Optimal inflation target in small open economies: the role of asymmetric nominal rigidities

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Abstract

This paper examines the optimal inflation target in a small open economy with potentially asymmetric nominal rigidities. Whereas symmetric nominal rigidities -as depicted in standard, closed economy, New Keynesian models- generally advocate for a zero inflation target, under asymmetric rigidities a positive average inflation becomes desirable. To explore this dichotomy we develop a model of a small open economy incorporating downward nominal wage rigidities via a linear-exponential (linex) adjustment cost function. The model also integrates two salient features for emerging markets: indexation to past inflation and the dollarization of international prices (for both exports and imports). We employ a second-order approximation to solve the model, selecting the parameters related with nominal rigidities using a method-of-moments approach, using data from Uruguay. Our findings suggest a long-term inflation target of 3.5% (on an annual basis), with targets in the range of 2 to 5% yielding relatively similar welfare costs. We further delve into how various model elements contribute to these findings, highlighting a novel mechanism stemming from the interplay between downward wage rigidities and wage indexation to past inflation.

JEL *classification*: E4 ; E5.
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1 Introduction

Countries conducting monetary policy under an inflation targeting-framework seek to keep inflation on average at a positive but small value, known as the inflation target. In contrast, many standard models pose that either a negative or a zero target is instead desirable, as highlighted by (Schmitt-Grohé and Uribe, 2010). For instance, the famous Friedman rule recommends using monetary policy to eliminate the opportunity cost of holding money, which in the long run leads to a negative average inflation. In this context, a large number of papers attempt to quantify what is the most desirable long-term inflation target. In this literature, a number of frictions and/or externalities that reduce the welfare of agents are considered and whose impact could be reduced with a positive inflation rate. Indeed, in the presence of price rigidities, a positive inflation can help to accelerate the adjustment of real prices, an argument that dates back to Tobin (1972), who argued that a positive inflation is necessary to "grease the wheels" of the economy. In a meta analysis of this literature, Diercks (2019) documents 440 different contributions that aim to quantify the optimal level of inflation. However, most of the literature has focused in closed economy frameworks: in the compilation done by Diercks (2019), less than 20 studies address what should be the optimal inflation in the context of a small open economy.[1]

Recently, some studies have explored the role of downward wage rigidities, as well as the impact of the dollar as the dominant international currency in determining the price of tradable goods. Moreover, in many emerging countries prices and, especially, wages feature a non trivial degree of indexation to past inflation; an inheritance from their high-inflation past. The role of these characteristics, which are empirically relevant for most emerging economies, have not yet been integrated into the analysis of the optimal inflation target in the context of small and open economies. This paper contributes to this discussion by incorporating these features into a small open economy model to study the optimal inflation target.

Downward nominal wage rigidities have been integrated in different ways into the standard New Keynesian framework to study optimal monetary policy (*e.g.*, with menu costs as in Fagan and Messina (2009), by considering nominal wage reductions extremely costly as in Benigno and Antonio Ricci (2011) or by imposing a constraint on the nominal wage as a function of its previous value as in Schmitt-Grohé and Uribe (2016, 2022)).[2] A computationally-convenient way to incorporate this feature is to model nominal wage rigidities using an adjustment-costs approach with a linear-exponential (linex) function as in Kim and Ruge-Murcia (2009, 2011), which yields nominal wages decreases being more costly than increases. Theses studies find that, when the central bank follows a simple Taylor rule, the optimal inflation rate for the US should be between 0.75 and 1% (in annualized terms), depending on the money demand assumption. Using the same specification for adjustment costs and adding labor-search frictions, Abo-Zaid (2013) concludes that the optimal inflation rate for the US should be close to 1.81% in the absence of money demand.[3] Again,

[1] An argument to target a positive inflation that has been widely analyzed is the existence of a zero lower bound of policy rate (*e.g.,* Billi et al., 2008; Coibion et al., 2012; Blanco, 2021; Amano and Gnocchi, 2020). We do not explore this characteristic, in part because, as the great-recession period showed, the zero lower bound seems to be less of a concern for emerging countries.

[2] See also Evans (2020).

[3] The study of Carlsson and Westermark (2016) considers the interaction between nominal (temporally fixed) wage rigidities and search and matching frictions. Their calibration on the US economy results in a Ramsey optimal

all these studies assume a closed economy framework.

Another main relevant feature in emerging economies is the role that the US dollar has as a dominant currency in the pricing (DCP) of tradable goods. Several studies have analyzed the effect of dominant currency pricing for optimal monetary policy (*e.g.,* Corsetti et al., 2007; Devereux et al., 2007; Goldberg and Tille, 2009; Casas et al., 2017; Egorov and Mukhin, 2020). Their main finding in terms of the optimal monetary policy is that emergent economies should aim to stabilize domestic prices. In addition, indexation, particularly of wages, seems to also be a pervasive feature in emerging economies; see, for instance, the evidence reported in Messina and de Galdeano (2014), Castellanos et al. (2004), Caballero et al. (2023) and the survey in Ha et al. (2019). However, the implications of these two characteristics for the optimal inflation target have not been addressed.

We build a small open economy model with downward nominal wage rigidities, wage indexation and dollar currency pricing (for exports and imports) to compute the welfare-maximizing inflation target, in the context of monetary policy conducted by a Taylor rule. Nominal rigidities are modeled as adjustment cost for changing prices, in the spirit of Rotemberg (1982). However, for wages we depart from the quadratic-adjustment cost approach in this seminal contribution, assuming instead a linex function (as in Kim and Ruge-Murcia (2009, 2011)), leading to wage cuts being much more costly than wage increases. In such a setup, reaching situations where it would be desirable to lower nominal wages is socially costly. Thus, the greater the probability that these circumstances materialize, the more convenient it is to have a higher average inflation rate, as it will minimize the likelihood of these undesirable events.

This asymmetric wage-adjustment setup is augmented by indexation, such that asymmetric costs are incurred whenever wage inflation differs from the previous-period CPI inflation. Besides wages, the model also features adjustment costs to change in prices. In particular, exports of domestic goods are assumed to be sticky in foreign currency, in line with the DCP paradigm. We calibrate our model using data from Uruguay, a country in which these previously-discussed characteristics are empirically relevant. Parameters related to nominal rigidities are chosen by a method-of-moments approach, trying to replicate selected second-moments characterizing the dynamics of prices and wages in Uruguay.

Under our baseline parametrization, we find an optimal inflation target of 3.5% in annualized terms. We also find that values in the 2 to 5% range generate only mild welfare costs relative to the optimal value, while larger deviations from the optimal are socially more costly. We then investigate how different model features affect these results. We uncover a non-trivial interaction between asymmetric wage adjustment and indexation: while in the absence of wage indexation to past inflation an asymmetric cost function generates a larger optimal target than with a symmetric specification, the opposite is true if wage are fully indexed to past inflation. Therefore, the emphasis of the previous literature on downward wage rigidities to justify a positive target needs to be re-evaluated if wage indexation is a relevant feature.

We also study how the choice of inflation target interacts with the way monetary policy is conducted around this target. In particular, when parameters of the Taylor rule make monetary

inflation rate of 1.15%. More recently, the analysis of Mineyama (2022) adds heterogeneity in labor productivity, introducing in this way additional inefficiencies in the allocation of labor across sectors. Considering that wage adjustment costs are represented by a fixed cost and a linear cost proportional to the size of wage changes, the calibration of the model for the US economy results in an optimal inflation rate of 2%.

policy relatively more dovish about inflation, the optimal target is larger than when monetary policy responds more actively to inflation deviations. This happens because a more dovish policy induces a larger nominal volatility, inducing additional welfare cost that can be reduced with a higher average inflation. In other words, the discussion about the optimal target is not independent from how monetary policy will be conducted when inflation deviates from the target.

The rest of the paper is organized as follows. The next section describes the baseline model, its parameterization and discusses the different trade-offs that arise in choosing an optimal inflation target. Section 3 presents the main results of our analysis. Section 4 concludes.

2 Baseline Model

The setup is one of a cashless small open economy with incomplete financial markets, under rational expectations. There are several goods: home, imported and final goods. The final consumption good is composed of home and imported goods. The home good can also be exported. Additionally, there exist an endowment of commodities that is fully exported. Except for commodities, the markets for other goods and labor have a monopolistic-competitive structure, where prices and wages are subject to adjustment costs. Prices of home goods are sticky in domestic currency when consumed locally, while they are sticky in dollars when they are exported (in line with the dominant-currency-pricing literature). Imported goods also face price adjustment costs. Households derive utility from consumption and leisure, and have access to international and domestic bonds. Monetary policy is implemented by a Taylor-type rule. The rest of this section describes the different agents in the model, the aggregation and market-clearing conditions, the policy rule, the calibration of the model and provides intuition regarding the optimal inflation target.

2.1 Households

Households seek to maximize,

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\log \left(c_t - \phi_C \frac{\tilde{c}_{t-1}}{a_{t-1}} \right) - \Xi^h \frac{(h_t)^{1+\varphi}}{1+\varphi} \right] \right\} \tag{1}$$

subject to the constraint,

$$P_t c_t + S_t B_t^{H^*} + B_t^T + T_t \leq \widetilde{W}_t h_t + S_t \frac{B_{t-1}^{H^*}}{a_{t-1}} R_{t-1}^* + \frac{B_{t-1}^T}{a_{t-1}} R_{t-1} + \Omega_t.$$

Here, $\beta \in (0,1)$ is the subjective discount factor, $\phi_C \in (0,1)$ captures habits in consumption, while $\Xi^h, \varphi > 0$ are parameters describing the dis-utility of labor. The growth rate of permanent (non-stationary) productivity shock is denoted by a_t,[4] c_t denotes consumption, $\tilde{c}_t$ is average consumption (in equilibrium $c_t = \tilde{c}_t$), h_t are hours worked, $B_t^{H^*}$ are holdings of foreign bonds (with gross interest rate R_t^*), B_t^T are holdings of domestic treasuries (with rate R_t), T_t are lump-sum taxes/transfers,

[4]We assume the model features a long-run stochastic real trend, in the form of a labor-augmenting total factor productivity (TFP) shock, inducing a balanced-growth path. Accordingly, the variables appearing in this description have already been detrended.

S_t is the nominal exchange rate (local currency units per unit of foreign currency), P_t is the price of final consumption goods, $\widetilde{W}_t$ is the nominal wage obtained by the representative household and Ω_t denotes profits from the ownership of all firms in the economy.[5]

Letting $\beta^t \frac{\lambda_t}{P_t}$ denote the Lagrange multiplier associated with the resource constraint, the optimality conditions are:

$$\lambda_t = \frac{1}{c_t - \phi_C \frac{c_{t-1}}{a_{t-1}}}, \qquad \widetilde{w}_t \lambda_t = \psi(h_t)^{\varphi}, \qquad \lambda_t = \frac{\beta}{a_t} R_t^* E_t \left\{ \frac{\pi_{t+1}^S \lambda_{t+1}}{\pi_{t+1}} \right\}, \qquad \lambda_t = \frac{\beta}{a_t} R_t E_t \left\{ \frac{\lambda_{t+1}}{\pi_{t+1}} \right\},$$

where $\widetilde{w}_t = \frac{\widetilde{W}_t}{P_t}$, $\pi_t \equiv \frac{P_t}{P_{t-1}}$, and $\pi_t^S \equiv \frac{S_t}{S_{t-1}}$.

The first equation links the Lagrange multiplier with the marginal utility of consumption, while the second represents the inter-temporal trade-off characterizing labor supply. The third and fourth equations characterize the inter-temporal trade-offs related to the choices of foreign and domestic bonds. For future references, let $\chi_{t,t+\tau} \equiv \frac{\beta^\tau}{a_t} \frac{\lambda_{t+\tau}}{\lambda_t} \frac{P_t}{P_{t+\tau}}$ be the stochastic discount factor for claims in domestic currency τ periods ahead. Moreover, P_t will represent the numeraire, used to compute relative prices.

2.2 Labor markets and wage setting

Households supply labor services to a continuum of intermediaries $i \in [0, 1]$, which in turn supply labor to firms. Households are indifferent between working in any of these markets and there are no differences in the quality of labor provided in each of them. The total number of hours allocated to the : $h_t = \int_0^1 h_{it} \mathrm{d}i$.

Firm's labor demand h_t^d is a CES combination of workers from each of these labor markets,

$$h_t^d = \left[\int_0^1 h_{it}^{1-\frac{1}{\epsilon_W}} \mathrm{d}i \right]^{\frac{\epsilon_W}{\epsilon_W - 1}},$$

where $\epsilon_W > 1$ is the elasticity of substitution across labor markets. Letting $W_{i,t}$ denote the nominal wage charged by intermediary i, and W_t the wage payed by firms, the demand for each labor variety is,

$$h_{it} = \left[W_{i,t} / W_t \right]^{-\epsilon_W} h_t^d.$$

Given this, the following is the relationship between the final wage W_t and those for each variety: $(W_t)^{1-\epsilon_W} = \int_0^1 W_{i,t}^{1-\epsilon_W} \mathrm{d}i$.

Taking the demand as given, the intermediary i hires homogeneous labor services from households paying wages $\widetilde{W}_t$ which, in addition to W_t and h_t^d, are taken as given. It's choice boils down to choosing wages to maximize the present value of profits, subject to adjustment costs given by:

$$\Phi_W \left(\frac{\pi_t^W}{\pi_t^{I,W}} \right) W_t h_t^d,$$

[5] Throughout this paper, uppercase letters denote nominal variables in levels, while lowercase letters indicate real variables (detrended if required, as previously discussed), relative prices, or rates of change. Variables without time subscript denote non-stochastic steady-state values. Finally, we use the notation $\widehat{x}_t \equiv \ln(x_t/x)$ for a generic variable x_t.

where $\Phi_W(\cdot)$ is a convex function satisfying $\Phi_W(1) = 0$ (we postpone the discussion about the specific functional forms). In addition, $\pi_t^{I,W}$ is the rate at which wages can change in period t without generating adjustment costs; capturing indexation (discussed below).

Using the factor $\chi_{t,t+h}$, the part of discounted profits relevant for the choice of $W_{i,t}$ is given by:

$$h_t^d \left[\left(\frac{W_{i,t}}{W_t} \right)^{-\epsilon_W} \left(W_{i,t} - \widetilde{W}_t \right) - \Phi_W \left(\frac{\pi_t^W}{\pi_t^{I,W}} \right) W_t \right] - E_t \left\{ \chi_{t,t+1} W_{t+1} h_{t+1}^d \Phi_W \left(\frac{\pi_{t+1}^W}{\pi_{t+1}^{I,W}} \right) \right\}.$$

Maximization yields the optimality condition,

$$\left[(1-\epsilon_W) \left(\frac{W_{i,t}}{W_t} \right)^{-\epsilon_W} + \epsilon_W \left(\frac{W_{i,t}}{W_t} \right)^{-\epsilon_W - 1} \frac{\widetilde{W}_t}{W_t} - \Phi_W' \left(\frac{\pi_t^W}{\pi_t^{I,W}} \right) \frac{W_t}{W_{i,t-1} \pi_t^{I,W}} \right] h_t^d + ...$$
$$+ E_t \left\{ \chi_{t,t+1} W_{t+1} h_{t+1}^d \Phi_W' \left(\frac{\pi_{t+1}^W}{\pi_{t+1}^{I,W}} \right) \frac{W_{i,t+1}}{(W_{i,t})^2 \pi_{t+1}^{I,W}} \right\} = 0.$$

Letting $\pi_t^W \equiv \frac{W_t}{W_{t-1}}$ and $w_t \equiv \frac{W_t}{P_t}$, and focusing in a symmetric equilibrium this condition becomes:

$$(\epsilon_W - 1) = \epsilon_W \frac{\widetilde{w}_t}{w_t} - \Phi_W' \left(\frac{\pi_t^W}{\pi_t^{I,W}} \right) \frac{\pi_t^W}{\pi_t^{I,W}} + E_t \left\{ \chi_{t,t+1} \frac{h_{t+1}^d}{h_t^d} \Phi_W' \left(\frac{\pi_{t+1}^W}{\pi_{t+1}^{I,W}} \right) \frac{(\pi_{t+1}^W)^2}{\pi_{t+1}^{I,W}} \right\}.$$

This is the non-linear version of the wage Phillips curve in this model.

2.3 Final consumption

At the wholesale level, a set of competitive firms supply the final consumption good using the following technology:

$$y_t^C = \left[\omega^{1/\eta} \left(c_t^H \right)^{1-1/\eta} + (1-\omega)^{1/\eta} \left(c_t^F \right)^{1-1/\eta} \right]^{\frac{\eta}{\eta-1}}. \tag{2}$$

These good are sold at price P_t. Nominal profits are given by $P_t y_t^C - P_t^H c_t^H - P_t^F c_t^F$, and its maximization leads to the following demands:

$$c_t^F = (1-\omega) \left(p_t^F \right)^{-\eta} y_t^c, \qquad c_t^H = \omega \left(p_t^H \right)^{-\eta} y_t^c,$$

with $p_t^F \equiv P_t^F / P_t$ and $p_t^H \equiv P_t^H / P_t$.

2.4 Home goods

They are produced competitively using labor (h_t^d) according to the production function

$$y_t^H = z_t a_t h_t^d,$$

where z_t is a temporary productivity shock and a_t is the growth rate of the stochastic productivity trend. Profit maximization generates the following optimization condition,

$$\tilde{p}_t^H z_t a_t = w_t,$$

where $\tilde{p}_t^H$ is the wholesale price of these goods (in relative terms of the numeraire).

These goods are sold at the retail level domestically and abroad by two different monopolistic-competitive structures: firms supplying to domestic consumers set prices in domestic currency units, while those selling abroad choose prices in foreign currency units, each of them facing price adjustment costs similar to those described for wages. This is in line with the dominant-currency pricing literature (*e.g.*, Gopinath et al., 2020) documenting that international price of tradables is generally denominated in a few dominant currencies. This in turn will limit the expenditure-switching channel, by preventing real depreciation to have a direct effect into export's demand.

Let mc_t^H and $mc_t^{H^*}$ be the real marginal costs for both type of monopolists (expressed in terms of their own goods price). These should satisfy

$$p_t^H mc_t^H = \tilde{p}_t^H, \quad rer_t p_t^{H^*} mc_t^{H^*} = \tilde{p}_t^H,$$

with $p_t^{H^*} = \frac{P_t^{H^*}}{P_t^*}$ and $rer_t \equiv \frac{S_t P^*}{P_t}$. Notice that, in the last equation $rer_t \equiv \frac{S_t P_t^*}{P_t}$ is included, as exporters are assumed to set prices in foreign currency.

The optimality conditions for prices chosen by monopolists in each group lead to the following non-linear Phillips curves:

$$(\epsilon_H - 1) = \epsilon_H mc_t^H - \Phi_H' \left(\frac{\pi_t^H}{\pi_t^{I,H}} \right) \frac{\pi_t^H}{\pi_t^{I,H}} + E_t \left\{ \chi_{t,t+1} \frac{(y_{t+1}^H - c_{t+1}^{H^*})}{(y_t^H - c_t^{H^*})} \Phi_H' \left(\frac{\pi_{t+1}^H}{\pi_{t+1}^{I,H}} \right) \frac{(\pi_{t+1}^H)^2}{\pi_{t+1}^{I,H}} \right\},$$

$$(\epsilon_{H^*} - 1) = \epsilon_{H^*} mc_t^{H^*} - \Phi_{H^*}' \left(\frac{\pi_t^{H^*}}{\pi_t^{I,H^*}} \right) \frac{\pi_t^{H^*}}{\pi_t^{I,H^*}} + E_t \left\{ \chi_{t,t+1} \frac{c_{t+1}^{H^*}}{c_t^{H^*}} \Phi_{H^*}' \left(\frac{\pi_{t+1}^{H^*}}{\pi_{t+1}^{I,H^*}} \right) \frac{(\pi_{t+1}^{H^*})^2}{\pi_{t+1}^{I,H^*}} \right\},$$

where $c_t^{H^*}$ denotes exports of home goods. These are analogous to that previously derived for wages.

2.5 Imported goods

Imported goods are sold domestically by two sets of firms. One of them includes competitive firms charging a domestic price equal to the foreign price multiplied by the exchange rate (*i.e.*, these goods have perfect pass-through), thus for them the relevant relative price is rer_t. The other group of firms buy imported goods from abroad and sell them domestically in a monopolistic-competitive structure, subject to price adjustment costs. Let $p_t^{Fs} = \frac{P_t^{Fs}}{P_t}$ be the (relative) price of these goods domestically (in local currency) and mc_t^F the real marginal costs, these two are related by:

$$rer_t = p_t^{Fs} mc_t^F.$$

Given this marginal cost, the optimality condition for these prices is analogous to those previously described for wages and home goods, *i.e.*,

$$(\epsilon_F - 1) = \epsilon_F mc_t^F - \Phi_F' \left(\frac{\pi_t^{Fs}}{\pi_t^{I,F}} \right) \frac{\pi_t^{Fs}}{\pi_t^{I,F}} + E_t \left\{ \chi_{t,t+1} \frac{c_{t+1}^F}{c_t^F} \Phi_F' \left(\frac{\pi_{t+1}^{Fs}}{\pi_{t+1}^{I,F}} \right) \frac{(\pi_{t+1}^{Fs})^2}{\pi_{t+1}^{I,F}} \right\},$$

where $\pi_t^{Fs} = \frac{P_t^{Fs}}{P_{t-1}^{Fs}}$. Finally, letting α_{Fs} denotes the fraction of imported goods whose prices are subject to adjustment costs, the following determines the overall domestic import price:

$$p_t^F = \left(p_t^{Fs}\right)^{\alpha_{Fs}} \left(rer_t\right)^{1-\alpha_{Fs}}.$$

2.6 Commodities

At any time t there is an endowment of commodities y_t^{Co} that is fully exported at an exogenous international price $P_t^{Co^*}$ (in foreign currency).

2.7 Fiscal and monetary policy

The consolidated balance sheet of the government is given by:

$$P_t g_t = S_t \left(B_t^{T^*} - R_t^* B_{t-1}^{*,T} \right) + \left(B_t^T - R_{t-1} B_{t-1}^T \right) + T_t,$$

where g_t is an exogenous process. In this setup, T_t adjusts to satisfy this constraint (fiscal policy is passive) and thus Ricardian equivalence holds (only the path of g_t matters for equilibrium determination).

In turn, the monetary authority sets a Taylor-type rule for interest rates:

$$\left(\frac{R_t}{\bar{R}} \right) = \left(\frac{R_{t-1}}{\bar{R}} \right)^{\alpha_R} \left[\left(\frac{\pi_t}{\bar{\pi}} \right)^{\alpha_\pi} \left(\frac{\Delta y_t^H}{a} \right)^{\alpha_{y^*}} \left(\frac{\pi_t^s}{\bar{\pi}^s} \right)^{\alpha_{\pi^s}} \right]^{1-\alpha_R}, \tag{3}$$

where Δy_t^H is the growth rate of non-commodity's GDP. The rule determines the evolution of the policy rate (relative to it's steady state value $\bar{R}$), as a function of deviations of inflation from the target ($\bar{\pi}$), GDP growth from the long-run trend (a), the nominal exchange rate from its steady state value ($\bar{\pi}^S$) and past interest rates. All steady state values $\bar{R}$, $\bar{\pi}$, $\bar{\pi}^S$ and a are consistent with each other (*i.e.*, as implied by equilibrium relationships). They are a function of the chosen inflation target $\bar{\pi}$ and parameters such as the discount factor β, productivity trend a and foreign average inflation π^*. The calibration of the parameters describing the rule will be discussed below.

2.8 Rest of the world

The domestic economy interacts with the rest of the world through several channels. The interest rate is given by:

$$R_t^* = R_t^W \exp \left\{ \phi_B \left(\bar{b} - b_t^* \right) \right\} \xi_t^*, \tag{4}$$

where R_t^W denotes the world interest rate, the term $\exp\left\{\phi_B\left(\bar{b}-b_t^*\right)\right\}$ is a debt-elastic premium (with $b_t^* \equiv (B_t^{H^*}-B_t^{T^*})/P_t^*$ denoting aggregate net-foreign assets in real terms) which serves as the "closing device" (see Schmitt-Grohé and Uribe, 2003), ϕ_B, $\bar{b}$ are parameters and ξ_t^* is a risk-premium shock that captures deviations from the interest rate parity. In the baseline model, ϕ_B is calibrated to a small but positive number, while $\bar{b}$ is pinned down by the average trade-balance to output ratio.

Finally, the foreign demand for exports is determined by:

$$c_t^{H^*} = \left(p_t^{H^*}\right)^{\eta^*} y_t^*,$$

where y_t^* denotes output in the rest of the world. As $p_t^{H^*} = \frac{P_t^{H^*}}{P_t^*}$ is a ratio of two dollar-denominated prices, the real exchange rate plays no direct role in determining exports; in line with the dominant-currency pricing assumption.

Overall, the following are exogenous processes determined in the rest of the world: foreign inflation $\pi_t^* = \frac{P_t^*}{P_{t-1}^*}$, the relative price of commodities $p_t^{Co^*} = \frac{P_t^{Co^*}}{P_t^*}$, the world interest rate R_t^W, the risk premium ξ_t^* and foreign output y_t^*.

2.9 Aggregation and market clearing

Market clearing conditions for home goods are,

$$y_t^H = c_t^H + c_t^{H^*} + g_t, \qquad y_t^H = z_t a_t h_t.$$

Moreover, we assume that all nominal adjustment costs are paid in final consumption units, such that aggregate supply of these goods (y_t^C) equals not only aggregate demand for these (c_t) but also all relevant adjustment costs:

$$\begin{aligned} y_t^C =& c_t + \Phi_P^H\left(\frac{\pi_t^H}{\pi_t^{I,H}}\right) p_t^H\left[y_t^H - c_t^{H^*}\right] + \Phi_P^{H^*}\left(\frac{\pi_t^{H^*}}{\pi_t^{I,H^*}}\right) p_t^{H^*} rer_t c_t^{H^*} + \Phi_F^{H^*}\left(\frac{\pi_t^{Fs}}{\pi_t^{I,F}}\right) p_t^{Fs} c_t^F \\ &+ \Phi_W\left(\frac{\pi_t^W}{\pi_t^{I,W}}\right) w_t h_t. \end{aligned}$$

In this way, as long as these adjustment costs are not zero, price rigidities makes the economy consume inside the production possibility frontier, leading to welfare losses.

In the labor market, the equilibrium condition is $h_t^d = h_t$. We also define real GDP as:

$$gdp_t = c_t + g_t + c_t^{H*} + y_t^{Co} - c_t^F,$$

In addition, the following relate inflation rates with relative prices:

$$\frac{p_t^H}{p_{t-1}^H} = \frac{\pi_t^H}{\pi_t}, \qquad \frac{rer_t}{rer_{t-1}} = \frac{\pi_t^s \pi_t^*}{\pi_t}, \qquad \frac{p_t^{F^*}}{p_{t-1}^{F^*}} = \frac{\pi_t^{F^*}}{\pi_t^*}, \qquad \frac{p_t^{H^*}}{p_{t-1}^{H^*}} = \frac{\pi_t^{H^*}}{\pi_t^*}, \qquad \frac{w_t}{w_{t-1}} = \frac{\pi_t^W}{\pi_t a_{t-1}}.$$

Finally, the evolution of net foreign assets follows from the resource constraints of households, firms and the government:

$$rer_t b_t^* + tb_t = rer_t * \frac{b_{t-1}^*}{a_{t-1}\pi_t^* R_{t-1}^*},$$

where the trade-balance in real terms tb_t is given by:

$$tb_t \equiv rer_t p_t^{Co^*} y_t^{Co} + p_t^H c_t^H - p_t^F c_t^F.$$

2.10 Functional forms

Here we describe the functional forms used for adjustment costs as well as the assumptions regarding the indexation process. Firms choosing prices face a quadratic adjustment cost as in Rotemberg (1982):

$$\Phi_j\left(\frac{\pi_t^j}{\pi_t^{I,j}}\right) = \frac{\phi_j}{2}\left[\frac{\pi_t^j}{\pi_t^{I,j}} - 1\right]^2, \tag{5}$$

for $j = H, H^*, F$. The parameter ϕ_j determines the degree of price stickiness (if $\phi_j = 0$, prices are flexible in sector j).

For wages we specify a linex function, following Kim and Ruge-Murcia (2009, 2011):

$$\Phi_W\left(\frac{\pi_t^W}{\pi_t^{I,W}}\right) = \frac{\phi_W}{\psi_W^2}\left[e^{-\psi_W\left(\frac{\pi_t^W}{\pi_t^{I,W}}-1\right)} + \psi_W\left(\frac{\pi_t^W}{\pi_t^{I,W}} - 1\right) - 1\right]. \tag{6}$$

Here, Φ_W captures the overall stickiness, while ψ_W determines the degree of asymmetry in the function (if $\psi_W \to 0$, the function converges to a quadratic equation as in (5)). Figure 1 plots the linex function for alternative parameter values, assuming no indexation, comparing also with the quadratic-adjustment-cost case. As it can be seen from Table 1, our baseline parametrization implies a curve close to the green one in the figure.

Finally, for all prices and wages featuring nominal rigidities we allow for the possibility of indexation. In particular, for prices we consider:

$$\pi_t^{I,j} = [\pi_{t-1}]^{\mu_j},$$

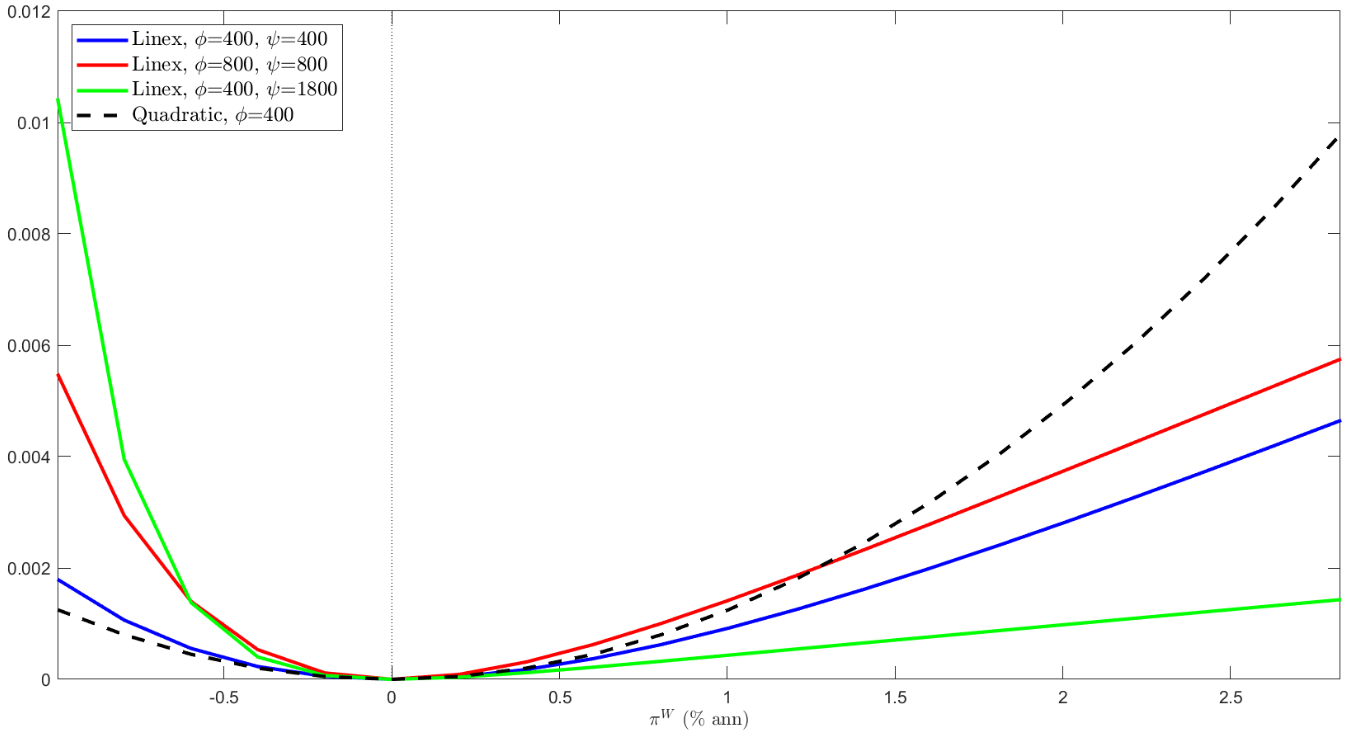
for $j = H, H^*, F$.

Here μ_j determines the degree of indexation to past inflation. The structure for wages is slightly different:

$$\pi_t^{I,W} = [\pi_{t-1}]^{\mu_W} a_{t-1}^{\mu_{Wa}}.$$

The parameter μ_{Wa} is included because, according to the model, nominal wages do not only increase in the long run due to inflation but also because of long-run productivity growth.

Figure 1: Linex adjustment-cost function



We calibrate our model based on the Uruguayan economy. Since 2005, wages in Uruguay are adjusted according to the result of negotiations between firms and workers of each production sector that takes place once a year at the Council of Wages (*Consejo de Salarios*), where the government serves as a facilitator and who may decide the wage adjustment if no agreement is achieved between both parties. This particular feature of the Uruguayan economy makes nominal wage reductions very costly. In addition, these wage agreement also feature indexation clauses that are also asymmetric (i.e. wages are updated if realized inflation is higher that the target). Therefore, the functional form chosen seems appropriate to model the aggregate of wages.

2.11 Parametrization

The selection of parameter values closely follows the estimation of a DSGE model for Uruguay carried out by Basal et al. (2016). Here, we discuss three key aspects that are most relevant for the analysis carried out in this paper; while Table 2 in the appendix presents the complete calibration. First, in terms of exogenous driving forces, we focus on those for which we have an empirical counterpart available. These are all the external shocks previously mentioned: foreign inflation π_t^*, the relative price of commodities $p_t^{Co^*} = \frac{P_t^{Co*}}{P_t^*}$, the world interest rate R_t^W, the risk premium ξ_t^* (approximated by the EMBI index for Uruguay) and foreign output y_t^* (commercial-partners real GDP). In addition, the process for output from the commodity sector, y^{Co}, is also estimated from the data. One exception is the stationary TFP process z_t, which is relevant to account for dynamics of GDP but for which we do not have an observable counterpart. For all these exogenous variables we assume that they are determined by an AR(1) processes and their parameters are chosen based on Basal et al. (2016).

Second, the baseline parameters for the Taylor rule are $\alpha_R = 0.74$, $\alpha_\pi = 1.6$, $\alpha_{y^*} = 0.4$, $\alpha_{\pi^s} = 0$; again following the estimation in Basal et al. (2016). Finally, parameters related to price and wage rigidities are chosen by a generalized-method-of-moments approach, seeking to minimize the distance between the following moments generated by the model and those observed in the data:

- Moments: Variance and auto-covariances of order 1 and 2.
- Variables: Core inflation of domestic goods, core inflation of imported goods (excluding Meat and Dairy products) and nominal wage inflation.

In this moment-matching process, second moments in the model are computed with a second-order approximation to the equilibrium condition. Table 1 describes the resulting values for nominal-rigidity-related parameters used in the baseline specification.

Table 1: Calibration of nominal rigidity parameters

ϕ_H	μ_H	ϕ_{H^*}	μ_{H^*}	ϕ_F	μ_F	ϕ_W	ψ_W	μ_W
821	0.53	3380	0	2	1	387	1807	1

Besides these, we assume $\mu_{Wa} = 1$ (to maintain a balanced growth path assumption) and we also set $\alpha_{Fs} = 0.66$ (following Cuitiño et al., 2022, estimation for Uruguay) implying that around 1/3 of import prices satisfy the law of one price.

In term of price rigidities, the estimation approach yields a relatively larger degree of price stickiness in the export price of home goods ($\phi_{H^*} = 3380$), although with no indexation. In turn, the domestic price of home goods features a smaller degree of price rigidities ($\phi_H = 821$) although with an indexation of more than 50% to previous period inflation ($\mu_H = 0.53$). In turn, the parameter characterizing import price rigidities yield a virtually flexible-price result ($\phi_F = 2$).

Finally, the estimated parameters imply a highly asymmetric wage adjustment cost function, with ψ_W being almost 4.7 times larger than ϕ_W. The estimation also assigns a value for $\mu_W = 1$ implying full indexation of wages to past inflation.

2.12 Discussion about optimal inflation target

The goal of the paper is to characterize the value of $\bar{\pi}$ in (3) that maximizes welfare (defined below). This choice, in turn, is related to the presence of nominal rigidities (otherwise money is neutral in this model, so alternative values for $\bar{\pi}$ would produce the same level of welfare). In the absence of indexation, either price and wage adjustment cost functions are minimized at zero inflation. In particular, as foreign inflation is assumed to be positive, achieving zero domestic imported inflation would require a negative nominal depreciation rate. Besides this observation, in steady state all these can be achieved simultaneously.

In a stochastic equilibrium there are, however, several trade-offs. First, full price and wage stability cannot be achieved at the same time; a trade-off that arises also in closed economy models. Second, in an open economy setup and leaving wages aside, there is also a trade-off because both domestic and export prices of home goods, as well as imported goods, are sticky and therefore using the nominal exchange rate to minimize distortions coming from domestic-price stickiness will exacerbate inefficiencies from import- and export-price rigidities. Thus, optimal policy will require a positive target in a stochastic equilibrium to balance these trade-offs.

As it is well known, welfare is affected by overall volatility (which requires working with a second-order of approximation to equilibrium conditions). In addition, if there are asymmetries (like those induced by the linex adjustment costs assumed for wages) it is desirable to reduce the chance of reaching situations in which the welfare costs are relatively higher; *i.e.*, those featuring negative inflation. This also provides a reason to have a positive inflation target, as emphasized by Kim and Ruge-Murcia (2009, 2011), Abo-Zaid (2013), among others. However, as we will see, indexation can interact non-trivially with asymmetric adjustment costs, a feature that (to the best of our knowledge) has not been explored yet in the related literature.

Finally, it is worth noticing that overall volatility is not only influenced by the size of the shocks hitting the economy. Endogenous propagation mechanisms as well as monetary policy can also contribute to overall volatility. For instance, indexation may play a non trivial role by endogenously increasing nominal volatility. Moreover, the question of optimal inflation target cannot be separated from how monetary policy is conducted whenever there are deviations from the target. For instance, it is expected that under a more dovish Taylor rule, it is optimal to target a higher level of inflation, as a more dovish policy increases overall volatility. All these relevant channels will be quantitatively evaluated in the next section.

3 Results

The main goal is to characterize the value of $\bar{\pi}$ in (3) that maximizes the unconditional welfare of the representative household. Results below are presented in terms of welfare-equivalent consumption relative to the value $\bar{\pi}^{opt}$ that maximizes welfare. In particular, for a given model configuration/parametrization we compute $\Lambda(\bar{\pi})$ such that:

$$Wel\left[c(\bar{\pi}^{opt}), h_t(\bar{\pi}^{opt})\right] = Wel\left[\left(1+\frac{\Lambda(\bar{\pi})}{100}\right)c_t(\bar{\pi}), h_t(\bar{\pi})\right],$$

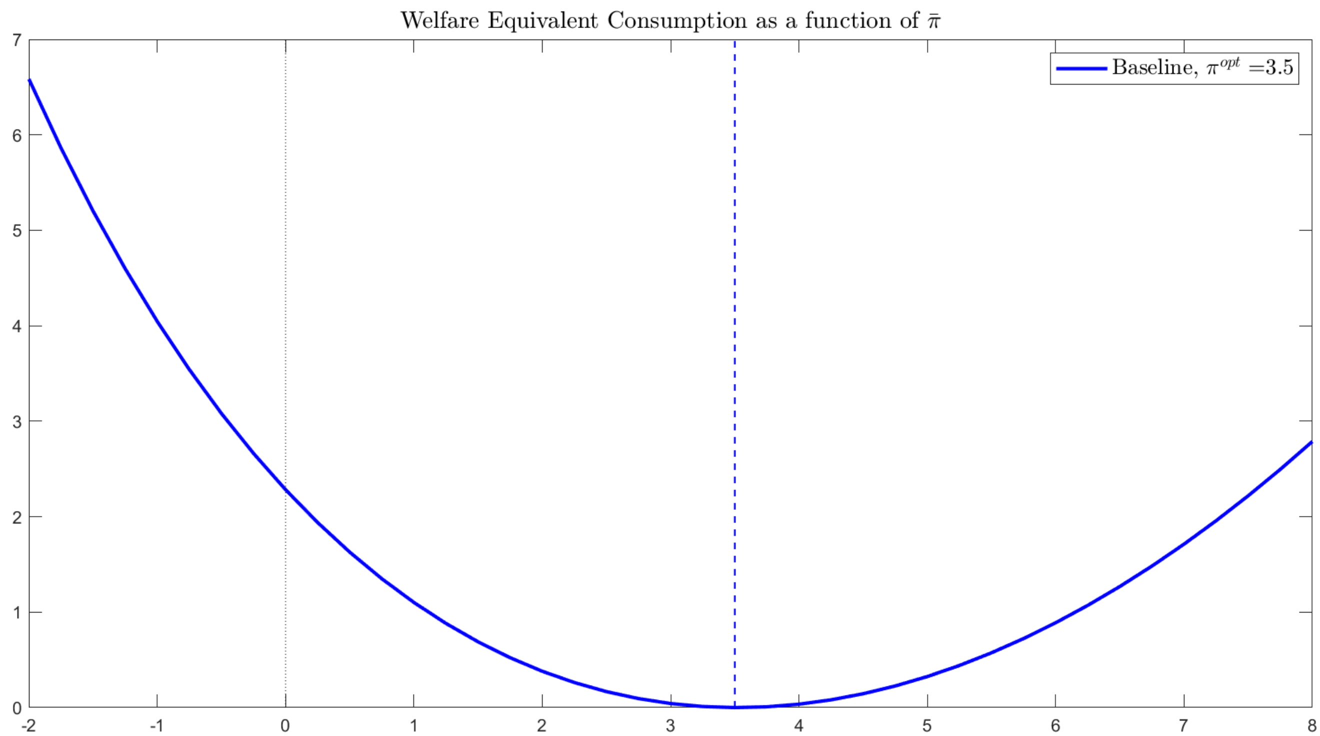
where $Wel\left[c_t(\bar{\pi}), h_t(\bar{\pi})\right]$ denotes the unconditional expectation of the life-time utility (1), while $c_t(\bar{\pi}), h_t(\bar{\pi})$ denote the state-contingent allocations of, respectively, consumption and labor obtained in the equilibrium where the target inflation equals an arbitrary value $\bar{\pi}$.

In other words, $\Lambda(\bar{\pi})$ measures the per-period consumption compensation (in percentage terms) that would make the representative household indifferent (in unconditional expected utility terms) between living in a world with an arbitrary level of inflation $\bar{\pi}$, relative to a world in which the inflation target is the optimal $\bar{\pi}^{opt}$. These unconditional welfare measure were obtained with a second-order approximation of the equilibrium conditions, using a pruning method (Andreasen et al., 2018) to numerically compute unconditional expectations, implemented in Dynare.

3.1 Baseline results

Figure 2 displays the welfare equivalent consumption for a range of values for $\bar{\pi}$ going from -2% to 8% (in what follows, inflation targets are expressed in annualized terms).

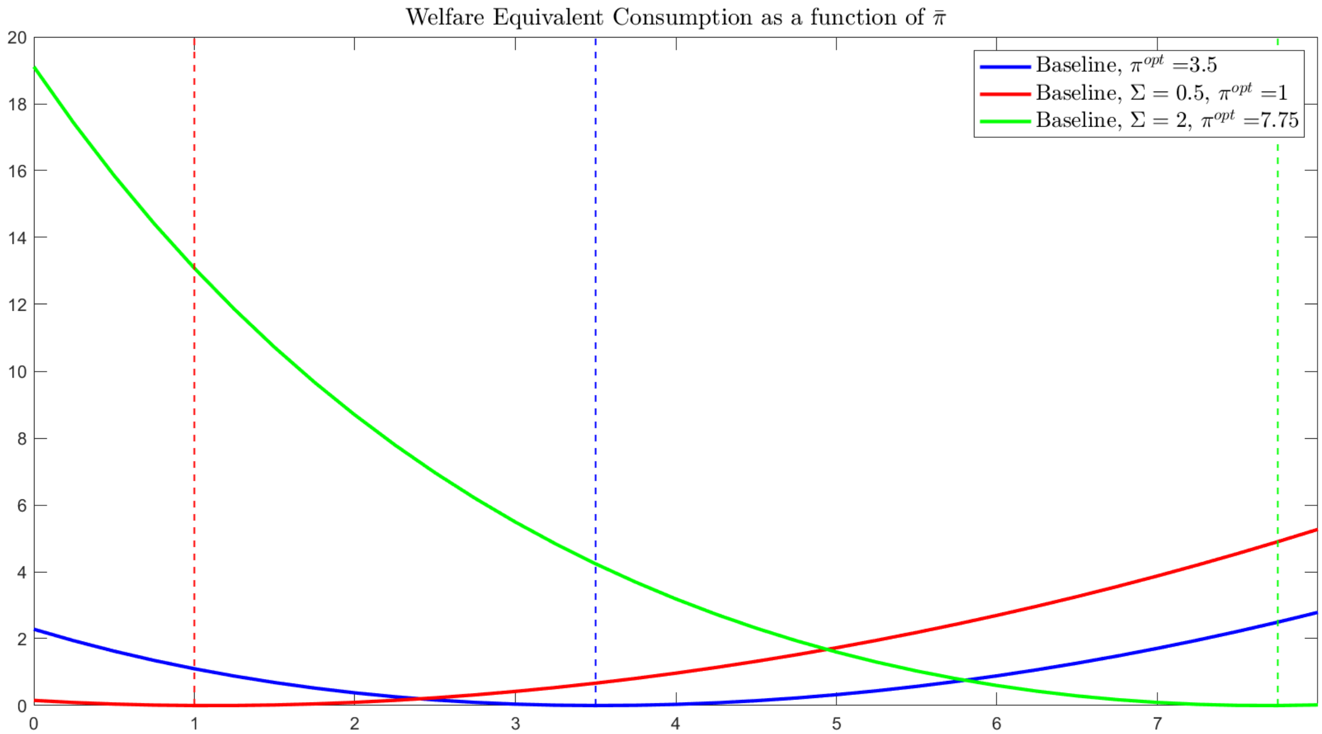
Figure 2: Welfare evaluation: Baseline model



We can see that the optimal inflation target for the baseline parametrization is 3.5% in annual terms. Moreover, targets in the 2 to 5% range induce a mild welfare cost relative to the optimal one, smaller than 0.4% of per-period consumption. However, the cost increases more than proportionally for values further away from the optimal target $\bar{\pi}^{opt}$. As expected, welfare costs rise faster for targets smaller than $\bar{\pi}^{opt}$ compared to those under larger target values; i.e., the plot for $\Lambda(\bar{\pi})$ is not symmetric around π^{opt} (e.g., $\Lambda(0) = 2.28$ while $\Lambda(7) = 1.71$). As a result, the welfare cost of a negative target is larger than under the positive values considered in this range. This is in part due to the presence of asymmetric wage adjustment costs that induce larger welfare costs for negative inflation realizations. In what follows, the figures will focus on positive values for $\bar{\pi}$ to help preserve a scale in the vertical axis that facilitates a visual comparison.

As discussed before, quantitatively the optimal level of inflation depends on the overall volatility of the shocks hitting the economy. Figure 3 compares the baseline results with those obtained by either doubling or halving the volatility of shocks to exogenous variables (Σ denotes the overall scale of shocks' standard deviations). We can see that if volatilities are doubled, we obtain an optimal target of 7.75%, while the optimal target is just 1% when shocks are half as volatile than in the benchmark. While these results are qualitatively expected given the previous discussion, quantitatively we see that the relationship between the optimal target and overall shock volatility is not linear.

Figure 3: Welfare evaluation: The role of overall volatility



Given this role for volatility in determining the target, a related question is which of the shock are relatively more important to determine the value of $\bar{\pi}^{opt}$. To that end, we re-compute the welfare equivalent consumption for different alternatives, each of them setting to zero the variance of one of the shocks at a time.[6] Results are displayed in Figure 4.

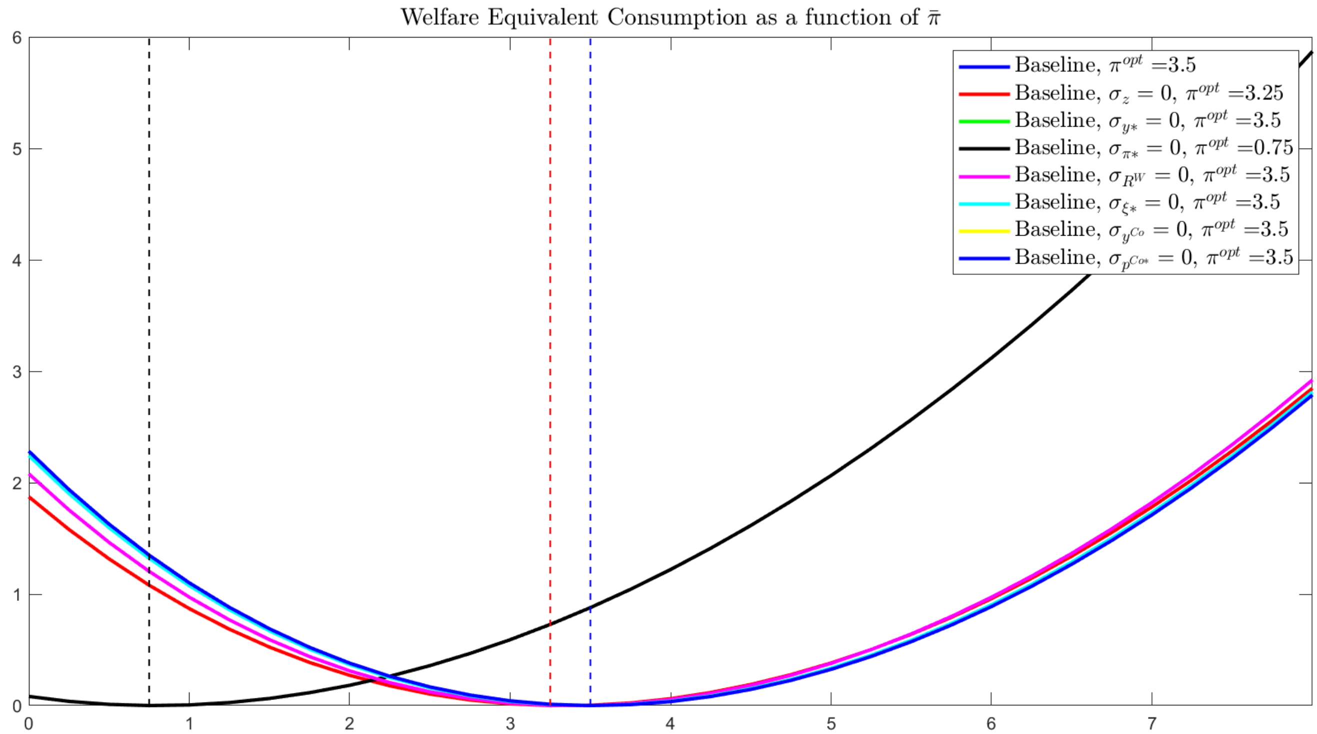
As it can be seen, the largest influence on $\bar{\pi}^{opt}$ is exerted by shock to foreign inflation π^*: in a world in which there are no shocks to this variable, the optimal inflation target is a fifth of the value obtained when the volatility of this shock is calibrated as in the baseline parametrization. The volatility of the other shocks have a negligible influence on the value of $\bar{\pi}^{opt}$.

3.2 The role of wage rigidities

We next investigate the importance of nominal wage rigidities. A first question is how the assumed linex function affects the results, being a symmetric quadratic adjustment cost (as the one used for prices) a natural benchmark. As it turns out, the functional form for wage adjustment costs interacts non-trivially with wage indexation to past inflation. In Figure 5 we can see that under the baseline parametrization (that recall features $\mu_W = 1$) using a quadratic adjustment cost function (assuming the same value for ϕ_W as in the benchmark) delivers a slightly larger value for $\bar{\pi}^{opt}$ (3.75 vs 3.5 in the baseline). This result may seem counter-intuitive at a first glance, for we would expect an asymmetric adjustment cost to deliver a relatively larger inflation target than with a symmetric functional form (as discussed in Section 2.12). However, we can also see that if we assume no indexation to past inflation ($\mu_W = 0$) but maintain the linex adjustment cost

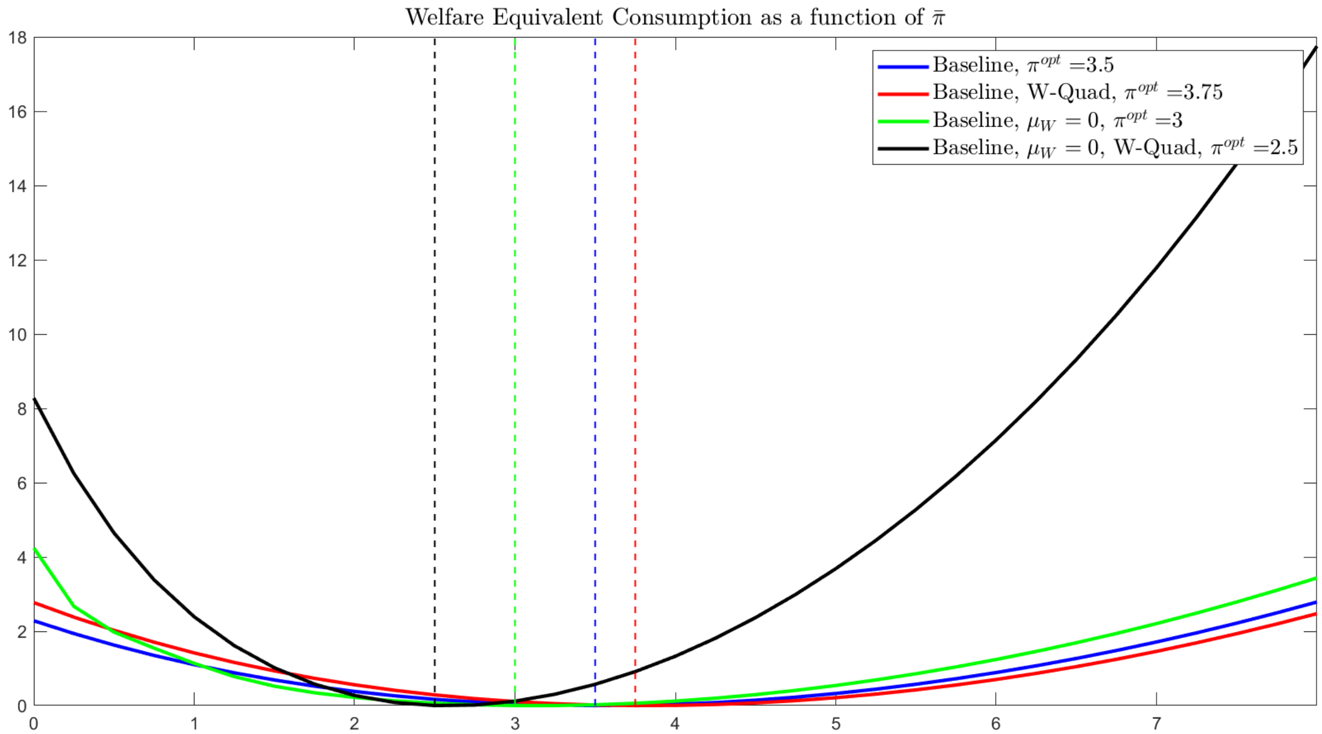
[6]As the model is solved with a second order of approximation, this is not the same as a variance-decomposition exercise like those performed in linear models; still it is illustrative of the relative relevance of each shock in determining the results.

Figure 4: Welfare evaluation: The contribution of each shock



function, the optimal target is smaller (3 vs 3.5 in the baseline). If we set no indexation ($\mu_W = 0$) and a quadratic wage adjustment cost, the value for $\bar{\pi}^{opt}$ is even smaller (2.5).

Figure 5: Welfare evaluation: Wage rigidities



From these results we learn two relevant lessons. First, in the absence of wage indexation to past inflation, an asymmetric adjustment cost function implies a larger value for $\bar{\pi}^{opt}$ than under a symmetric specification. This echoes the results that Kim and Ruge-Murcia (2009, 2011), Abo-Zaid (2013), among others, obtained under a closed economy setting with no indexation.

Second, we can also see that the presence of wage indexation increases the optimal inflation target, either if the adjustment cost function is linex (going from $\mu_W = 0$ to $\mu_W = 1$ under a linex specification rises the target by 0.5 percentage points) or if it is quadratic (the difference in $\bar{\pi}^{opt}$ between $\mu_W = 1$ and $\mu_W = 0$ is 1.25). Intuitively, more indexation leads to more persistence in wage and price inflation (they reinforce each other), which in turn induces more nominal volatility. More volatility leads to a larger desired target, either if it is generated by a larger shock variance (as in the case of Σ discussed previously in Figure 3) or if it is induced by an endogenous amplification mechanism, like indexation. This result speaks directly to those in Kim and Ruge-Murcia (2009, 2011), Abo-Zaid (2013) and others: if indexation is an empirically relevant feature (as it is in many emerging countries) evaluating the role of asymmetric wage adjustments costs becomes more complicated.

3.3 The role of price rigidities

Figure 6 explores how the rigidities on prices affect the results. First, if we reduce the indexation of domestic home prices μ_H to zero (from a value $\mu_H = 0.53$ in the baseline) the optimal target falls to 2%. As before, less indexation reduces overall nominal volatility, leading to a lower target. In turn, if we just lower the adjustment cost parameter to $\phi_H = 400$ (around half of the baseline calibration), π^{opt} increases to 5%. Finally, if we also eliminate indexation (i.e., $\mu_H = 0$ and $\phi_H = 400$), the optimal value of inflation is 3%. As it can be seen, a lower degree of price rigidities implies a larger inflation target for a given indexation assumption: as the inefficiencies generated are less relevant, optimal inflation becomes larger in order to try to reduce the burden originated by asymmetric wage adjustment costs.

Figure 6: Welfare evaluation: Price rigidities

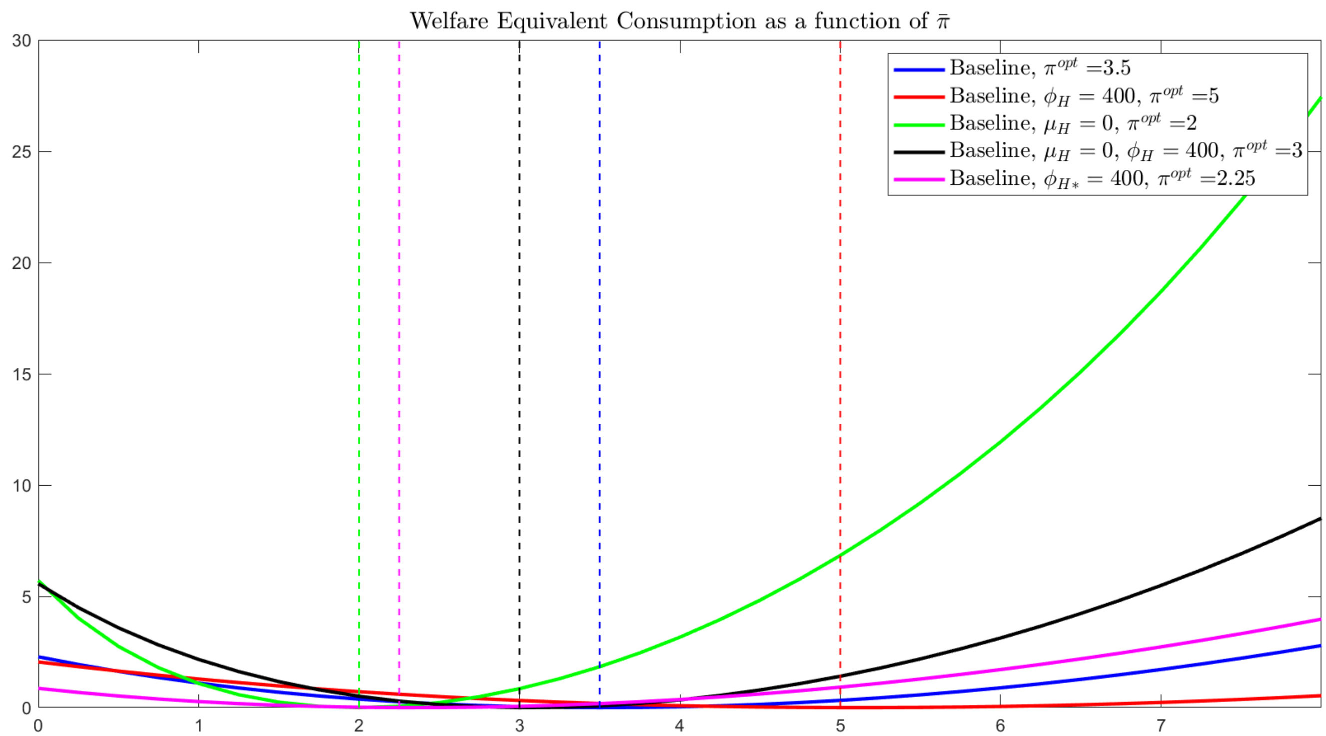
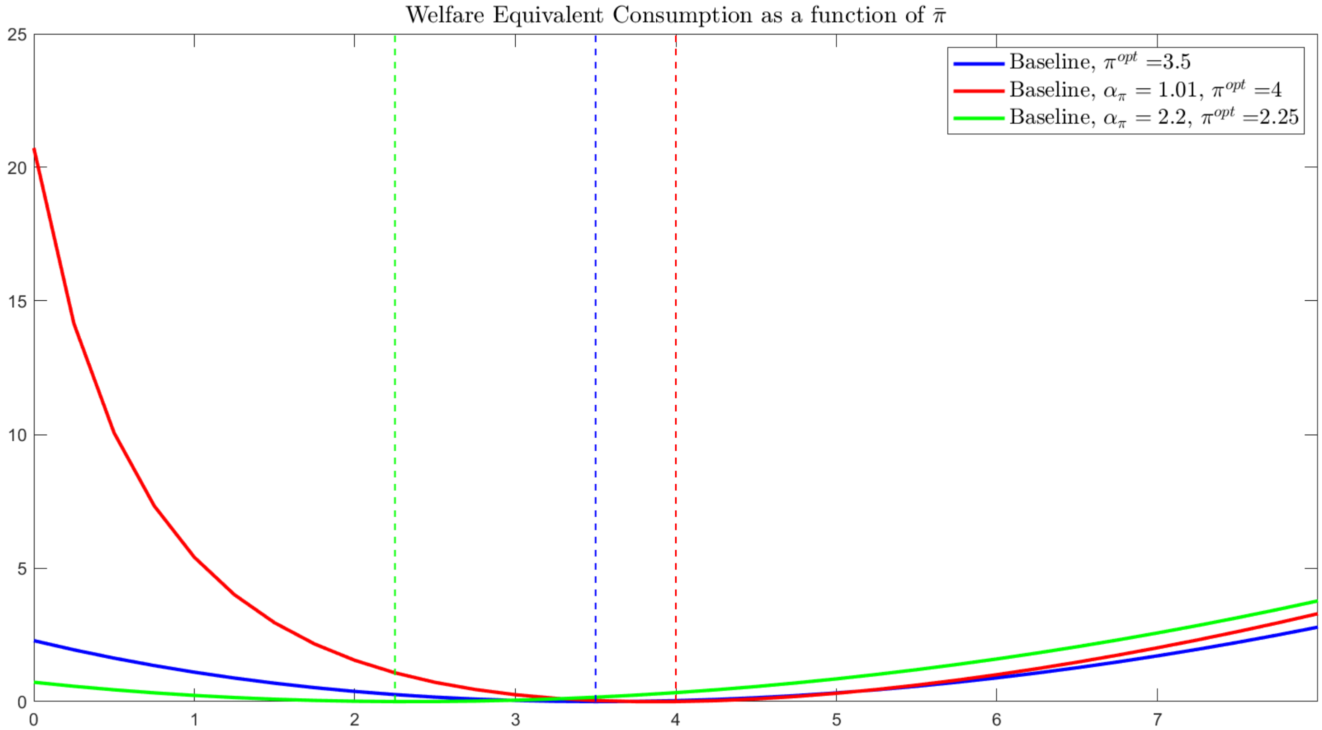


Figure 6 also shows that reducing the relevance of rigidities in P^{H^*} generates a smaller value for π^{opt}. Thus, while reducing the degree of home price stickiness leads to a higher target, doing the same for export prices has the opposite effect. This result is also related to the role that shocks to π^* play (as we uncover in Figure 4): a relatively more flexible P^{H^*} will induce less inefficiencies due to fluctuations in π^*, requiring a smaller inflation target.

3.4 The role of the monetary policy rule

As previously discussed, a non-trivial interaction is expected between the optimal inflation target and the way monetary policy reacts to deviations relative to the target. Figure 7 compares the baseline Taylor rule, with an inflation-reaction parameter $\alpha_\pi = 1.6$, against two alternatives: one with a lower value ($\alpha_\pi = 1.01$, barely enough to keep the equilibrium determinate) and another with a larger coefficient ($\alpha_\pi = 2$).

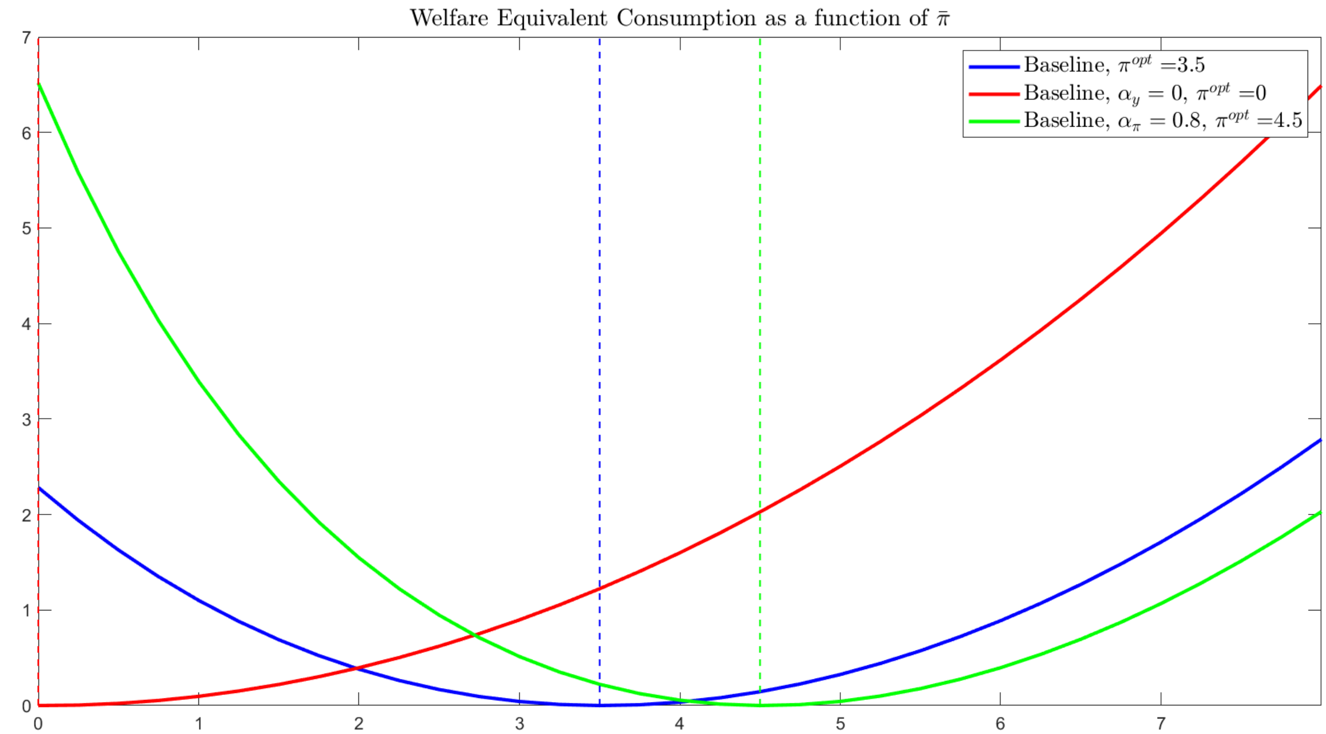
Figure 7: Welfare evaluation: The role of α_π



The optimal target is decreasing in the aggressiveness of the Taylor rule to deviations of inflation from the target. As a more hawkish rule reduces overall inflation volatility, the probability of facing situations with reductions in inflation (which are relatively more socially costly) is diminished and therefore the economy can afford a target closer to zero. We can also see that, quantitatively, the impact of different degrees of inflation reaction on the optimal target is asymmetric: a more hawkish rule induces a larger reduction in the optimal target than the increase that is observed with a similar reduction in α_π.

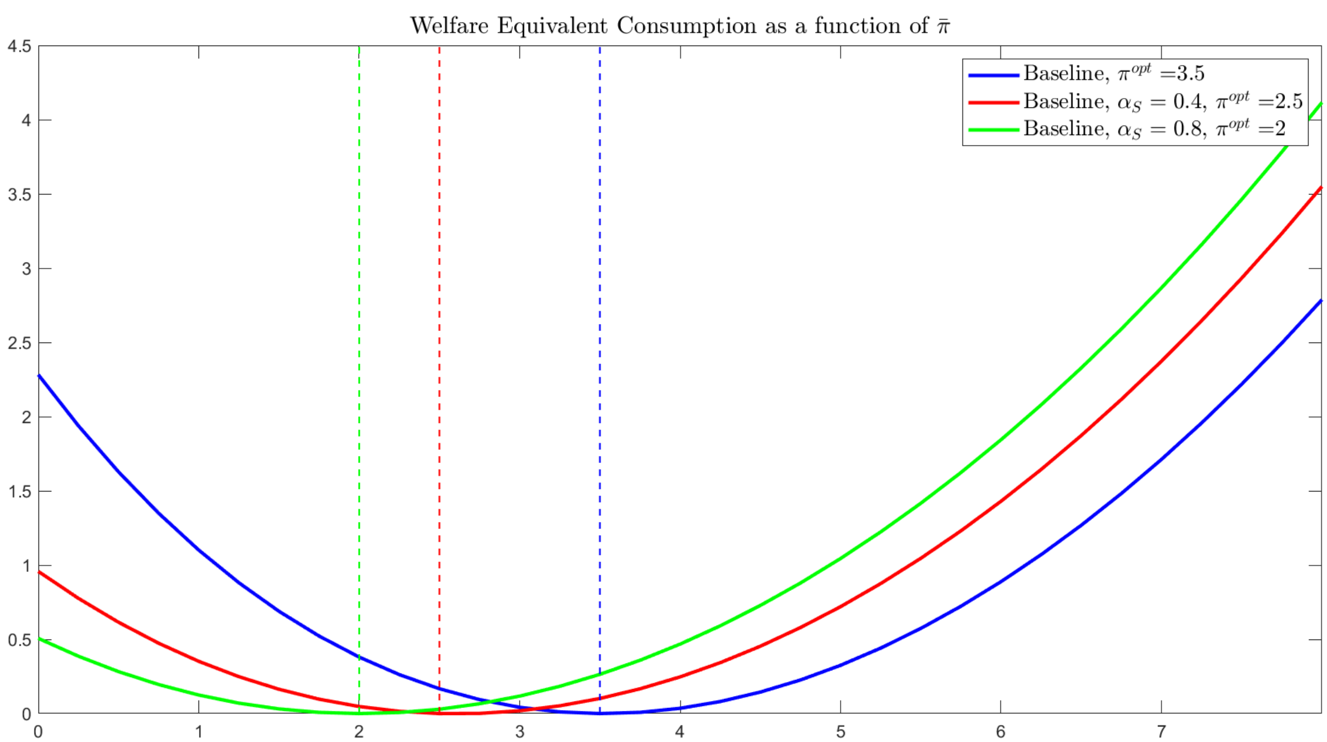
Figure 8 displays the comparison in terms of the Taylor-rule reaction to output-growth deviations from trend growth (α_y, which is equal to 0.4 in the baseline). Here we see a similar result than what we obtained for α_π. In this case, a larger α_y represents a central bank relatively less concerned with inflation. As such, inflation is more volatile and therefore a larger target is optimally required to reduce the chance of facing situations with negative inflation.

Figure 8: Welfare evaluation: The role of α_π



Finally, Figure 9 explores the potential role for an exchange rate concern in the Taylor Rule (α_S, which is set to zero in the baseline).

Figure 9: Welfare evaluation: The role of α_S



As it can be seen, a reaction to nominal depreciations different from the one consistent with the inflation target plays a qualitatively similar role than increasing the concern for inflation. For such a rule will limit exchange rate fluctuations, which in turn reduces overall inflation and the inefficiencies associated with imported price stickiness, requiring a lower inflation target to maximize welfare.

4 Conclusions

This paper studies the optimal inflation targeting in small open economies. In particular, we explore the role of three distinctive characteristics of emerging countries: asymmetric nominal rigidities, indexation to past inflation and dominant currency pricing. We build upon the standard New Keynesian framework, introducing downward nominal wage rigidities through a linex adjustment cost function, indexation to past inflation and price dollarization of international prices (for export and imports). We calibrate our model for the Uruguayan economy, a striking example of a small open economy featuring these characteristics. We compute a second order approximation of our DSGE model using a method-of-moments approach to choose the parameter values related to nominal rigidities.

Our baseline model finds a long-term inflation target in annual terms of 3.5%, with inflation levels in the 2 to 5% range inducing a relatively mild welfare cost relative to the optimal one, smaller than half of a percentage point of per-period consumption. We unveil a non-trivial interaction between downward wage rigidities and wage indexation to past inflation that has been so far neglected in the literature. We also describe how the choice of inflation target is not independent from other features of monetary policy, most importantly, on how the policy instrument reacts when shocks make inflation deviate from the target.

In this study we have put the focus of our analysis on cases in which monetary policy follows a Taylor rule. Complementary, the Ramsey optimal optimal policy could also be characterized. We choose not to pursue this avenue in this paper to focus in cases that are closer to practical policy discussion. Instead, a Ramsey optimal equilibrium, while theoretically better suited to discuss optimal policy, is harder to interpret in terms of practical policy recommendations; for the optimal Ramsey policy is a complex function of the shocks hitting the economy. However, comparing the rule discussed in this paper with the optimal Ramsey allocation, and also exploring optimal simple rules (as in, for instance, Schmitt-Grohé and Uribe, 2010), are interesting extensions to this paper that could be pursued in future research.

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A Appendix

A.1 Baseline calibration

Table 2: Baseline calibration

Param.	Value	Param.	Value	Param.	Value
ρ_z	0.86	$\rho_{p^{Co*}}$	0.00	a^{ss}	1.005
σ_z	0.039	$\sigma_{p^{Co*}}$	0.057	g^{ss}	0.053
z^{ss}	1	$p^{Co*,ss}$	1	π^{ss}	1.019
ρ_{R^W}	0.95	β	0.996	ϕ_H	821
σ_{R^W}	0.0003	σ	1	μ_H	0.530
$R^{W,ss}$	1	ψ	23.104	ϵ_H	11
ρ_{y^*}	0.90	φ	1	ϕ_{H^*}	3380
σ_{y^*}	0.003	ϕ_c	1	μ_{H^*}	0
$y^{*,ss}$	0	ω	0.550	ϵ_{H^*}	11
ρ_{π^*}	0.30	η	1.10	ϕ_F	2
σ_{π^*}	0.010	ϕ_d	0.01	μ_F	1
$\pi^{*,ss}$	1	η^*	0.30	ϵ_F	11
ρ_{ξ^*}	0.80	$\overline{d}$	6.13	α_{Fs}	0.667
σ_{ξ^*}	0.0004	α_π	1.59	ϕ_W	387
$\xi^{*,ss}$	1	α_y	0.39	ψ_W	1807
$\rho_{y^{Co}}$	0.67	α_R	0.74	μ_W	1
$\sigma_{y^{Co}}$	0.011	α_{π^S}	0	ϵ_W	11
$y^{Co,ss}$	0.023			μ_{Wa}	1