delta_0$.

The Ramsey policymaker (magenta dash-dotted line) improves upon the flexible-price allocation, which is implemented by the discretionary policymaker with a domestic inflation objective (blue dashed line). Policy credibility plays a key role for

Figure 11: Welfare cost for the SOE: Commitment vs discretion
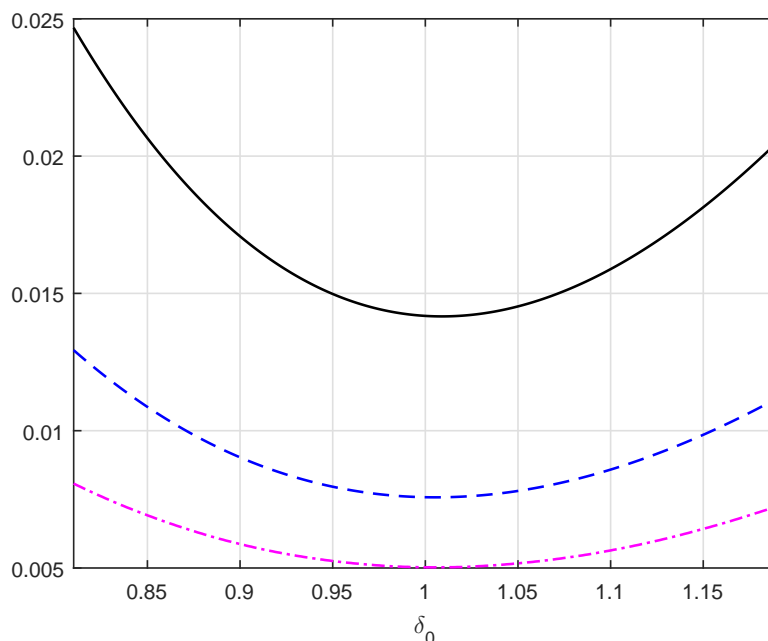


Note: Welfare costs associated with the optimal benevolent discretionary policymaker (solid black line), the discretionary policymaker with a strict domestic inflation-targeting objective (blue dashed line), and the Ramsey policymaker (magenta dash-dotted line). The welfare-cost measure $\tau^p$ is defined by equation (35) and expressed in percent.

the attainability of this welfare improvement. Without commitment, the benevolent policymaker (solid black line) is associated with higher welfare cost than the strict domestic inflation-targeting policymaker. Quantitatively, the welfare cost from deviations from domestic price stability under discretion are larger than the respective welfare gain under commitment.

## Numerical algorithm and solution accuracy

I solve the stochastic SOE model using the collocation method with linear splines as basis functions. The time iteration procedure proceeds in the following steps:

1. Construct the grid points (collocation nodes) for the state variables. Use a Gaussian quadrature scheme to discretize the normally distributed innovations to the exogenous state variables.

2. Start with a guess for the basis coefficients.

3. Use the current guess for the basis coefficients to approximate the expectation terms associated with next period's decisions.

4. Solve the system of equilibrium conditions for the current period's decisions.

5. Update the guess for the basis coefficients using the obtained decisions for the current period. If the new guess is sufficiently close to the old one, the algorithm has converged. Otherwise, go back to step 3.

The collocation nodes are distributed with a support covering 4 unconditional standard deviations below and above the steady state of the exogenous state variables. I use MATLAB routines from the CompEcon toolbox of Miranda and Fackler (2002) to obtain the Gaussian quadrature approximation of the shock innovations, and to evaluate the basis functions.

The solution accuracy is assessed by means of the Euler equation error function

$$
EE(\mathbb{S}_t) \equiv \left| 1 - \beta R(\mathbb{S}_t) E_t \frac{\delta_{t+1}}{\delta_t} \left( \frac{C(\mathbb{S}_{t+1})}{C(\mathbb{S}_t)} \right)^{-\sigma} \pi_H(\mathbb{S}_{t+1})^{-1} \frac{g(s(\mathbb{S}_t))}{g(S(\mathbb{S}_{t+1}))} \right|.
$$

In case of the Ramsey policy regime, $\mathbb{S}_t$ has to be replaced with $\tilde{\mathbb{S}}_t = \left[ \mathbb{S}_t, \lambda^{PC}_{t-1} \right]$. Table 2 reports the average of the Euler equation error function for the baseline calibration of the model with preference shocks. Results are based on a simulated equilibrium path with 100,000 periods and reported in base 10 logarithms. Hence, according to the simulations agents in the economy on average make less than a \$1 mistake for each \$1 million spent.

Table 2: Solution accuracy: Euler equation errors in base 10 logarithms

| Regime | Average error |
| --- | --- |
| Benevolent policymaker (discretion) | -6.80 |
| Domestic inflation-targeting policymaker (discretion) | -8.59 |
| Ramsey policymaker (commitment) | -6.28 |

**Sebastian Schmidt**
European Central Bank, Frankfurt am Main, Germany; email: sebastian.schmidt@ecb.europa.eu