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Dealing with Time-Inconsistency: Inflation Targeting vs. Exchange Rate Targeting[*]

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Abstract

Abandoning an objective function with multiple targets and adopting a single mandate can be an effective way for a central bank that cannot commit to overcome the classic time-inconsistency problem. Two single mandates that have proved popular among many central banks have been inflation targeting and nominal exchange rate targeting. In a small open economy model, we compare the outcome of these two single mandates to welfare maximizing optimal monetary policy under commitment or discretion. Both simple rules are effective ways to overcome the time-inconsistency problem. However, the relative ordering of these two simple rules depends on particular features of the small open economy. For an economy that is relatively closed to trade, inflation targeting yields higher social welfare, but for an economy that is very open to trade exchange rate targeting is preferable. Empirical results using a panel of both developed and developing countries show that as central banks become less credible they are more likely to adopt a pegged exchange rate, and crucially the empirical link between central bank credibility and the tendency to peg the exchange rate depends on trade openness.

JEL codes: E50, E30, F40

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1 Introduction

The work of Kydland and Prescott (1977) and Barro and Gordon (1983) highlight the importance of time consistency in policy making. Countries with a weak institutional framework may lack the ability to commit to a future course of monetary policy. This problem arises when a central bank tries to maximize an objective function with multiple terms. There is the motivation to use policy to make temporary gains in some variables (like output) by taking advantage of the fact that expectations about other variables (like inflation) are fixed in the short run. In this case optimal monetary policy may be to switch from a central bank objective where the central bank tries to maximize total welfare and instead adopt a simpler single mandate like inflation targeting or nominal exchange rate targeting.

This is the motivation behind the famous conservative central banker in Rogoff (1985). As discussed by Bernanke, Laubach, and Mishkin (2001), an inflation targeting single mandate can help overcome the time-inconsistency problem and an inflation target can help anchor inflation expectations. Even since the adoption of an inflation targeting single mandate by the Reserve Bank of New Zealand in 1989, there have been a number of empirical studies that have shown that the adoption of an inflation targeting single mandate leads to a significant reduction in inflation and inflation expectations in both developed and developing countries.[1]

Historically the adoption of a nominal exchange rate targeting single mandate has been the preferred solution to the time-inconsistency problem in many countries. Bordo and Kydland (1995) discuss this practice of pegging one's currency to gain credibility in terms of the pre-World War 1 gold standard. Bordo (2003) discusses how the development of institutions like strong, independent central banks has been an important precursor to the widespread adoption of floating currencies by many developed countries since the end of the Bretton Woods system. Giavazzi and Pagano (1988) and Giavazzi and Giovannini (1989) discuss how "tieing ones hands" by to pegging the currency to the German Deutsche Mark was an important motivation behind the European Exchange Rate Mechanism, the precursor to the euro. Similarly, Calderón and Schmidt-Hebbel (2003) discuss the practice of pegging to gain credibility in many Latin American countries, and Mishkin and Calvo (2003) and Husain, Mody, and Rogoff (2005) discuss this practice in many developing and emerging market economies.[2]

[1]Mishkin and Schmidt-Hebbel (2007), Gonalves and Salles (2008), Walsh (2007), Crowe (2010), Grkaynak, Levin, and Swanson (2006), Grkaynak, Marder, Levin, and Swanson (2007), Beechey, Johannsen, and Levin (2011), Benati (2008), Mehrotra and Yetman (2014), Davis (2014) all argue that the adoption of inflation targeting has led to lower and more stable inflation and inflation expectations. However, Ball and Sheridan (2005), Brito and Bystedt (2010), Lin and Ye ((2007, 2009)) argue the opposite and argue that these effects are due to common time components or a sort of selection bias and reversion to the mean.

[2]The argument can be made that an exchange rate peg should not impart extra credibility and should not overcome the time-inconsistency problem since after all, a peg can be broken. However, Klein and

This paper will explore the costs and benefits of adopting one of these two single mandates to overcome the time-inconsistency problem. To do this we calculate optimal monetary policy in a New Keynesian model of a small open economy, as in Gali and Monacelli (2005) or de Paoli (2009). We first show that both single mandates result in a significant welfare improvement over welfare optimizing optimal policy by a central bank that cannot commit. However, we show that the decision of which single mandate to chose depends on characteristics of the small open economy, most notably trade openness. By definition, welfare optimizing optimal monetary policy under commitment always results in higher social welfare than monetary policy based on a single mandate. Furthermore, the single mandate results in higher welfare than optimizing policy under discretion, but for the relatively closed economy, the inflation targeting mandate is better than the nominal exchange rate targeting mandate, but for the highly open economy, the ordering is the opposite and nominal exchange rate targeting results in higher social welfare.

This is because greater trade openness increases the cost of inflation targeting but decreases the cost of nominal exchange rate targeting. We show through analytical closed form solutions of the model that the cost of inflation targeting, higher output volatility, is increasing in an economy's trade openness. However the cost of nominal exchange rate targeting, higher inflation volatility, is decreasing in trade openness.

We then examine this question with a more granular approach, and thus we explicitly model how a central bank will find it optimal to adopt one of these two single mandates as their credibility falls. Instead of assuming the extreme boundary cases of welfare maximizing policy under commitment, welfare maximizing policy under discretion, an inflation targeting single mandate, or a nominal exchange rate targeting single mandate, we assume that central bank credibility lies on a continuum between perfect commitment and perfect discretion. In this more granular approach, we adopt the "loose commitment" framework of Schaumburg and Tambalotti (2007) and Debortoli and Nunes (2010). The central bank will renege on previous commitments with a certain exogenous probability.

Perfect commitment and perfect discretion are nested as boundary cases in this model of loose commitment. The optimal policy equilibrium can be solved for all values of the commitment probability along the continuum from commitment to discretion. When the central bank tries to maximize social welfare taking the probability of commitment as given, as the probability of commitment falls, the outcome from welfare maximizing optimal monetary policy gets progressively worse. We then explore how the central bank could improve total

Shambaugh (2008) argue that while there are some well known examples of exchange rate pegs that break, most exchange rate pegs tend to be fairly persistent in the data, and when a peg is broken, it is many times later reestablished.

social welfare by adopting a different objective function: either one that places a higher weight on inflation stabilization (like the Rogoff conservative central banker) or one that places weight on nominal exchange rate stability. We solve numerically for the optimal extra weight on inflation stability or on nominal exchange rate stability in the central bank's objective function and show that this extra weight is a function of the commitment probability. In that way we can analyze the link between the probability of commitment and the optimal degree of inflation or exchange rate targeting.

In the model, we find that for the small open economy, trade openness has little effect on the link between the probability of commitment and the optimal degree of inflation targeting. In the model the central bank finds it optimal to switch from welfare optimizing policy to an inflation targeting single mandate when the probability of commitment falls below a certain threshold, and this threshold does not depend on trade openness. However we find that trade openness does affect the link between the probability of commitment and the optimal degree of nominal exchange rate targeting. For the small open economy that is relatively closed to trade, the commitment probability has to be pretty low before the central bank will find it optimal to switch from welfare optimizing policy to an exchange rate targeting single mandate, but for a country that is very open to trade, the central bank will quickly abandon optimal policy and instead adopt exchange rate targeting at even a relatively high level of the commitment probability.

We then empirically test the model's prediction that improvements in central bank credibility lead to looser exchange rate pegs. Using central bank independence as a proxy for central bank credibility (see e.g. Cukierman (1992) and Alesina and Summers (1993)) we show in a panel of 96 developed and developing countries from 1998-2010 that improvements in central bank independence lead to increasing exchange rate flexibility. We then test the model's predictions about the role of trade openness. We find that the empirical link between central bank credibility and exchange rate flexibility is itself a function of an economy's trade openness. For a relatively closed economy, this empirical link is weak, but for a very open economy, this tendency to allow the currency to float as credibility improves (or alternatively to fix the currency as credibility falls) is strong.

Devereux and Engel (2003) and Engel (2011) discuss the optimality of a fixed exchange rate regime, but in these models, the central bank can commit. The prevalence of local currency pricing and the violation of the law of one price either diminishes the expenditure switching benefit of a floating currency or imposes a cost in terms of increased price dispersion. Thus the prevalence of local currency pricing may be a possible motivation behind adopting a fixed exchange rate. That channel is not present in this paper. Here we assume producer currency pricing and that the Law of One Price holds at the level of the individual good. In this paper, central bank credibility drives the decision by a central bank to adopt a fixed currency. Similarly, in a model where the central bank can commit, Kamenik and Kumhof (2014) compare the welfare outcomes of a fixed exchange rate regime to a floating regime that follows a Taylor-type feedback rule with a medium term inflation target.

In addition to the papers mentioned earlier that explore the relationship between central bank credibility and currency pegs in the historical context, Calvo and Reinhart (2002) present a model where a central bank that lacks credibility would find it optimal to adopt a fixed exchange rate when discussing why countries may have a ”fear of floating”. Herrendorf (1997, 1999) discusses adopting a currency peg as an effective communication device by a central bank that practices discretionary policy. Empirically, Levy Yeyati, Sturzenegger, and Reggio (2010) show that the strength of political institutions is one key factor in explaining exchange rate regime choice. Similarly, Hakura (2005) finds that exchange rate flexibility in emerging market countries has increased over the past decade, and argues that this "learning to float" appears to have involved a strengthening of monetary and financial policy frameworks in many countries. Ghosh (2014) finds that trade openness leads to the tendency to adopt a fixed currency in many emerging markets. Yamada (2013) applies a propensity score matching function and compare the inflation outcomes in inflation targeting regimes, fixed exchange rate regimes, and flexible/non-inflation targeting regimes, and finds that the inflation targeting regime and the exchange rate targeting regime result in a lower level of inflation than a flexible/non-inflation targeting regime. There is not a major difference in inflation outcomes between inflation targeting regimes and exchange rate targeting regimes.

The rest of this paper is organized as follows. The New Keynesian model of a small open economy is presented in section 2. Here we pay special attention to different monetary policy regimes, either welfare maximizing policy under commitment, welfare maximizing policy under discretion, an inflation targeting single mandate, or a nominal exchange rate targeting single mandate (we refer to these four monetary regimes as the boundary cases). The results from both closed form analytical solutions of the model and numerical simulations are presented in section 3. First, through closed for analytical solutions, then impulse responses, then the numerical calculation of welfare costs we compare these four boundary cases and show how the relative ordering of these four monetary regimes depends on an economy's level of trade openness. We then adopt a more granular approach with the model of ”loose commitment” and show how a central bank that cannot perfectly commit will find it optimal to place greater weight on either inflation or the nominal exchange rate in their own objective function, and that this weight is a decreasing function of the central bank's commitment probability. In section 4 we present evidence from a panel data model that supports the model's main finding that as central bank credibility increases, the central bank will loosen the exchange rate peg and move towards a floating exchange rate regime, and that this empirical link between central bank credibility and exchange rate regime is a function of an economy's level of trade openness. Finally, section 5 concludes with some suggestions for further research.

2 Model

In the model there are two countries, home and foreign. The home country is of size n and the foreign country is of size $1-n$, as $n \to 0$, the model becomes that of a small open economy. The small open economy is populated by a representative household and a continuum of firms. Firms employ labor to produce a tradable consumption good and set prices according to a Calvo style price setting framework. In the small open economy there is a central bank that sets policy to maximize the second-order approximation of household welfare. The central bank displays limited credibility. It can commit and honor past promises only with an exogenous probability γ and thus in any period it will renege on past promises and reoptimize policy with some exogenous probability $1-\gamma$.

2.1 Households

In the small open home economy, the representative household chooses consumption, C_t, and labor effort, h_t, to maximize expected lifetime utility given by:

$$\max \sum_{t=0}^{\infty} \beta^t \left[\ln\left(C_t\right) - \frac{H_t^{1+\eta}}{1+\eta} \right] \tag{1}$$

where β is the household's discount factor and η is the inverse of the Frisch labor supply elasticity.

The consumption good is produced in a perfectly competitive final goods sector that simply aggregates home and foreign goods in a CES production function:

$$C_t = \left[(1-\lambda)^{\frac{1}{\theta}} \left[\left(\left(\frac{1}{n}\right)^{\frac{1}{\sigma}} \int_0^n C_t^H\left(i\right)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \right]^{\frac{\theta-1}{\theta}} + (\lambda)^{\frac{1}{\theta}} \left[\left(\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}} \int_n^1 C_t^F\left(j\right)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}} \right]^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{2}$$

where $C_t^H\left(i\right)$ is the quantity of goods sold to the home market by home country firm $i \in [0\ n]$ and $C_t^F\left(j\right)$ is the quantity imported into the home market and sold by foreign country firm $j \in (n\ 1]$. θ is the elasticity of substitution between home and foreign goods, σ is the elasticity of substitution between goods from different firms within the same country, and λ is the steady-state import share.

From the aggregator function in (2), the demand for either the home consumption good from firm i or the foreign consumption good from firm j are given by:

$$C_t^H(i) = (1-\lambda)\left(\frac{P_t^H(i)}{P_t^H}\right)^{-\sigma}\left(\frac{P_t^H}{P_t}\right)^{-\rho} C_t \tag{3}$$
$$C_t^F(j) = \lambda\left(\frac{P_t^F(j)}{P_t^F}\right)^{-\sigma}\left(\frac{S_t P_t^F}{P_t}\right)^{-\rho} C_t$$

where $P_t^H(i)$ is the price set by firm i and $P_t^F(j)$ is the price set by foreign firm j (in the foreign currency). The Law of One Price holds, so if the good has a price $P_t^H(i)$ in the home market, then its price in the foreign market is $\frac{P_t^H(i)}{S_t}$, where S_t is the nominal exchange rate in units of the domestic currency per units of the home currency. Thus the various price indices are given by:

$$P_t^H = \left(\frac{1}{n}\int_0^n P_t^H(i)^{1-\sigma}\,di\right)^{\frac{1}{1-\sigma}}$$
$$P_t^F = \left(\frac{1}{1-n}\int_n^1 \left(S_t P_t^F(j)\right)^{1-\sigma}\,dj\right)^{\frac{1}{1-\sigma}}$$
$$P_t = \left[(1-\lambda)\left(P_t^H\right)^{1-\theta} + \lambda\left(S_t P_t^F\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

From the last identity we can express consumer price inflation $\pi_t = \frac{P_t}{P_{t-1}}$, as a weighted average of the inflation rate of home and foreign produced goods and appreciation in the nominal exchange rate:

$$\pi_t = (1-\lambda)\pi_t^H + \lambda\left(\hat{S}_t - \hat{S}_{t-1} + \pi_t^F\right)$$

In addition, the household's labor supply decision can be expressed as:

$$H_t{}^{\eta} = \frac{W_t}{P_t}\frac{1}{C_t} \tag{4}$$

2.1.1 Asset Market Structure

We assume that asset markets are complete both domestically and internationally. Thus agents have access to a complete set of state-contingent securities. This implies that the intertemporal marginal rate of substitution is equalized across countries:

$$\frac{C_{t+1}}{C_t}\pi_{t+1} = \frac{S_{t+1}}{S_t}\frac{C^*_{t+1}}{C^*_t}\pi^{f*}_{t+1} \tag{5}$$

where $\pi_{t+1} = \frac{P_{t+1}}{P_t}$ is the inflation rate over the next period. The nominal interest rate $\acute{\imath}_t$ is simply given by:

$$i_t = \frac{C_{t+1}}{\beta C_t}\pi_{t+1} - 1 \tag{6}$$

Using this equation and the definition of the real exchange rate, $Q_t = \frac{S_t P^*_t}{P_t}$, it follows that:

$$Q_t = \frac{C_t}{C^*_t} \tag{7}$$

Thus under complete asset markets, the price of the foreign consumption good relative to the home consumption good, Q_t, is equal to the marginal utility of foreign consumption divided by the marginal utility of home consumption.

2.2 Firms

Home country firm $i \in [0\ n]$ produces output with the following production technology:

$$Y_t(i) = h_t(i) \tag{8}$$

where $h_t(i)$ is the labor employed by the firm in period t. Market clearing in the labor market requires that the total demand for labor by firms is equal to the supply of labor from households, $\int_0^1 h_t(i)\, di = H_t$. The firm's marginal cost of production, MC_t, is simply equal to the wage rate.

Firms set prices according to a Calvo price setting framework. In period t, the firm will be able to change its price in the domestic market with probability $1 - \xi_p$.

Thus if allowed to change their price in period t, the firm will set a price to maximize:

$$\max_{P_t(i)} E_t \sum_{\tau=0}^{\infty} \beta^\tau (\xi_p)^\tau \Lambda_{t+\tau} \left(P^H_t(i) - MC_{t+\tau}(i)\right) Y_{t+\tau}(i)$$

where Λ_t is the marginal utility of household consumption in period t. The firm that is able to change its price in period t will set its price to:

$$\tilde{P}_t^H(i) = \mu_t \frac{E_t \sum_{\tau=0}^{\infty} \beta^\tau (\xi_p)^\tau \Lambda_{t+\tau} MC_{t+\tau}(i) Y_{t+\tau}(i)}{E_t \sum_{\tau=0}^{\infty} \beta^\tau (\xi_p)^\tau \Lambda_{t+\tau} Y_{t+\tau}(i)} \tag{9}$$

where μ_t is the mark-up that the firm charges over expected future marginal cost. This mark-up is stochastic and follows an AR(1) process with a steady state value $\bar{\mu} = \frac{\sigma}{\sigma-1}$.

Firms that can reset prices in period t will all reset to the same level, so $\tilde{P}_t^H(i) = \tilde{P}_t^H$. Substitute this optimal price into the price index $P_t^H = \left(\int_0^1 \left(P_t^H(i)\right)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$. Since a firm has a probability of $1-\xi_p$ of being able to change their price, then by the law of large numbers in any period $1-\xi_p$ percent of firms will reoptimize prices. Thus the price index for domestic traded goods, P_t^H, can be written as:

$$P_t^H = \left(\xi_p \left(P_{t-1}^H\right)^{1-\sigma} + (1-\xi_p)\left(\tilde{P}_t^H\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

2.2.1 Linearized model equations

The log-linearized equilibrium in this small open economy model can be expressed as a series of five equations. The derivation of each of these linearized equations is presented in the appendix.

The firm's pricing decision in (9), combined with the labor market equilibrium condition in (4) and the asset market equilibrium condition in (7) yields the following derivation for the New Keynesian Phillips Curve:

$$\hat{\pi}_t^H = \kappa\left(\eta \hat{Y}_t + \frac{1}{1-\lambda}\hat{Q}_t + \hat{\mu}_t\right) + \beta \pi_{t+1}^H \tag{10}$$

where $\kappa = \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}$. $\hat{Y}_t$ denotes output, $\hat{Q}_t$ the real exchange rate, and π_t^H and $E_t\left(\pi_{t+1}^H\right)$ are the current and future expected rate of inflation for home country production. A "hat" over a variable represents log-deviation from the steady state value.

In addition, the market resource constraint can be expressed as an equation linking output in the small open economy to the real exchange rate:

$$\hat{Y}_t = (1-\lambda)\frac{1}{\rho}\hat{Q}_t + \frac{\theta\lambda(2-\lambda)}{1-\lambda}\hat{Q}_t, \tag{11}$$

The model is driven by a mark-up shock $\hat{\mu}_t$ that follows an AR(1) process:

$$\hat{\mu}_{t+1} = \rho_\mu \hat{\mu}_t + \varepsilon_t \tag{12}$$

These three equations and the solution to the optimal policy problem discussed in the next subsection are all that is needed to solve for equilibrium in the model under most circumstances, but when discussing the optimal policy problem, we will entertain the possibility that the central bank follows a policy of stabilizing the nominal exchange rate, in which case the nominal exchange rate, S_t, enters as a variable in the model and from the definition of the real exchange rate:

$$\hat{Q}_t - \hat{Q}_{t-1} = (1-\lambda)\left(\hat{S}_t - \hat{S}_{t-1} - \pi_t^H\right) \tag{13}$$

When the nominal exchange rate is included as a variable in the model, we are left with five variables and four equations, the last equation is the monetary policy rule, which is determined either as the solution to the central bank's maximization problem or a simple rule like inflation targeting or nominal exchange rate targeting.

2.3 Monetary Policy

The central bank sets monetary policy in order to maximize the second-order approximation of the household's welfare in (1). As shown in de Paoli (2009), in this model, the maximization of the second-order approximation of welfare is equivalent to the minimization of the quadratic loss function of the output gap, the inflation rate of home country produced goods, and the real exchange rate:

$$L_t = \frac{1}{2}\sum_{t=0}^{\infty}\beta^t\left(\Phi_y\left(\hat{Y}_t - \hat{Y}_t^T\right)^2 + \Phi_\pi\left(\pi_t^H\right)^2 + \Phi_q\left(\hat{Q}_t\right)^2\right) \tag{14}$$

where $\hat{Y}_t^T$ is the log-deviation of output from its steady-state level in a flex-price equilibrium. The weights Φ_y, Φ_π, and Φ_q are functions of the constants in the model and are described in detail in the appendix.

Monetary policy will maximize the social welfare function in (14) subject to the linearized model equations presented in the last section.

In the first set of results in section 3.1 we will close the model under four boundary cases of monetary policy. The first case is where the central bank that can perfectly commit, and thus the central bank will maximize L_t at $t = 0$ by specifying the future path $\left\{\pi_t^H\right\}_{t=0}^{\infty}$. The second is where the central bank practices discretionary policy and will re-optimize each period.

When the central bank cannot commit, the presence of multiple terms in the objective function gives rise to the classic time-inconsistency problem. The costs of this time inconsistency can be mitigated by assigning the central bank an objective function with only one term. In the third boundary case we will assume that the central bank has a mandate for perfect inflation stability. And thus instead of an optimization problem the model is simply closed with the central bank's inflation targeting mandate, $\pi_t^H = 0$. A perfect inflation targeting central bank is of course the extreme version of the conservative central banker in Rogoff (1985). In another simulation we assume that in order to mitigate this time inconsistency problem, the central bank is given a mandate for perfect nominal exchange rate stability, and thus the central bank's optimization problem is simply replaced with the expression $\hat{S}_t = 0$.

2.3.1 Beyond boundary cases: Loose commitment and partial targeting

In the second set of results in section 3.2, we take a more granular approach. Instead of assuming that the central bank can either practice perfect commitment or perfect discretion, we assume that the central bank displays imperfect credibility or loose commitment, as in Schaumburg and Tambalotti (2007), Debortoli and Nunes (2010), Debortoli, Maih, and Nunes (2014), and Dennis (2014). Policy makers have a commitment technology, but with a certain exogenous probability they may renege on their earlier commitment. This exogenous probability is known by all agents in the model. In any given period, the central bank will honor past commitments with probability γ and it will renege on previous commitments and reoptimize with probability $1 - \gamma$.

The central bank will seek to minimize the loss function in (14) subject to the model equations described in the previous section and the commitment probability γ. Due to the central bank's limited commitment, the solution will be the solution to a Markov problem, where agents' expectation of the next period's inflation rate depends on whether the central bank will honor or renege on their commitment this period.

To improve ex-ante social welfare and partially make up for the fact that the central bank display limited commitment, the central bank may ex-ante choose to minimize a different loss function than the social loss function. This alternative loss function is known to all agents in the model and is a way to tie the central bank's hands and force them to adopt a policy that better mirrors the policy under perfect commitment. This alternative loss function doesn't actually make the central bank able to commit, it still will renege with the exogenous probability $1-\gamma$, but by adopting a different objective function, the central bank that cannot perfectly commit can partially mitigate the time inconsistency problem and thus improve total social welfare given i's limited ability to commit.

Using the idea of the conservative central banker from Rogoff (1985), one potential candidate for the alternative central bank objective function is the following:

$$\tilde{L}_t = \frac{1}{2}\sum_{t=0}^{\infty}\beta^t \left(\Phi_y \left(\hat{Y}_t - \hat{Y}_t^T\right)^2 + \Phi_\pi \left(1 + \phi_\pi \left(\gamma\right)\right) \left(\pi_t^H\right)^2 + \Phi_q \left(\hat{Q}_t\right)^2\right) \tag{15}$$

where $\phi_\pi(\gamma)$ is the extra weight that the central bank places on inflation stabilization in their loss function. For every given value of the commitment probability γ there is a value $\phi_\pi(\gamma)$ that will maximize the true social loss function in (14). As the value of $\phi_\pi(\gamma)$ gets larger, optimal monetary policy approaches the case of pure inflation targeting, $\pi_t^H = 0$. Alternatively the central bank could adopt the following alternative loss function:

$$\tilde{L}_t = \frac{1}{2}\sum_{t=0}^{\infty}\beta^t \left(\Phi_y \left(\hat{Y}_t - \hat{Y}_t^T\right)^2 + \Phi_\pi \left(\pi_t^H\right)^2 + \Phi_q \left(\hat{Q}_t\right)^2 + \phi_S \left(\gamma\right) \left(\hat{S}_t\right)^2\right) \tag{16}$$

As the value of $\phi_S(\gamma)$ gets larger, optimal monetary policy approaches the case of pure nominal exchange rate targeting, $\hat{S}_t = 0$.

These modifications of the social loss function, $\phi_\pi(\gamma)$ and $\phi_S(\gamma)$, can be derived from numerical simulations of the model.

2.4 Calibration

The calibrated values of the different parameters in the model are presented in table 1. These parameter values are all taken from either Gali and Monacelli (2005) or de Paoli (2009). The Calvo (1983) price stickiness parameter is set such that firms reset price on average once a year. In the next section we show how the results of the model change under different values of this price stickiness parameter. The subjective discount factor is set such that the steady state annualized real interest rate is about 4%. The inverse of the Frisch labor supply elasticity and the elasticity of substitution between differentiated goods from the same country are both from de Paoli (2009). The unitary elasticity of substitution between home and foreign goods is taken from Gali and Monacelli (2005).

Numerical simulations of the model are calculated in response to home country mark-up shocks. We assume that these shocks follow an AR(1) process with an autoregressive parameter of $\rho = 0.8$. In the next section we show how the results of the model change under different values of this parameter. Since the numerical simulations are calculated with a first-order linearization, assume that these shocks have a standard deviation of 1%.

3 Model Results

To examine the costs and benefits of adopting a simple rule like inflation targeting or nominal exchange rate targeting, we first welfare costs under four assumptions about monetary policy. In one, monetary policy is set to maximize social welfare and the central bank can commit, in the second, monetary policy is set to maximize social welfare and the central bank cannot commit, in the third, the central bank follows a simple inflation targeting rule, and in the fourth the central bank follows a simple nominal exchange rate targeting rule. We show that the ordering of these four monetary policy regimes depends on the economy's level of trade openness. In the last section we discussed the intuition behind why a central bank with loose commitment might want to alter their own objective function in order to deliver a better outcome for overall social welfare. We then adopt a more granular approach. With the "loose commitment" framework, perfect commitment and perfect discretion are boundary cases where the commitment probability is either 1 or 0. We can then calculate how a central bank with a given commitment probability might find it optimal to maximize a social welfare function that either places more weight on inflation stabilization or places weight on nominal exchange rate stabilization.

3.1 Boundary Cases - Inflation targeting vs. Exchange Rate Targeting

By definition, since the policy rule derived under perfect commitment is derived from a maximization of social welfare, policy under perfect commitment always yields a better outcome that either discretion or the adoption of a simple rule like inflation targeting or nominal exchange rate targeting. Since the adoption of a simple rule introduces some element of history dependence into the policy rule, Jensen (2002) and Vestin (2006) discuss how this history dependence can mitigate some of the adverse effects arising from purely discretionary policy. So while welfare maximizing optimal policy under commitment always yields higher welfare than a simple rule like inflation targeting or exchange rate targeting, welfare maximizing optimal policy under discretion always yields lower welfare than either simple rule.

But which simple rule is preferable depends on the characteristics of the small open economy, most notably trade openness. As we shall soon show, the small open economy that is relatively closed to trade would benefit more from the adoption of a simple rule like inflation targeting, but the small open economy that is very open to trade would benefit more from the adoption of a simple rule like nominal exchange rate targeting. The actual calculation of social welfare under each of these rules is very messy and is best shown through numerical simulations, but how trade openness affect factors like output and inflation volatility under these simple policy rules is straight forward and intuitive.

Under strict inflation targeting, $\pi_t^H = 0$. Thus from the New Keynesian Phillips curve in (10) and the market resource condition in (11) simple substitution can be used to derive a closed form expression for fluctuations in output as a function of the exogenous mark-up shock:

$$\hat{Y}_t = -\frac{\phi}{\eta\phi + 1}\hat{\mu}_t$$

where $\phi = \frac{1}{\rho} - 2\left(\frac{1}{\rho} - \theta\right)\lambda + \left(\frac{1}{\rho} - \theta\right)\lambda^2$. Thus $var\left(\hat{Y}_t\right) = \left(\frac{\phi}{\eta\phi+1}\right)^2 var\left(\hat{\mu}_t\right)$. Since the coefficient $\frac{\phi}{\eta\phi+1}$ is increasing in the import share parameter λ, under inflation targeting, output volatility increases as trade openness increases.

Under nominal exchange rate targeting, $\hat{S}_t = 0$, the combination of the definition of the real exchange rate in (13) and the market resource constraint in (11) yields the following simple rule linking inflation to output growth:

$$\hat{Y}_t - \hat{Y}_{t-1} = -\phi\hat{\pi}_t^H$$

and after a messy solution for a rational expectations equilibrium:

$$var\left(\hat{\pi}_t^H\right) = 2\frac{B^2}{1+A} var\left(\hat{\mu}_t\right)$$
$$var\left(\hat{Y}_t\right) = \phi^2\frac{B^2}{1-A^2} var\left(\hat{\mu}_t\right)$$

where $A = \frac{(1+\beta+\kappa(\eta\phi+1)) - \sqrt{(1+\beta+\kappa(\eta\phi+1))^2 - 4\beta}}{2\beta}$ and $B = -\frac{2\kappa(1-\lambda)}{\left(1+\beta+\kappa(\eta\phi+1)+\sqrt{(1+\beta+\kappa(\eta\phi+1))^2-4\beta}\right)}$. Since $\frac{dA}{d\lambda} > 0$ and $\frac{dB^2}{d\lambda} < 0$, $\frac{dvar\left(\hat{\pi}_t^H\right)}{d\lambda} < 0$. Under nominal exchange rate targeting, the volatility of inflation falls as the import share increases. The sign of $\frac{dvar\left(\hat{Y}_t^H\right)}{d\lambda}$ is not clear in this analytical expression. In numerical simulations the sign is positive, but $\frac{dvar\left(\hat{Y}_t^H\right)}{d\lambda}$ under nominal exchange rate targeting is less than $\frac{dvar\left(\hat{Y}_t^H\right)}{d\lambda}$ under inflation targeting, so output becomes more volatile as the import share increases under both inflation targeting and nominal exchange rate targeting, but the speed at which output volatility increases is faster under inflation targeting. The derivation of these analytical expressions are presented in the appendix.

The benefit of adopting an inflation targeting single mandate is that inflation volatility is reduced to zero. However the cost is greater output volatility, and as the import share increases, this cost gets higher. A single mandate based on nominal exchange rate targeting delivers the same stability as an inflation targeting single mandate, but at the cost of higher inflation volatility, but as the import share increases, inflation volatility falls under nominal exchange rate targeting. Thus both an inflation targeting single mandate and a nominal exchange rate targeting single mandate eliminate the time inconsistency problem and deliver stability for the central bank that can't commit, but as the import share increases, the cost of an inflation targeting mandate increases and the cost of an exchange rate targeting decreases. This is shown in these analytical results, but can most clearly be seen with numerical simulations. We first examine the responses of the variables in the model to a shock under different monetary regimes, then we will calculate welfare loss under these same regimes and show how the preference for one regime over another depends on an economy's trade openness.

3.1.1 Impulse responses under different monetary regimes

The response of the home country output gap, inflation rate, real exchange rate, and nominal interest rate to a home country mark-up shock are shown in figure 1. The left-hand column of the figure presents the results from the model assuming a low import share, and the right-hand column assumes a high import share. The blue line in each figure presents the results assuming social welfare maximizing monetary policy under commitment, the purple line assumes social welfare maximizing monetary policy under discretion, the red line assumes perfect inflation targeting, and the green line assumes nominal exchange rate targeting.

We first compare the responses under welfare maximizing monetary policy under commitment to optimal policy under discretion. The responses show that when the central bank that can commit responds optimally to the mark-up shock, there is a fall in the output gap, an increase in inflation, and an appreciation in the real exchange rate. When the central bank cannot commit these responses are amplified. When the central bank cannot commit agents know that the central bank will renege on past commitments, and set expectations accordingly. Following a shock, inflation expectations rise by more than they would have under perfect commitment. Knowing that this will happen, the central bank that cannot commit is forced to tighten monetary policy by more than they would have under perfect commitment. The impulse responses show that the central bank that can commit barely adjusts the nominal interest rate following the shock because expectations are so well contained. However, the central bank that cannot commit is forced to raise the nominal interest rate by 20-30 basis points in response to the same shock simply to contain expectations, and this results in a much greater fall in output and a much greater increase in the real exchange rate.

The figure shows how abandoning welfare maximizing monetary policy and simply adopting a rule like inflation targeting or nominal exchange rate targeting can contain expectations. The adoption of a simple rule eliminates the time inconsistency problem inherent in optimizing with multiple objectives. As a result, inflation expectations remain anchored without the central bank being forced to resort to dramatic increases in the nominal exchange rate. The figure shows that under inflation targeting inflation remains perfectly contained, although the cost in terms of loss in output can be high. Under nominal exchange rate targeting, fluctuations in output are significantly reduced, but there is greater inflation volatility.

Turning now to the role of trade openness. Under inflation targeting, the fall in the output gap in the model with a low import share is about 0.3%. If we assume a high import share, the fall in the output gap following the same shock is about 0.4%. The figure shows that the steady state trade share barely affects the response of the output gap under either commitment or nominal exchange rate targeting.

Increasing trade openness actually slightly dampens the response of inflation under the nominal exchange rate targeting regime. The second row in the figure shows that in the model with a low import share, inflation increases by about 0.025% following a shock under nominal exchange rate targeting, and this response is actually greater than the response under both commitment and discretion. When the model is parameterized with a high import share, now the response of inflation under the nominal exchange rate targeting regime is slightly smaller at about 0.02%, and the responses under both commitment and discretion are higher.

3.1.2 Social loss under different monetary regimes

The volatility of the output gap, inflation rate, and real exchange rate and the total social loss as a function of the import share λ are presented in figure 2. The blue line in each figure presents the results assuming social welfare maximizing monetary policy under commitment, the red line assumes perfect inflation targeting, and the green line assumes nominal exchange rate targeting. The volatilities and welfare losses assuming social welfare maximizing monetary policy under discretion are significantly larger and are omitted to present the figure with a reasonable scale. These volatilities under discretion are available from the authors upon request.

The figure with volatilities and welfare losses repeats the same trends that we see in the impulse response analysis. Output gap volatility is lowest under nominal exchange rate targeting and highest under inflation targeting, and inflation volatility is highest under nominal exchange rate targeting and zero under inflation targeting. In addition, output gap volatility is increasing as trade openness increases under every monetary regime, but the speed of increase is greatest under an inflation targeting single mandate. Inflation volatility is a declining function of the import share under nominal exchange rate targeting.

The results for total welfare loss show that optimization under perfect commitment is of course always better than either inflation targeting or nominal exchange rate targeting. The results under discretion are omitted to preserve the scale of the figures, but optimization under discretion is always worse than both inflation targeting and nominal exchange rate targeting. However, the figure shows that for low levels of trade openness, inflation targeting delivers a lower social loss than nominal exchange rate targeting, but as trade openness increases, the gap between social welfare under the two single mandate regimes falls. At some point, under this calibration where $\lambda \approx 0.3$, the ordering changes and nominal exchange rate targeting results in a lower social loss than inflation targeting. The particular calibration of the model will determine the exact crossing point, but under any set of parameters, as trade openness increases, the gap between social welfare loss under nominal exchange rate targeting and under inflation targeting will fall.

3.2 The optimal weight on exchange rate stability, ϕ

We now turn away from the boundary cases of perfect commitment, perfect discretion, inflation targeting, and nominal exchange rate targeting, to a more granular approach. For this granular approach we turn to the "loose commitment" framework of Schaumburg and Tambalotti (2007) and Debortoli and Nunes (2010). In this loose commitment framework policy makers have a commitment technology, but with a certain exogenous probability they may renege on their earlier commitment. This exogenous probability is known by all agents in the model. In any given period, the central bank will honor past commitments with probability γ and it will renege on previous commitments and reoptimize with probability $1-\gamma$. The perfect commitment and perfect discretion boundary cases from the previous section are special cases where $\gamma = 1$ or $\gamma = 0$.

The change in welfare as the central bank's commitment probability γ changes is plotted in the lower half of figure 3. The left-hand graph in the bottom half of the figure is for the model parameterized with low trade openness, and the right-hand graph is for the model parameterized with a high degree of trade openness. The blue line in the figure is the welfare loss, L, as a function of γ under welfare maximizing optimal monetary policy. The figure shows that the welfare loss is a sharply decreasing function of the commitment probability γ, and $\frac{dL}{d\gamma}$ is steeper (more negative) for the highly open economy than for the relatively closed economy.

We now turn to ways that the central bank can modify their objective function in order to minimize the social loss function in (14) for a given commitment probability γ. One possible solution for the central bank to overcome the problem of loose commitment is minimize an objective function that is different than the social welfare function. Two possible candidates are given in (15) and (16). The alternative objective function in (15) involves placing greater weight, $\phi_\pi(\gamma)$ on the inflation term in the social loss function. This is of course very similar to the conservative central banker in Rogoff (1985). Another alternative objective function in (16) involves placing weight, $\phi_S(\gamma)$ on the nominal exchange rate.

The value of ϕ_π or ϕ_S in the central bank's objective function that minimize total social loss at each given value of γ is solved for numerically. These numerically derived functions $\phi_\pi(\gamma)$ and $\phi_S(\gamma)$ are presented in the top half of figure 3. The left hand chart plots the numerically derived function $\phi_\pi(\gamma)$: the extra weight on inflation in the central bank's objective function in (15) that will minimize the social loss for each given value of γ. The right-hand chart plots the numerically derived function $\phi_S(\gamma)$: the weight on the nominal exchange rate in the central bank's objective function in (16) that will minimize the social loss for each given value of γ. In each graph, three lines are plotted. The black line is for the relatively closed economy, the green line is for the very open economy, and the red line is for a medium level of trade openness.

As $\phi_\pi(\gamma)$ or $\phi_S(\gamma)$ get larger, monetary policy approaches the boundary cases of inflation targeting or nominal exchange rate targeting, and for practical purposes in this numerical simulation, when $\phi_\pi(\gamma)$ or $\phi_S(\gamma)$ approach 100, monetary policy converges to one of these single mandate rules. Both charts show that when γ is close to 1, indicating near perfect commitment, the optimal values of $\phi_\pi(\gamma)$ or $\phi_S(\gamma)$ are 0, and as γ falls the optimal weight increases, so $\frac{d\phi_\pi(\gamma)}{d\gamma} < 0$ and $\frac{d\phi_S(\gamma)}{d\gamma} < 0$. The figure shows that trade openness has almost no effect on the numerically derived function $\phi_\pi(\gamma)$. In the model, the optimal strategy of the central bank is to change from welfare optimizing optimal monetary policy (and thus $\phi_\pi(\gamma)$ is close to 0) to perfect inflation targeting right around $\gamma = 0.6$. So for a commitment probability greater than 60% the central bank just minimizes the social loss function in (14) and for a commitment probability less than 60%, the central bank would rather adopt an inflation targeting single mandate. The slope $\frac{d\phi_\pi(\gamma)}{d\gamma}$ does not depend on the level of trade openness.

If instead the central bank is minimizing the objective function in (16) and placing weight on the nominal exchange rate, trade openness has an effect on the numerical function $\phi_S(\gamma)$. For a country that is very open to trade, the central bank switches from welfare maximizing optimal policy to a nominal exchange rate targeting single mandate when the commitment probability falls below 80%. For the relatively closed economy the change from welfare maximizing optimal policy to a nominal exchange rate targeting mandate is more gradual and occurs at a much lower value of γ. The slope $\frac{d\phi_S(\gamma)}{d\gamma}$ depends on the level of trade openness, the slope is steeper (more negative) for a very open economy than for a relatively closed economy, so the numerically derived function $\phi_S(\gamma)$ can more accurately be written as $\phi_S(\gamma;\lambda)$, where $\frac{d^2\phi_S(\gamma;\lambda)}{d\gamma d\lambda} < 0$. As discussed earlier, the cost of nominal exchange rate targeting is higher inflation variability, and this cost is smaller for a very open economy. So a very open economy is quick to switch from welfare optimizing policy to nominal exchange rate targeting, but the costs are higher for a relatively closed economy, so a relatively closed economy is much more hesitant to adopt an exchange rate targeting single mandate.

Returning now to the welfare loss graphs in the bottom half of figure 3. As discussed earlier, the blue line in each graph represents the welfare loss under welfare maximizing optimal policy. The red line represents the welfare loss when the central bank is instead minimizing the alternative objective function in (15) with an optimally chosen extra weight on inflation $\phi_\pi(\gamma)$. The graph shows that for both the relatively closed and the very open economies, the red line and the blue line are indistinguishable for high levels of γ, but right around the point where $\gamma = 0.8$, the red line breaks away and becomes nearly horizontal. This is where the central bank switches from a low value of $\phi_\pi(\gamma)$ to a high value of $\phi_\pi(\gamma)$ right around the point where $\gamma = 0.8$. When the optimal value of $\phi_\pi(\gamma)$ is very high the central bank has adopted an inflation targeting single mandate, the time-inconsistency problem is eliminated, and welfare loss no longer depends on the commitment probability γ.

The green line in these two graphs represents the welfare loss when the central bank minimizes the alternative objective function in (16) with an optimally chosen weight on the nominal exchange rate $\phi_S(\gamma)$. Once again the graph shows that the green and the blue lines are indistinguishable at high levels of γ, but at lower levels of γ the two lines diverge and the green line becomes horizontal as $\phi_S(\gamma)$ gets high and policy approaches a nominal exchange rate targeting single mandate. The two graphs show that this divergence occur at a higher level of γ in the very open economy. Furthermore, the two graphs show restate the ordering between the policy regimes that we discussed in the earlier section on boundary cases. For a relatively closed economy, welfare maximizing optimal policy with a might commitment probability delivers the highest social welfare, followed by an inflation targeting mandate, followed by a nominal exchange rate targeting mandate, followed by welfare optimizing policy with a low commitment probability. For an economy that is very open to trade, the relative ordering of inflation targeting and nominal exchange rate targeting are reversed.

4 Empirical

The model in the previous section shows how a central bank that cannot fully commit to future actions can improve their monetary policy outcome by choosing to peg the nominal exchange rate to that of a more credible partner. In this section we show empirical evidence that as a central bank gains credibility, it tends to loosen any currency pegs and adopt a floating exchange rate. Furthermore, we show that the empirical link between central bank credibility and exchange rate flexibility depends on a country's level of trade openness.

4.1 Empirical model, variables, and data

To establish this empirical link between central bank credibility and a floating exchange rate, we will estimate a panel data model with an index of exchange rate flexibility as the dependent variable and a proxy for central bank credibility as the independent variable. In this panel we use annual data from 96 countries over 13 years, from 1998-2010. The full list of countries can be found in the appendix.

The dependent variable in this empirical exercise is an index of whether a country has a fixed or floating exchange rate is from Ilzetzki, Reinhart, and Rogoff (2008). This index varies from (1) - "no separate legal tender" to (13) - "freely floating" and in between covers varying degrees of exchange rate pegs. The exact definitions for each of the 13 index values are found in the appendix. This fixed-floating index represents the inverse of the value $\phi_S(\gamma)$ in the alternative central bank objective function (16). In the model, an increasing $\phi_S(\gamma)$ meant that the central bank placed more weight on nominal exchange rate stabilization in their objective function, which would be represented by smaller value in the Ilzetzki, Reinhart, and Rogoff (2008) fixed-floating index.

As a proxy for central bank credibility we use the index of central bank independence from Dincer and Eichengreen (2013). Central bank independence has been used as a proxy for central bank credibility and institutional quality from as early as Cukierman (1992) and Alesina and Summers (1993). Blinder (2000) reports that a vast majority of both central bank governors and academic economists cite central bank independence as one of the most important factors behind central bank credibility. For this reason, this measure of central bank independence is a proxy for the commitment probability parameter γ.

We also include a measure of trade openness (the sum of imports and exports divided by GDP) as another independent variable and in one regression specification we estimate the interaction between central bank independence and trade openness.

As control variables in this panel data regression we add the inflation rate in the previous year and the GDP growth rate in the previous year.

4.2 Empirical Results

The results from this panel data regression of exchange rate flexibility on central bank independence is presented in table 2. The first four columns of the table present the results from the panel that includes all 96 countries, and the last four columns in the table present the results for the subsample of 75 developing and emerging market countries.

The table shows that when cross-section fixed effects are not included in the panel data regression, there is a strong negative correlation between central bank independence and exchange rate flexibility in the full sample of 96 countries. This suggests that there is a strong negative correlation between the two in the cross-section. The Euro Area countries in the sample drive this negative correlation. These are countries with a very independent central bank that score a 1 on the fixed-floating index. This strong negative cross-sectional correlation disappears in the sub-panel of only developing and emerging market countries.

Including cross-section fixed effects controls for the cross-sectional correlation between central bank credibility and the index of exchange rate flexibility. The coefficient of central bank independence is now positive and significant, indicating that when central bank independence improves in year $t-1$, holding all else equal, the index of exchange rate flexibility will shift towards floating in year t. Since the fixed-floating index that is the dependent variable in this regression is the inverse of $\phi_S(\gamma)$ in the theoretical model, the positive and significant coefficient in the regression implies that $\frac{d\phi_S(\gamma)}{d\gamma} < 0$, exactly as in the model.

In the second column in the table we include an interaction term between central bank credibility and the level of trade openness. The coefficient on this interaction term is positive and significant, indicating that the link between central bank credibility and the desire to peg the nominal exchange rate is a function of a country's level of trade openness. The desire to peg the exchange rate as central bank credibility falls is strongest for a very open economy, in other words, $\frac{d^2\phi_S(\gamma;\lambda)}{d\gamma d\lambda} < 0$, exactly as in the model.

The lagged values of the inflation rate or the GDP growth rate do not have an effect on the degree of exchange rate flexibility. The last 4 columns in the table show that these same results hold not just for the full panel of 96 countries but for the sub-panel of 75 developing and emerging market countries.

5 Summary and Conclusion

Historically, the lack of central bank credibility has been a motivation to adopt a single mandate, either a currency peg, or more recently, an inflation target. This paper sought to model this motivation in a small open economy where the central bank cannot perfectly commit to a future course of policy. In the model the central bank has limited credibility, with some exogenous probability it will renege on its previous promises and re-optimize. This limited credibility imposes a welfare cost on society. Inflation and inflation expectations are not well anchored if agents assume that the central bank will renege on past promises. In this case, the social welfare is actually improved by assigning the central bank to minimize a loss function which is different from the social loss function. By either increasing the weight they place on inflation stabilization, or including a term for nominal exchange rate stabilization in their loss function, the central bank with limited credibility can communicate their commitment to keeping inflation low and stable, and thus inflation expectations remain anchored. The central bank with limited credibility can deliver a significant welfare improvement by adopting an objective function that contains a role for exchange rate stabilization.

In this model, limited credibility had a specific meaning. It meant the probability that the central bank will honor past commitments. In technical terms, it is the probability that previous inflation expectations appear as a constraint in the central bank's maximization problem. The central bank still has the same underlying preferences and discount factor as the rest of society.

In many historical cases of a central bank that lacks credibility, the central bank or monetary authority actually has different preferences from the rest of society. This is most clearly illustrated when monetary policy is in the hands of an elected politician. Here one could say that the elected politician has a different discount factor or places a different weight on output in the output/inflation trade-off that society at large, and may try to stimulate the economy in the short run in order to win an upcoming election, at the cost of higher inflation in the long-run, after the election. Historically, this type of monetary arrangement has led to high and variable inflation, and many countries have been forced to adopt currency pegs, currency boards, or complete dollarization in order to control inflation arising from a monetary authority with different preferences than society at large. That channel is not included in this model. Here the central bank can't commit but it's preferences are the same as the rest of society. An interesting direction for further research would be to see how the motivation to peg the currency can also depend on the central bank's preferences. This paper shows that limited credibility can be a motivation, what about a monetary authority that is less patient than the rest of society. Would the impatient central banker have the same motivation to tie their hands?

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A Appendix

A.1 Model

A.1.1 The social welfare function

The central bank sets monetary policy in order to maximize the second-order approximation of the household's welfare in (1). As shown in de Paoli (2009), in this model, the maximization of the second-order approximation of welfare is equivalent to the minimization of the quadratic loss function of the output gap, the inflation rate of home country produced goods, and the real exchange rate:

$$L_t = \frac{1}{2}\sum_{t=0}^{\infty}\beta^t\left(\Phi_y\left(\hat{Y}_t - \hat{Y}_t^T\right)^2 + \Phi_\pi\left(\pi_t^H\right)^2 + \Phi_q\left(\hat{Q}_t\right)^2\right)$$

where:

$$\Phi_y = (\eta+\rho)(1-\phi) + \frac{(\rho-1)\left[-l(1-\phi)-(\lambda-\phi)\right]}{1+l} + Lx_1\left[\eta+\rho+\eta(\eta+1)-\frac{\rho(\rho-1)}{1+l}\right] - Lx_2\frac{(1-\lambda)^2\lambda(\rho\theta-1)}{1+l},$$

$$\Phi_q = -\frac{(\lambda+l)(\rho-1)}{(1-\lambda)\rho^2} + \frac{Lx_1 l(\rho-1-l)}{(1-\lambda)^2\rho} + \frac{Lx_2\lambda(\rho\theta-1)\left[\rho\theta(1-\lambda)+\lambda+l\right]}{\rho^2} + \frac{Lx_3\lambda(\theta-1)}{1-\lambda},$$

$$\Phi_\pi = \frac{\sigma}{\bar{\mu}\kappa} + (1+\eta)\frac{\sigma}{\kappa}Lx_1.$$

and:

$$Lx_1 = \frac{1}{\rho+\eta+l\eta}\left(-\frac{l}{\bar{\mu}} + 1 - \lambda - \frac{1}{\bar{\mu}}\right),$$

$$Lx_2 = \frac{1}{\rho+\eta+l\eta}\left[\rho\left(\frac{1}{\bar{\mu}} - 1 + \lambda\right) + (1-\lambda)(\eta+\rho)\right],$$

$$Lx_3 = \frac{1}{\rho + \eta + l\eta}\left[- \left(\rho\theta - 1\right)\left(1 - \lambda\right)\frac{1}{\bar{\mu}} - \left(\eta\theta + 1\right)\right],$$

and:

$$l = \left(\rho\theta - 1\right)\lambda\left(2 - \lambda\right),$$

$$\bar{\mu} = \frac{1}{1 - \lambda},$$

$$\kappa = \frac{\left(1 - \alpha\beta\right)\left(1 - \alpha\right)}{\alpha\left(1 + \sigma\eta\right)},$$

$$\phi = 1 - \frac{1}{\bar{\mu}} = \lambda,$$

and $\hat{Y}_t^T = \frac{-Lx_1(1+\eta)}{\Phi_y}\hat{\mu}_t$

A.1.2 Derivation of New Keynesian Phillips Curve

As presented in the text, the optimal price for a firm that can change their price, $\mathbf{P}_t^H$, is given by:

$$\mathbf{P}_t^H = \mu_t \frac{E_t \sum_{\tau=0}^{\infty} \beta^\tau \left(\xi_p\right)^\tau \Lambda_{t+\tau} MC_{t+\tau}\left(i\right) Y_{t+\tau}\left(i\right)}{E_t \sum_{\tau=0}^{\infty} \beta^\tau \left(\xi_p\right)^\tau \Lambda_{t+\tau} Y_{t+\tau}\left(i\right)}$$

Furthermore, the expression for the evolution of the home goods price index is:
$P_t^H Y_t = \frac{1}{n}\int_0^n P_t^H\left(i\right) Y_t\left(i\right) di$

$$P_t^H = \left(\xi_p\left(P_{t-1}^H\right)^{1-\sigma} + \left(1 - \xi_p\right)\left(\mathbf{P}_t^H\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

The linearized form of these two expressions is given by:

$$\hat{\mathbf{P}}_t^H = \hat{\mu}_t + (1-\beta\xi_p)\left(M\hat{C}_t(i)\right) + \beta\xi_p E_t\left(\hat{\mathbf{P}}_{t+1}^H\right)$$
$$\hat{P}_t^H = \xi_p\left(\hat{P}_{t-1}^H\right) + (1-\xi_p)\hat{\mathbf{P}}_t^H$$

Furthermore note that the linearization of the price index can be rewritten as $\hat{\mathbf{P}}_t^H = \hat{P}_t^H + \frac{\xi_p(1+\eta\sigma)}{(1-\xi_p)}\pi_t^H$ and $E_t\left(\hat{\mathbf{P}}_{t+1}^H\right) = E_t\left(\hat{P}_{t+1}^H\right) + \frac{\xi_p(1+\eta\sigma)}{(1-\xi_p)}E_t\left(\pi_{t+1}^H\right)$. After a few substitutions, the New Keynesian Phillips Curve equation is given by:

$$\pi_t^H = \hat{\mu}_t + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}\left(M\hat{C}_t - \hat{P}_t^H\right) + \beta E_t\left(\pi_{t+1}^H\right)$$

Recall that $\hat{P}_t = (1-\lambda)\hat{P}_t^H + \lambda\left(\hat{S}_t + \hat{P}_t^F\right)$, $\hat{Q}_t = \hat{S}_t + \hat{P}_t^F - \hat{P}_t$, $M\hat{C}_t = \hat{W}_t$, and from the household's labor supply decision $\eta\hat{H}_t + \hat{C}_t = \hat{W}_t - \hat{P}_t$, then we can write the NKPC as:

$$\pi_t^H = \hat{\mu}_t + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}\left(\eta\hat{H}_t + \hat{C}_t + \frac{\lambda}{1-\lambda}\hat{Q}_t\right) + \beta E_t\left(\pi_{t+1}^H\right)$$

Recall that $\hat{Y}_t = \hat{H}_t + \sigma\hat{P}_t^H - \sigma\int_0^1 \hat{P}_t^H(i)\,di$, $\hat{Q}_t = \hat{C}_t - \hat{C}_t^*$ and $Y_t = C_t^H + C_t^{F*}$. After substituting the demand functions for home country consumption of home goods, C_t^H, and foreign country consumption of home goods, C_t^{F*} this last expression can be written as:

$$\pi_t^H = \hat{\mu}_t + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}\left(\eta\left(\hat{Y}_t - \sigma\hat{P}_t^H + \sigma\int_0^1 \hat{P}_t^H(i)\,di\right) + \hat{C}_t + \frac{\lambda}{1-\lambda}\hat{Q}_t\right) + \beta E_t\left(\pi_{t+1}^H\right)$$
$$\pi_t^H = \hat{\mu}_t + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}\left(\eta\hat{Y}_t + \hat{C}_t + \frac{\lambda}{1-\lambda}\hat{Q}_t\right) + \beta E_t\left(\pi_{t+1}^H\right)$$

$$Y_t = \left(\frac{P_t^H}{P_t}\right)^{-\theta}\left[(1-\lambda)C_t + \lambda\left(\frac{1}{Q_t}\right)^{-\theta}C_t^*\right]$$

Since in response to a home country mark-up shock, $\hat{C}_t^* = 0$, this becomes:

$$\pi_t^H = \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}\left(\hat{\mu}_t + \eta\hat{Y}_t + \frac{1}{1-\lambda}\hat{Q}_t\right) + \beta E_t\left(\pi_{t+1}^H\right)$$

The market resource constraint can be written as:

$$Y_t = \left(\frac{P_t^H}{P_t}\right)^{-\theta}\left[(1-\lambda)C_t + \lambda\left(\frac{1}{Q_t}\right)^{-\theta}C_t^*\right]$$

$$\hat{Y}_t = -\theta\left(\hat{P}_t^H - \hat{P}_t\right) + (1-\lambda)\hat{C}_t - \theta\lambda\hat{Q}_t$$

$$\hat{Y}_t = -\theta\left(\lambda\hat{P}_t^H - \lambda\left(\hat{Q}_t + \hat{P}\right)\right) + (1-\lambda)\hat{C}_t - \theta\lambda\hat{Q}_t$$

$\hat{Q}_t - \hat{P}_t^F + \hat{P} = \hat{S}_t$

$\hat{Y}_t = (1-\lambda)\frac{1}{\rho}\hat{Q}_t + \frac{\theta\lambda(2-\lambda)}{1-\lambda}\hat{Q}_t,$

A.2 Derivation of analytical expressions under exchange rate targeting

Under nominal exchange rate targeting, $\hat{Y}_t - \hat{Y}_{t-1} = -\phi\hat{\pi}_t^H$. This when combined with the New Keynesian Phillips curve and the market resource constraint yields the following:

$$\beta\hat{Q}_{t+1} = (1+\beta+\kappa(\eta\phi+1))\hat{Q}_t - \hat{Q}_{t-1} + \kappa(1-\lambda)\hat{\mu}_t$$

Use the method of undetermined coefficients and assume that $\hat{Q}_t$ follows the following process:

$$\hat{Q}_t = A\hat{Q}_{t-1} + B(1-\lambda)\hat{\mu}_t$$

After solving using the method of undetermined coefficients, the values of A and B are:

$$A = \frac{(1+\beta+\kappa(\eta\phi+1)) - \sqrt{(1+\beta+\kappa(\eta\phi+1))^2 - 4\beta}}{2\beta}$$
$$B = -\frac{2\kappa}{\left(1+\beta+\kappa(\eta\phi+1) + \sqrt{(1+\beta+\kappa(\eta\phi+1))^2 - 4\beta}\right)}$$

From this it is simple to show that:

$$var\left(\hat{Q}_t\right) = \frac{B^2(1-\lambda)^2}{1-A^2} var(\hat{\mu}_t)$$
$$var\left(\hat{Y}_t\right) = \phi^2 \frac{B^2}{1-A^2} var(\hat{\mu}_t)$$
$$var\left(\hat{\pi}_t^H\right) = 2\frac{B^2}{1+A} var(\hat{\mu}_t)$$

A.3 Countries in the Estimation

The 96 countries, 21 developed and 75 developing and emerging markets, in the panel data regressions are:

Developed countries: Australia, Austria, Belgium, Canada, Germany, Spain, Finland, France, UK, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, Norway, New Zealand, Portugal, Sweden, USA

Developing countries: Angola, Albania, Argentina, Armenia, Azerbaijan, Bulgaria, Bahamas, Bosnia, Belarus, Belize, Barbados, Bhutan, Botswana, Chile, China, Colombia, Czech Republic, Estonia, Fiji, Georgia, Guyana, Croatia, Hungary, Iceland, Indonesia, India, Israel, Jamaica, Jordan, Kenya, Kyrgyzstan, Cambodia, Laos, Sri Lanka, Lesotho, Lithuania, Latvia, Moldova, Maldives, Mexico, Macedonia, Mongolia, Mozambique, Mauritius, Malawi, Malaysia, Namibia, Nigeria, Oman, Peru, Philippines, Papua New Guinea, Poland, Romania, Russia, Saudi Arabia, Singapore, Solomon Islands, Sierra Leone, El Salvador, Seychelles, Syria, Thailand, Trinidad and Tobago, Tunisia, Turkey, Tanzania, UAE, Uganda, Venezuela, Vanuatu, Samoa, Yemen, South Africa, Zambia

Table 1: Model parameter values.

Parameters	Values	Explanation
ξ_p	0.66	Percent of firms that cannot change price in a given period
β	0.99	Subjective discount factor
η	0.47	Inverse of the Frisch elasticity
σ	10	Elasticity of substitution among differentiated goods from same country
θ	3	Elasticity of substitution between home and foreign goods
κ	0.021	$\frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p(1+\eta\sigma)}$

Table 2: Results from a panel data regression of an index of currency flexibility on central bank indepenence. Results from the full sample of 96 countries.

	Dependent variable: FX Float(t)							
	All Countries				Developing and Emerging Countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ind(t-1)	1.332*	-0.678	-5.788***	-3.866***	1.475*	-1.435	0.838	8.881***
	(0.689)	(1.159)	(0.495)	(0.899)	(0.841)	(1.491)	(0.587)	(1.156)
open(t-1)	0.809***	-0.244	-1.823***	-1.063***	0.897**	-0.435	-0.978***	1.406***
	(0.295)	(0.570)	(0.216)	(0.367)	(0.358)	(0.668)	(0.237)	(0.376)
Ind(t-1) x open(t-1)		2.289**		-1.939**		3.170**		-8.369***
		(1.062)		(0.758)		(1.343)		(1.048)
dGDP(t-1)	-0.218	-0.115	-0.046	-0.203	-0.182	-0.144	-1.937	-2.620
	(0.780)	(0.780)	(2.146)	(2.141)	(0.937)	(0.934)	(2.099)	(2.025)
Pi(t-1)	-0.581	-0.648	-0.433	-0.069	-0.614	-0.662	-2.334	-0.911
	(0.946)	(0.945)	(2.857)	(2.853)	(1.108)	(1.104)	(2.708)	(2.617)
Country FE	yes	yes	no	no	yes	yes	no	no
Adj. R2	0.914	0.915	0.157	0.161	0.848	0.849	0.023	0.093
Obs.	1079	1079	1079	1079	827	827	827	827

Notes: Standard errors in parenthesis. * denotes significance at the 10% level, ** denotes significance at the 5% level, *** denotes significance at the 1% level

Table 3: Exchange rate flexibility index values from Ilzetzki, Reinhart, and Rogoff (2008)

1	No separate legal tender
2	Pre announced peg or currency board arrangement
3	Pre announced horizontal band that is narrower than or equal to +/-2%
4	De facto peg
5	Pre announced crawling peg
6	Pre announced crawling band that is narrower than or equal to +/-2%
7	De facto crawling peg
8	De facto crawling band that is narrower than or equal to +/-2%
9	Pre announced crawling band that is wider than or equal to +/-2%
10	De facto crawling band that is narrower than or equal to +/-5%
11	Moving band that is narrower than or equal to +/-2% (i.e., allows for both appreciation and depreciation over time)
12	Managed floating
13	Freely floating

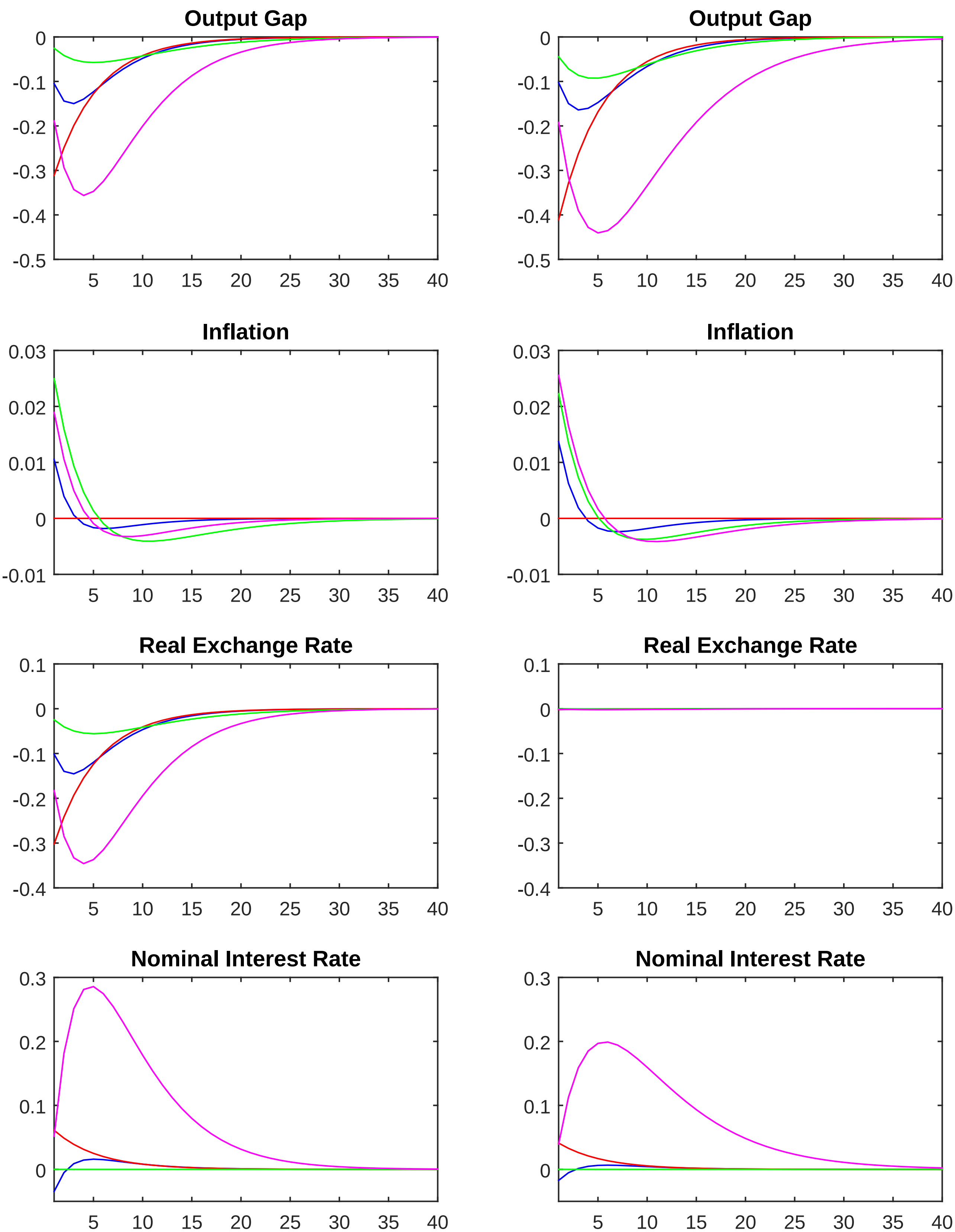

Figure 1: Responses to a cost push shock. Left hand column is for the economy with a low import share and the right hand column is for a high import share. Blue: Committment, Purple: Discretion, Red: Inflation Targeting, Green: Exchange Rate Targeting

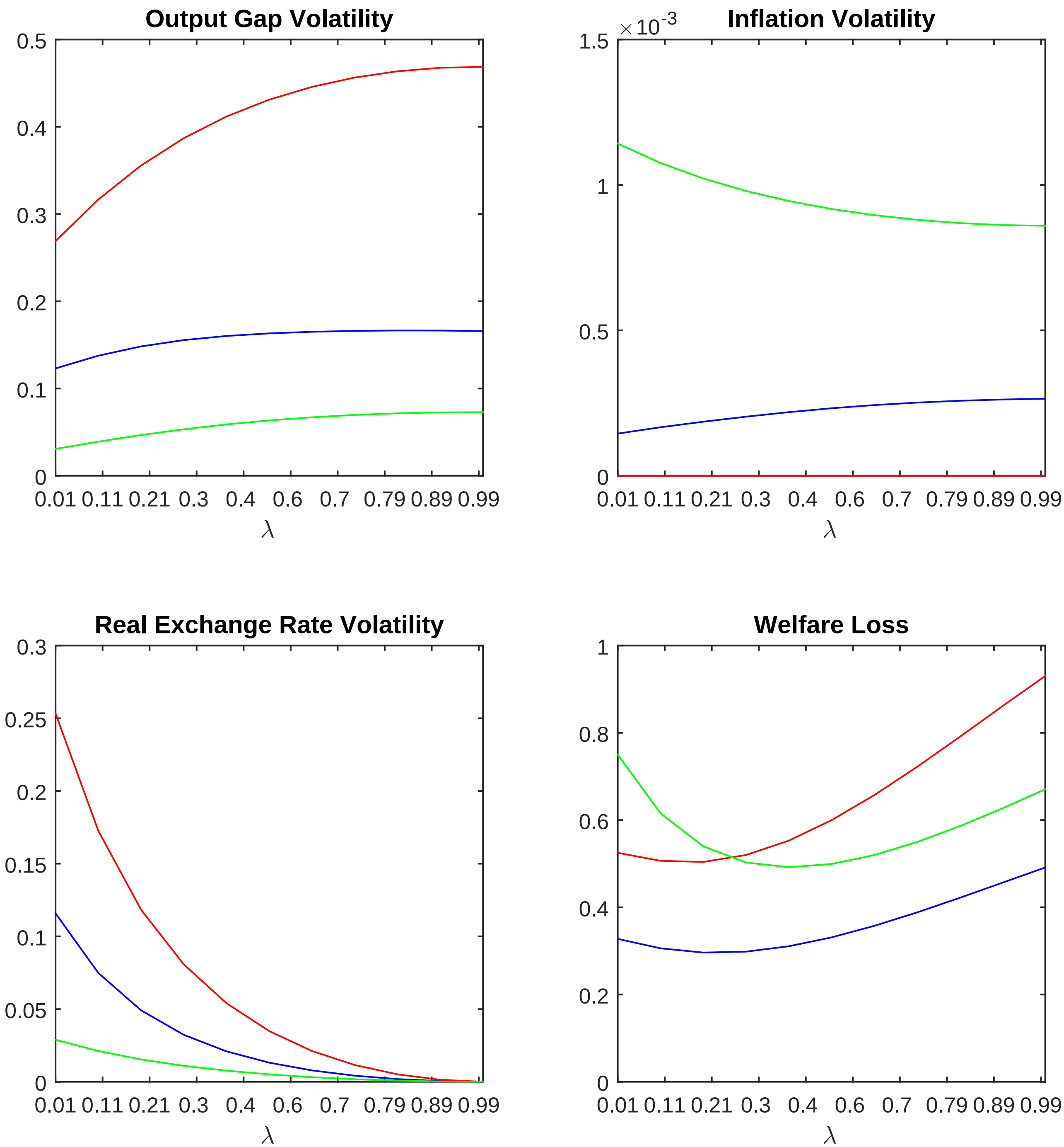

Figure 2: Volatilities of the output gap, inflation, and the real exchange rate as a function of the import share. Blue: Committment, Red: Inflation Targeting, Green: Exchange Rate Targeting

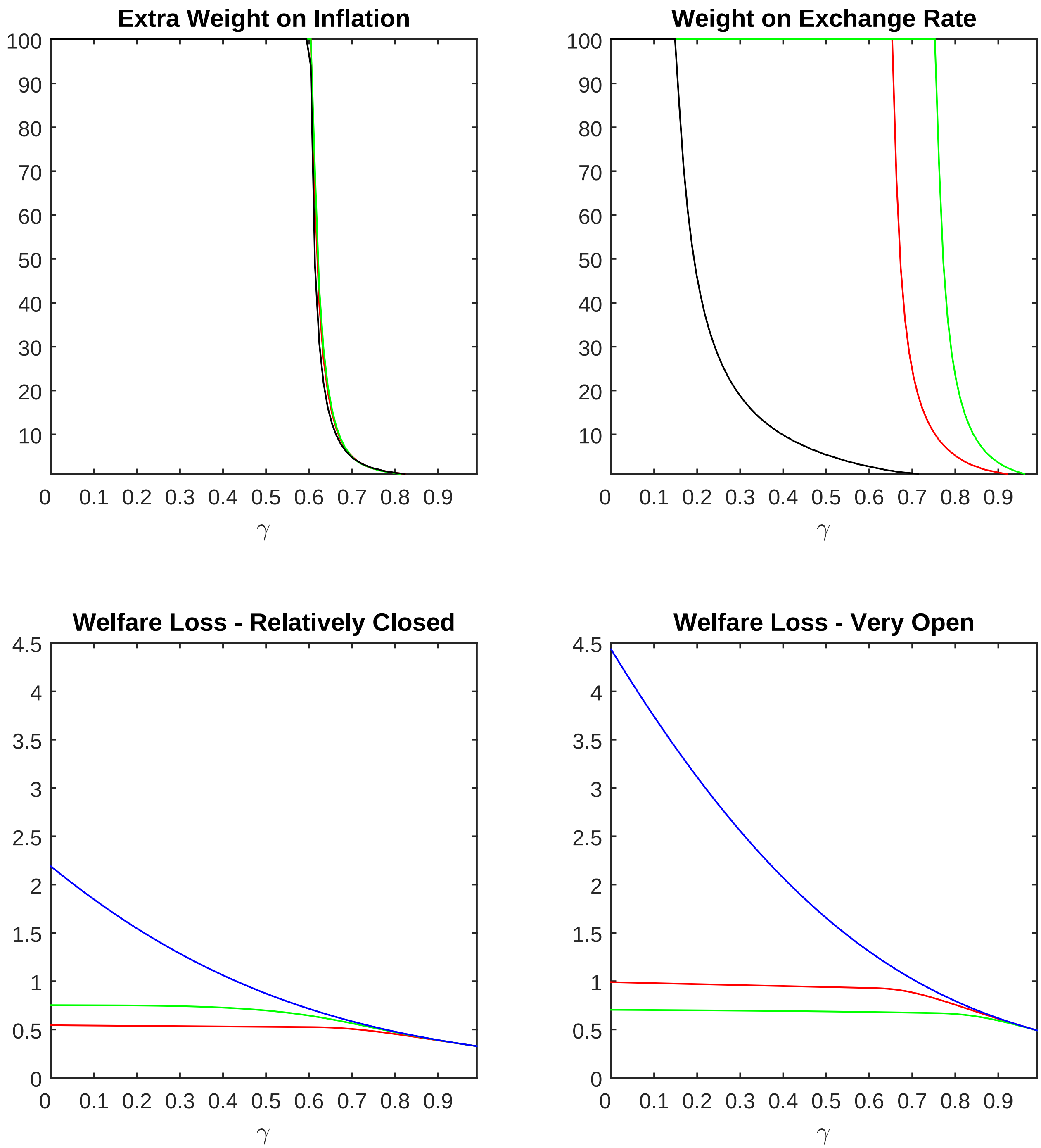

Figure 3: Top half - Optimal extra weight on inflation or the nominal exchange rate in the central bank's objective function as a function of the commitment probability γ. Black: Relatively closed economy, green: very open economy, red: middle level of trade openness. Bottom half - Welfare loss from optimal policy as a function of the commitment probability γ. Blue: No modifications to central bank objective function, red: optimal extra weight on inflation, green: optimal weight on the nominal exchange rate.