Sticky Wages, Incomplete Pass-Through and Inflation Targeting: What is the Right Index to Target?

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OPTIMAL MONETARY POLICY WITH STICKY WAGES, INCOMPLETE PASS-THROUGH AND INFLATION TARGETING *

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Abstract

This paper studies optimal monetary policy in a small open economy with Inflation Targeting, incomplete pass-through and rigid nominal wages. The paper shows that the right index to target depends on the structure of the individual economy. When wages are fully flexible, the consumer price index (CPI) is better to target given low to moderate levels of pass-through. On the other hand, assuming complete pass-through, economies with relatively high degrees of wage rigidity and wage indexation should either target their CPIs or fully stabilize nominal wages. Also, CPI targeting and nominal wage targeting are superior to targeting the Producer Price Index (DPI) in relatively high degrees of pass-through given that wages are relatively rigid and indexation degrees are high. The results of the paper suggest that, by committing to a common monetary policy in a common-currency area, some countries may not be conducting monetary policy optimally.

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I. INTRODUCTION

Since the Early 1990s several countries followed New Zealand, and started to conduct their monetary policy by means of Inflation Targeting (IT). Although the implementation of this regime has many similarities across counties, there are still few differences and controversial issues. The right price index to target is one of them. A country adopting the IT regime can, in principal, either target its Consumer Price Index (CPI) which embodies the prices of imported goods, or target some measure of Domestic Price Index (DPI) and thus allow for exchange rates adjustments. Based on the contribution of Gali and Monacelli (2005), hereafter GM, the current study revisits this topic by discussing the implications of allowing for both rigid import prices (i.e. incomplete pass-through) and rigid nominal wages on the choice of right index to target. The rigidities in both nominal wages and imports prices have been reported in several studies of recent years. [1]

In general, the paper shows that the right index to target depends on the structure of the individual economy; some countries may find targeting CPI better than targeting the alternative, while other economies may better choose to target their DPIs. Targeting nominal wages is optimal for countries with relatively high degrees of nominal wage rigidity and wage indexation. These findings may imply that adopting the same regime for countries that differ in their structures, as is this case in common-currency areas, may not be optimal for some countries.

The choice of the right index has been discussed in several recent theoretical studies. In a relatively similar model to GM (2005), Clarida, Gali and Gertler (2001) found DPI to be better to

[1] Smets and Wouters (2003), Christiano, Eichenbaum and Evans (2005) among others show evidence for wage rigidity. Campa and Goldberg (2005a, 2005b) show evidence for incomplete pass-through from exchange rate movements into import prices.

target giving complete pass-through and fully flexible wages**.** Assuming complete pass-through but rigid wages in the GM framework, Campolmi (2006) showed that the best Taylor Rule to follow is the one targeting wage inflation and CPI inflation (given positive indexation levels). In a model with fully flexible wages, Devereux, Lane and Xu (2006) also recommend targeting DPI in high pass-through environments. They however show that targeting the CPI is more desirable when pass-through is low. Based on typical interest rate feedback rules, Huang and Liu (2005) suggest that the Monetary Authority (MA) should respond to a weighted average of CPI and DPI. Recently, Flamini (2007) suggest that targeting DPI is better even when pass-through is low. In general, the rationale behind these results is that targeting the CPI requires responding to exchange rates movements which makes interest rates, and hence real activity, more volatile.

The model assumed here is a standard New Keynesian (NK) framework calibrated for a prototype small open economy and it is based on the work of Gali and Monacelli (2005). In particular, the model assumes that domestic prices, import prices and nominal wages are rigid. Wages that are not reset during a specific period are assumed to be indexed to past CPI inflation. The original work of GM abstracted from rigidity in nominal wages and imports prices and it supported targeting the DPI.[2]

Wage stickiness might be crucial for the choice of the right index to target. This indexation scheme gives a rise for CPI stabilization since a variable CPI leads to variable aggregate wages and hence to relatively volatile marginal costs of domestic firms. This renders full stabilization of the DPI harder and costly to achieve. Indeed, in a closed economy framework, Erceg,

[2] The study of Aoki (2001) suggests that these results should may be surprising. In a two sector model, he showed that a country better target the price index in the more rigid sector. Hence, assuming only rigid domestic prices by GM (2005) makes targeting DPI more natural.

Henderson and Levine (2000) show that strict inflation targeting is suboptimal when both prices and wages are rigid.

Relaxing the assumption of complete pass-through (CPT) is another important step to capture reality. One advantage of a floating exchange rate is that it adjusts in response to external shocks and thus helps stabilizing the real economy (Devereux, Lane and Xu, 2006). But, when pass-through is high this boosts inflation. Therefore, if the Monetary Authority targets the CPI, any movement in the exchange rate requires stronger response and this leads to higher variability in both the interest rate and the output gap. This renders CPI targeting less desirable. When pass-through is low, however, the cost of the variability of exchange rate is relatively low and hence the MA can target CPI inflation and still have the exchange rate responding to external shocks. Thus, the desirability of CPI targeting rises in this case. [3]

This paper also considers the possibility of targeting nominal wages (i.e. targeting zero wage inflation rate). In this sense, nominal wages can be seen as an intermediate goal for monetary policy since the stabilization of nominal wages helps stabilizing the marginal cost and hence domestic prices. The main focus however will be on the favorability of CPI targeting versus DPI targeting since they have been typically the main indices under study.

The key findings of this paper are as follows. When wages are fully flexible, CPI targeting is favorable in low to moderate pass-through degrees (around 0.40 or lower). On the other hand, when pass-through is complete, CPI is found to be favorable when both wage rigidity and indexation levels are high (around 0.75 or more). When both of the two frictions are

[3] Note that I abstract here from imported inputs. Allowing for imported inputs can significantly enrich the model since in this case marginal costs of *domestic* firms will be directly affected by movements in the exchange rate and therefore stabilizing *domestic* inflation will be harder to achieve.

incorporated, CPI is better to target for relatively high levels of pass-through, wage rigidity and indexation. The relevant degrees of pass-through, wage rigidity and indexation are in general, in line with some empirical findings. Also, for high degrees of wage rigidity, indexation and pass-through, it might even be better to target nominal wages rather than the DPI. Finally, in other cases, the study shows that targeting the DPI is favorable.

Given these findings, one may wonder whether adopting a similar monetary policy for a group of countries that differ in their labor markets, pass through and domestic products markets, is optimal. Once committing to a region-wide policy, some countries may indeed be conducting the optimal policy. Others, however, may not be so doing. Although region-wide policy may have its advantages over time, it renders some countries committing to a policy that would not otherwise been chosen. A research that study differences between countries empirically can be helpful to assess these conjectures.

The remainder of the paper proceeds as follows. Based on the GM framework, section II outlines the model economy with the proposed modifications. Section III describes the calibration methodology and presents the main results of the study. Some sensitivity analyses are presented in section IV. Section V concludes.

II. THE MODEL ECONOMY

This section describes the model economy, a modification of the GM (2005) framework. As discussed above, this paper relaxes both the assumption of complete pass-through as well as fully flexible wage setting. Since the model is based on GM (2005) and to keep the focus on the main modifications, in what follows I only outline the main setup of the model. Therefore, in several occasions the reader may refer to their work, as well as Monacelli (2005) for further details.

II.A. Households

The representative household in our Small Open Economy has an access to complete foreign asset markets and seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t [U(C_t) - V(N_t)] \tag{1}$$

where N denotes labor and C stands for *composite* consumption. The maximization is subject to the following sequence of budget constraints

$$\int_0^1 [P_{H,t}(i) C_{H,t}(i)] di + \int_0^1 [P_{F,t}(i) C_{F,t}(i)] di + Q_{t,t+1} D_{t+1} \leq D_t + W_t N_t + T_t \tag{2}$$

With $P_{H,t}(i)$, $P_{F,t}(i)$, $C_{H,t}(i)$ and $C_{F,t}(i)$ denoting the price of domestic good *i*, the price of foreign good *i* and their quantities respectively. W_t is the nominal wage, $Q_{t,t+1}$ is a stochastic factor in time *t+1* of the portfolio hold at the end of time *t*, D_{t+1}. T_t denotes the net lump sum transfers.

Composite consumption is given by

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

with $C_{H,t}$ and $C_{F,t}$ denoting aggregate consumption of domestic (home) goods and foreign goods, respectively. The parameter α represents the degree of openness of the economy while η measures the elasticity of substitution between home and foreign goods. Both domestic and foreign consumption are given by the following CES aggregators

$$C_{H,t} = \left(\int_0^1 C_{H,t}(i)^{\frac{\varepsilon_H - 1}{\varepsilon_H}} \right)^{\frac{\varepsilon_H}{\varepsilon_H - 1}}$$

$$C_{F,t} = \left(\int_0^1 C_{F,t}(i)^{\frac{\varepsilon_F - 1}{\varepsilon_F}} \right)^{\frac{\varepsilon_F}{\varepsilon_F - 1}}$$

In the above setup, the general price level, i.e. the Consumer Price Index (CPI), is given by

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

Assuming the following functional forms $U(C_t) = \frac{C_t^{1-\sigma}}{1-\sigma}$ and $V(N_t) = \frac{N_t^{1+\varphi}}{1+\varphi}$ and maximizing preferences subject to the sequence of budget constraints give the following (Log-Linearized) optimality conditions

$$w_t - p_t = \sigma c_t + \varphi n_t \tag{5}$$

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(r_t - E_t \pi_{t+1} - \rho) \tag{6}$$

where a lower case letter denotes the log of the respective upper case variable, w_t is the wage rate, π_t is the CPI inflation rate and ρ represents time preference. Note that condition (5) is the typical Intratemporal condition between consumption and labor stating that in equilibrium households equate the marginal rate of substitution between consumption and leisure to the real wage. Condition (6) is the typical Euler Equation in consumption, to which we can also refer as the New Keynesian IS curve. Current consumption depends positively on the expected future consumption and negatively on the expected real interest rate.

II.B. Firms

As is typical in NK models, each firm *j* is monopolistically competitive and a produces a differentiated good with a linear technology in labor of the form

$$Y_t(j) = A_t N_t(j) \tag{7}$$

with *A* denoting technology. The aggregate production in this economy can be written (in a Log-Linearized form) as $y_t = a_t + n_t$.

Cost minimization by domestic firms gives the following expression for the real marginal cost

$$mc_t = w_t - p_{H,t} - a_t - v \tag{8}$$

where *v* is an employment subsidy that offsets the market power of firms. Prices set by domestic firms are assumed to be staggering (as in Calvo, 1983), with only a fraction $1-\theta_H$ allowed to reoptimize each period. Other firms simply keep their prices at time *t* similar to time *t-1* prices. The Domestic Price Index (DPI) can thus be written as

$$p_{H,t} = (1-\theta_H)\tilde{p}_{H,t} + \theta_H p_{H,t-1} \tag{9}$$

where $\tilde{p}_{H,t}$ stands for the price set by firms who are allowed to change prices. Finally, the last result can be combined with the expression for the marginal cost to obtain the following forward-looking Phillips Curve (or the AS Curve) for domestic prices:[4]

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda_H \hat{mc}_t \tag{10}$$

where $\lambda_H = \frac{(1-\theta_H)(1-\beta\theta_H)}{\theta_H}$.

[4] See Gali and Monacelli (2005) for further details on deriving this expression.

II.C. The Real Exchange Rate and Pass-Through

In this subsection I discuss how does the introduction of incomplete pass-through (IPT) affect the setup of GM (2005). Note first that Log-Linearized for CPI inflation is given by

$$\pi_t = \alpha\pi_{F,t} + (1-\alpha)\pi_{H,t} \tag{11}$$

Also, the real exchange rate can be written as

$$q_t = e_t + p_t^* - p_t \tag{12}$$

with p_t^* and e_t being foreign prices and the nominal exchange rate, respectively. In terms of our model, complete pass-through (or the Law of One Price) implies that $p_{F,t} = e_t + p_{F,t}^*$. Assuming that the Rest of the World is big and hence the prices of the SOE are negligible in determining foreign prices, we have $p_{F,t}^* = p_t^*$. Therefore

$$p_{F,t} = e_t + p_t^* \tag{13}$$

To allow for incomplete pass-through, I follow Monacelli (2005) and assume that each period only a fraction $1-\theta_F$ of the local import retailers are allowed to change their prices. Also, retailers import foreign goods at a price (cost) of $\varepsilon_t \cdot P_{F,t}^*$ and charge a price of $P_{F,t}$ for these goods. The above setup leads to an analog expression of (9) given by

$$p_{F,t} = (1-\theta_F)\tilde{p}_{F,t} + \theta_F p_{F,t-1} \tag{14}$$

Having IPT in place, the deviation from the Law of One Price (LOP) is measured by

$$\psi_{F,t} = (e_t + p_t^*) - p_{F,t} \tag{15}$$

In this setup, we can think about the deviation from the LOP as a marginal cost for the importers: they import foreign goods with a price of $(e_t + p_t^*)$ but charge only $p_{F,t}$.

Given IPT, the real exchange rate can be written now as

$$q_t = (1-\alpha)s_t + \psi_{F,t} \tag{16}$$

Also, one can obtain an analog for (10) given by

$$\pi_{F,t} = \beta E_t \pi_{F,t+1} + \lambda_F \psi_{F,t} \tag{17}$$

where $\lambda_F = \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F}$. Therefore, import price inflation is higher the higher $\psi_{F,t}$ is. Also, the parameter θ_F plays a major role in determining import price inflation. Other things equal, a lower θ_F (implying higher degree of pass-through) leads to higher import price inflation. As discussed in Monacelli (2005), there are two sources for fluctuations in the real exchange rate. The first, due to TOT fluctuations, is captured by the first term in (16), while the second arises because of deviations from the LOP.

II.C. Wage Setting

Motivated by the empirical evidence of wage rigidities reported in several papers in recent years (e.g. Christiano *el al*, 2005 and Smets and Wouters, 2003), this paper relaxes the assumption of fully flexible wages. In particular, the aggregate labor input of each firm is given by a CES function of the different types of labor inputs hired. Formally,

$$N_{i,t} = \left(\int_0^1 N_{i,t}(j)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} \right)^{\frac{\varepsilon_w}{\varepsilon_w - 1}}$$

In addition, only a fraction $(1-\theta_w)$ of households can reset their wages (to $\tilde{w}_t$) each period, while other households (partially) index their wages to past CPI inflation.[5] Such an indexation scheme appears in both Smets and Wouters (2003) and Christiano *el al* (2005). Under these assumptions, the aggregate wage level each period is given by

$$w_t = (1-\theta_w)\tilde{w}_t + \theta_w w_{t-1} + \gamma_w \theta_w \pi_{t-1} w_{t-1} \tag{18}$$

with γ_w capturing the degree of indexation (e.g. γ_w =1 corresponds to full indexation). Denoting the wage markup by μ_t^w and the deviation of the markup from its frictionless level by $\hat{\mu}_t^w$ give the following expression for wage inflation

$$\pi_{w,t} = \beta E_t \pi_{w,t+1} - \lambda_w \hat{\mu}_t^w - \theta_w \gamma_w \beta \pi_t + \gamma_w \pi_{t-1} \tag{19}$$

where $\lambda_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\varphi\theta_w)}$, $\hat{\mu}_t^w = (w_t - p_t) - (\sigma c_t + \varphi n_t) - \mu^w$ and μ^w being the wage markup in a frictionless environment. Note that the first two terms of (19) are typical in wage inflation equations with no indexation (e.g. Gali, 2002). Current wage inflation is higher the higher the expected future wage inflation. If the markup is higher than its frictionless level (i.e. $\hat{\mu}_t^w$ >0), then wage inflation today tend to decrease in order to prevent a situation of losing competitiveness in the labor market. The indexation scheme assumed here introduces two more terms that will turn to be significant. Past inflation have a positive effect on wage inflation since workers who are not allowed to reset their wages at time *t* will have higher wages the higher past inflation is. On

[5] Smets and Wouters (2003) reported a degree of indexation of about 0.75 for the EURO area.

the other hand, because of indexation, households today know that even if they cannot reset their wages next period, the higher current inflation implies higher wages next period.[6]

Having sticky wages together with incomplete pass-through, it will prove useful to rewrite the above expressions for both DPI and CPI inflation rates in a more explicit way. Note first that the marginal cost of domestic firms can be rewritten as follows

$$m\hat{c}_t = (\varphi + \frac{\sigma}{\omega_s})x_t + (1 - \frac{\omega_\psi}{\omega_s})\psi_{F,t} + \hat{\mu}_t^w \ , \quad \omega_\psi = 1 + \alpha(\sigma\eta - 1) \text{ and } \omega_s = 1 + \alpha(2-\alpha)(\sigma\eta - 1) \quad (20)$$

with x being output gap (the difference between output and its frictionless level). In GM, only the first term in the right hand side appears. The two modifications clearly affect the determination of the marginal cost of domestic firms: a fluctuating wage markup or LOP gap leads to a less stable marginal cost. Note also that the expression for $m\hat{c}_t$ can be substituted into (10) to obtain

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_x x_t + \kappa_\psi \psi_{F,t} + \lambda_H \hat{\mu}_t^w \ , \qquad \kappa_x = \lambda_H(\varphi + \frac{\sigma}{\omega_s}),\ \kappa_\psi = \lambda_H(1 - \frac{\omega_\psi}{\omega_s}) \quad (21)$$

The last two terms of (21) introduce more tradeoff for monetary policy makers and they endogenously justify the ad-hoc cost-push shock assumed in some NK studies.[7] In particular, the Monetary Authority cannot stabilize DPI inflation, the output gap, the deviation from the LOP and the wage markup simultaneously. To see this consider for example a positive productivity shock. As a result, the output gap falls but there is a nominal depreciation that boosts the LOP

[6] In other words, households balance between low wages today in expectation of higher wages in future through the indexation channel. The reason is that setting too high wage today will render them losing some competitiveness in labor market.

[7] The lack of such tradeoff is called the Divine Coincidence in the terminology of Blanchard and Gali (2007) and it requires introducing more factors that the policy makers should account for.

gap (assuming $\kappa_{\psi}>0$). Increasing the interest rate to close the LOP gap will result in higher output gap. On the other hand, if the MA attempts to fully stabilize the output gap by lowering the interest rate, the LOP will rise thus boosting CPI inflation.

There is another reason for the inability of the monetary authority to fully stabilize all prices and wages when prices and wages are rigid. Since the path of the real wage is tied to the path of the marginal product of labor (i.e. technology), the real wage fluctuates with the fluctuations in technology. In this case, full stabilization of the wage inflation and price inflation is inconsistent with this path. Hence, the monetary authority should choose the best choose the best combination of price and wage stabilization that, on one hand allow for real wages to adjust, while on the other, leads to lower welfare losses.

Finally, by using the definition of CPI inflation (equation 11), a similar expression for CPI inflation is obtained

$$\pi_t = \beta E_t \pi_{t+1} + (1-\alpha)\kappa_x x_t + ((1-\alpha)\kappa_{\psi} + \alpha\lambda_F)\psi_{F,t} + (1-\alpha)\lambda_H \hat{\mu}_t^w \qquad (22)$$

As for the case of domestic price inflation, the presence of both rigid wages and import prices introduce more tradeoffs for policy making. Notice also the importance of the openness degree in this expression and in particular its role in the tradeoff between inflation stabilization and output gap stabilization.[8] For this reason, the calibration part will devote special attention to the openness degree by presenting the effects of varying this parameter on the benchmark result.

[8] Contrary to the case of DPI inflation, the tradeoff between stabilizing CPI inflation and other variables (i.e. output gap) exists also in the case of $\kappa_{\psi}=0$ (because of the term $\alpha\lambda_F$).

II.E. Optimal Monetary Policy and Inflation Targeting

As is typical in the NK literature, the Monetary Authority seeks to maximize the following welfare (loss) criterion subject to conditions B1-B7 in Appendix B [9]

$$W=-\frac{(1-\alpha)}{2\omega_s}\sum_{t=0}^{\infty}\beta^t[(1+\varphi)x_t^2+\frac{\varepsilon_H}{\lambda_H}\pi_{H,t}^2+\frac{\varepsilon_w}{\lambda_w}\pi_{w,t}^2+\beta\gamma_w^2\frac{\varepsilon_w}{\lambda_w}\pi_t^2+\frac{\varepsilon_F}{\lambda_F}\pi_{F,t}^2] \tag{23}$$

Also, as shown in GM (2005) among others, this welfare function can be written as

$$L=-\frac{(1-\alpha)}{2\omega_s}[(1+\varphi)Var(x_t)+\frac{\varepsilon_H}{\lambda_H}Var(\pi_{H,t})+\frac{\varepsilon_w}{\lambda_w}Var(\pi_{w,t})+\beta\gamma_w^2\frac{\varepsilon_w}{\lambda_w}Var(\pi_t)+\frac{\varepsilon_F}{\lambda_F}Var(\pi_{F,t})] \tag{24}$$

with *var(z)* denoting the variance of the variable *z*. In GM (2005), only the first two terms of (24) appear (i.e. the variances of both domestic inflation and the output gap). In this paper, however, the welfare criterion includes three more terms, namely the variabilities of wage inflation, CPI inflation and import price inflation. The Monetary Authority cannot now stabilize domestic inflation costlessly.

II.F. Policy Target in the Rest of the World (ROW)

Following Gali and Monacelli (2005) as well as Monacelli (2005) I assume that the Monetary Authority in the Rest of the World simultaneously stabilize foreign inflation and output gap and hence replicate the flexible price allocation. Note that under the assumption that the Rest of the World is too big, foreign CPI coincides with foreign DPI and hence the insignificance of the issue of pass-through. Also, for simplicity, I keep to assume no wage rigidity in the foreign economy. In short, the ROW is assumed to be as in study of GM (2005).

[9] In deriving this expression I have benefited from Erceg el al. (2000), GM (2005) as well as Campolmi (2006).

III. Calibration

This section outlines the calibration part of the paper and presents the main results. The first subsection briefly presents the parameters used in the paper. Subsection III-2 shows the results of the paper when only IPT is allowed for (i.e. wages are fully flexible). Subsection III-3 presents my findings in an environment of rigid wages but complete pass-through. By so doing, we are able to see the effects of each modification on the choice of optimal monetary policy. Finally, subsection III-4 closes the calibration part by allowing for both rigid wages and incomplete pass-through. The last step helps to assess how the results of GM can be altered in a more realistic environment in which domestic prices, imported prices and nominal wages are not fully flexible.

III.A. Parameterization

To allow for good comparisons to GM (2005), I will use their parameter values in my benchmark calibration, although some sensitivity analysis will be presented later. As in their study I assume logarithmic utility in consumption (and hence σ is set to 1). This assumption makes the derivation of the welfare criterion simpler. Next, φ is set to be 3 implying a labor supply elasticity of 1/3. All gross markups (of domestic firms, importers and workers) will be set to 1.2 and hence all the elasticities are assumed to be 6 (i.e. $\varepsilon_H = \varepsilon_F = \varepsilon_w = 6$). Domestic prices are assumed to be readjusted every one year, and therefore the parameter θ_H takes the value of 0.75. The openness degree is set to 0.4 which implies 'home bias' in consumption. The degrees of wage rigidity, pass-through and indexation will be varied in the analysis below.

One major change will be in the elasticity of substitution between domestic and foreign goods (η) assumed to be unity in GM (2005). I follow Monacelli (2005) and set it to 1.5 in the baseline calibration although the effects of varying this parameter will be discussed in the sensitivity analysis section. The reasons for setting η different from one are twofold. First, setting η to 1 is a special and perhaps a restrictive assumption. Second, setting η to unity, together with $\sigma=1$, makes both ω_{ψ} and ω_s being 1 and hence κ_{ψ} is zero. But, this renders the third term in the right hand side of (25) insignificant. Hence, in this case the whole idea of assuming incomplete pass-through is missed since there is no tradeoff stemming from this channel. Setting $\eta = 1.5$ means that κ_{ψ} is positive and hence all the discussion becomes more relevant.

Note however that as discussed in GM (2005), when $\sigma\eta$ differs from one, some equations hold only up to first order approximation, while they hold exactly when $\sigma\eta$ is one. Hence, in choosing η, I trade-off between exact relationships on one hand and gaining some intuition from the other (which is more likely when η from one). Given the Linear-Quadratic (LQ) approach applied here, this assumption clearly adds to the relevance of the discussion with only a mild expense in terms of precision. [10]

[10] In this regard, the parameter ω_s in the welfare function differs from one. Assuming $\eta = 1.0$ gives $\omega_s = 1$ and hence delivers a loss function similar to that of GM (2005), but of course with more terms.

III.B. Results: Incomplete Pass-Through and Fully Flexible Nominal Wages

Figure I shows the difference in welfare losses, the loss under CPI targeting minus the loss under DPI targeting for various degrees of pass-through (all losses are expressed in terms of steady state consumption). As in GM (2005), when PT is complete, targeting the DPI is highly favorable. DPI is better to target also in the case of intermediate to high degrees of PT, although the difference in losses shrinks. However, when PT is relatively low (around 0.43 or lower), it is better to target the CPI. This is the first important finding of the current study, and it suggests the significance of relaxing the assumption of complete pass-through.[11]

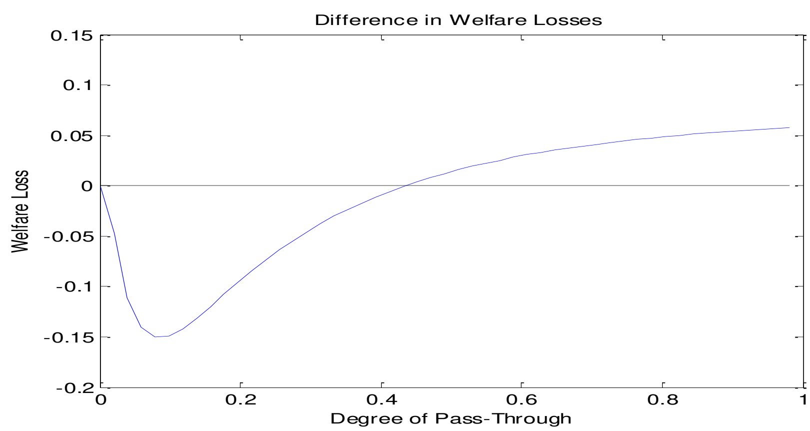

FIGURE I: Difference in Welfare Losses under CPI and DPI Targeting for various values PT

To better understand these results we may consider the behavior of our main variables under different degrees of PT (Figure A in the appendix). When PT is complete, targeting domestic prices delivers zero output gap and output gap variability and hence the zero loss. On the other

[11] Notice also that in the limit (when PT is almost zero), imported prices are fully rigid and hence the two regimes coincide. In particular, if imported price are fully rigid, the only variability in CPI comes from domestic prices. Hence, setting domestic inflation to zero implies zero CPI inflation and vise versa.

hand, when CPI is targeted, the variabilities of both DPI and output gap are relatively high. Reducing the degree of PT makes things different. As the degree of PT falls, the variabilities of both domestic inflation and the output gap under CPI targeting fall, thus implying lower welfare loss. In this case however, another factor comes into play- the variability of imported prices. Figure A.1 shows that a country targeting its DPI allows for more fluctuations in imported prices. When the loss function is expanded to include the variability of these prices, the loss under DPI may turn to be higher. Our results above indicate that this is indeed the case.

Before closing this subsection I present the effects of varying the degree of openness on my main results (Table I and Figures B.1 and B.2). Since my focus is mainly on the optimality of CPI targeting versus CPI targeting, I only show the losses under these two regimes. Also, the table presents the results for complete PT and then for PT of 0.35 and lower since complete PT is a useful benchmark while when PT is below 0.35 or lower, DPI may not be optimal to target. Contrarily, the favorability of DPI targeting seems to hold when the Pass-Through degrees is between 0.35 and 1.0 given that the economy is not completely open. Note that for scale reasons, I present the actual losses (in percents) and the differences in losses between CPI targeting and DPI targeting and not the relative losses as I will do later.[12]A positive difference in losses indicates that the DPI is optimal to target.

Few observations are worth-noting. First, targeting CPI leads to lower welfare loss when PT is relatively low regardless of the openness degree. This is a significant finding since as shown in Campa and Goldberg (2005a), few Inflation Targeting countries have degrees of PT around 0.40

[12] When PT is complete, DPI targeting delivers zero loss while CPI targeting delivers positive losses. Therefore, dividing the loss under CPI by the loss under DPI creates scale problems.

or lower. Second, regardless of the openness degree, in the case of complete pass-through, targeting CPI cannot be favorable. This result is supportive of the findings in Gali and Monacelli (2005). Third, for a given openness degree, lowering the degree of pass-through gives higher loss under DPI targeting (with the exception of course of the case of zero PT). Contrarily, for a given openness degree, the loss under CPI targeting tends to decrease as PT falls. Finally, When PT is zero, import prices are fully rigid and therefore import price inflation is zero. In this case, the only source for fluctuations in the CPI is domestic price volatility. Hence, fully stabilizing domestic prices will fully stabilize consumer prices and vise versa (i.e. the two regimes coincide). In overall, the results here indicate that my earlier finding is robust to varying the degree of openness in the more plausible ranges.

TABLE I: WELFARE LOSSES UNDER CPI AND DPI TARGETING FOR VARIOUS VALUES OF OPENNESS AND PT DEGREES, AS PERCENTAGE OF STEADY STATE CONSUMPTION.

	PT=1.00		PT=0.35		PT=0.25		PT=0.00	
Openness	DPI	CPI	DPI	CPI	DPI	CPI	DPI	CPI
0.00	0.0000	0.0000	0.2589	0.2037	0.3998	0.2579	0.0000	0.0000
0.25	0.0000	0.0415	0.1204	0.0735	0.1878	0.0904	0.0000	0.0000
0.50	0.0000	0.0622	0.0591	0.0491	0.0923	0.0456	0.0000	0.0000
0.75	0.0000	0.0497	0.0246	0.0391	0.0383	0.0322	0.0000	0.0000
1.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

III.C. Results: Complete Pass-Through and Nominal Wage Rigidity

This subsection assumes perfect pass-through, but considers the case of rigid wages. As discussed above, the degree of indexation (γ_w) is another important parameter to account for in this case. Hence, in what follows I will outline the results for some levels of wage rigidity as well as for specific degrees of indexation.

Figure II shows the losses under CPI and WI targeting relative to the loss under DPI targeting. Hence, DPI serves here as a benchmark. I choose to compare the losses under CPI and WI relative to DPI since the later has been typically suggested as the best to target. Also, Figure 2 assumes an indexation degree of 0.75 in line with empirical findings. It should be noted however that all results reported here holds qualitatively also for higher indexation degrees and in particular when indexation is full (i.e. $\gamma_w = 1$). Depending on the wage rigidity degree, some of the results hold also when the indexation degree is relatively low (around 0.65).

The main result coming out of this Figure is that the relative loss under both CPI targeting and nominal wage targeting is lower when the wage rigidity degree is around 0.80 (zero wage inflation is the best even for less than 0.80). The main explanation for this finding is as follows. When nominal wages are "fundamentally" highly rigid (i.e. θ_w is high), stabilizing nominal wages by policy means is relatively less costly than stabilizing the domestic price index. That is, the nature of the labor market makes it relatively less costly compared to stabilizing other indices. Although of course the rigidity in nominal wages affects the output gap considerably, it is still less costly than implementing a policy that aims at stabilizing domestic prices when nominal wage are highly indexed to inflation or when nominal wage are highly flexible. Also, the stabilization of nominal wages helps stabilizing domestic prices and this offsets some of its negative effect on welfare through the output gap. In other words, targeting nominal wages delivers both zero wage inflation and lower variability in domestic inflation, hence lower welfare loss.

The result that targeting the CPI might be favorable for relatively high degrees of wage rigidity and wage indexation confirms our earlier expectations and it is the second important finding of the current study. Note that the required levels of wage rigidity and wage indexation to prefer WI or CPI targeting over DPI targeting are in line with some empirical studies (e.g. Smets and Wouters, 2003; Christiano *et al*, 2005) and hence the importance of this result.[13]

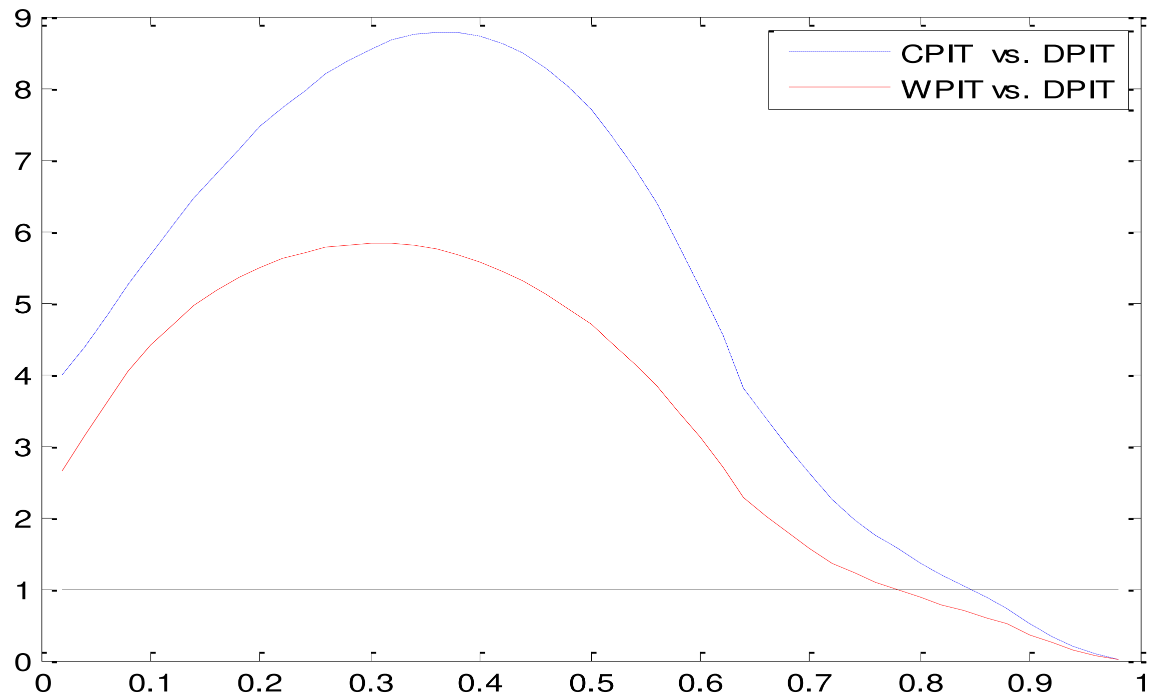

FIGURE II: The Losses under CPI targeting and Wage Inflation Targeting Relative to the Loss under DPI Targeting with Complete Pass-Through and Rigid Wages.

[13] Also, Bodart et al. (2006) and Bockerman et al. (2006) report similar estimates for wage rigidity in Belgium and Finland.

Two more important observations come out from Figure 2. First, the relative losses under either CPI targeting or WI targeting are higher for low to moderate degrees of wage rigidity and they are actually increasing when θ_w varies between zero and 0.40. The main reason is the low loss under DPI targeting for relatively low degrees of wage rigidity. To see this, note that the losses under the three type of regimes are increasing with θ_w resulting from higher nominal distortions. However, for θ_w less than 0.40, the loss under DPI increases by less compared to the other two regimes. This pattern changes for higher levels of θ_w since at some point the effect on the output gap under DPI targeting becomes very high and it actually targeting outweighs the losses under the two other indices.

Second, since the relative loss under CPI targeting is typically higher than relative loss under WI targeting, we also infer that the loss under CPI targeting tends to be higher than under WI targeting, especially for moderate levels of wage rigidity. It therefore seems that stabilizing nominal wages is the best policy to follow when the degrees of wage rigidity and indexation are around 75% or higher. Note however that when θ_w approaches 1, the two regimes deliver the same loss. This is result is as expected: when θ_w is one, the only variation in nominal wages comes from indexation to (past) CPI inflation. Hence if the CPI is completely stabilized at all dates, nominal wages will be stabilized as well. In fact, fully stabilizing nominal wages can occur only if CPI inflation is zero. In short, the two regimes coincide in the limit.

As in the previous case, I examine the effects of different openness degrees on my main results (Figure C). The Figure shows the loss under CPI relative to the loss under DPI targeting where the wage rigidity degree is 0.75 and the indexation rate is 0.50. CPI targeting seems to be optimal to target when the openness degree is around 0.67. This is an interesting result since recall that for these degrees of wage rigidity and wage indexation, the benchmark case (which assumes openness degree of 0.40) indicates that DPI is favorable. Also, although not shown here, for higher degrees of wage rigidity and wage indexation, CPI becomes the right index to target for even lower degrees of openness. Finally, DPI is the is found as the right index to target given low levels of openness regardless of the wage indexation and wage rigidity. These results only suggest the intuitive idea that more open economies should try to stabilize the price index that embed the price of foreign goods since this is simply the more relevant one.

III.D. Results: Incomplete Pass-Through and Nominal Wage Rigidity

In this subsection I discuss the ranking of the three indices when the two frictions are both introduced.[14] In this case we need to look at three important parameters simultaneously: the degrees of PT, wage rigidity and wage indexation. To do so, I first choose some indexation level. Next I choose some PT degrees and finally the degrees of wage rigidity.

Figures III and IV show the results when γ_w is 0.75 and 0.90, respectively. I choose these degrees of indexation both because they are in line with empirical evidence and since the results for lower indexation degrees generally indicate DPI as a better index to target, especially compared to CPI targeting. To focus on the main findings of the paper on one hand and in order to economize in presentation, I present only the results for these levels of indexations. Also, since I need to account for the degrees of pass-through, I show the results for two levels of pass-through (0.80 and 0.90 respectively).

As before, each Figure presents the losses under CPI targeting and WI targeting relative to DPI targeting. Figure III reveals that when nominal wages rigidity is relatively high (θ_w =0.90 or more) and the indexation degree is 0.75, targeting the wage inflation index is better than targeting the DPI. This result is particularly true when pass-through is 0.90. Also, targeting the wage inflation seems to be better than targeting the CPI inflation for almost all levels of wage rigidity (but note again that the two regimes coincide in the limit). Figure IV supports these conclusions. In this case, targeting both the CPI and the WI become favorable if wages are

[14] Note that the former subsection can be seen as a particular case of the current with pass-through being complete.

highly rigid (around 0.85 or more), although the degree of wage rigidity needed is a bit lower. This result holds for similar reasons as discussed in the last subsection.

Few more observations can be inferred from Figure 3 and 4. The higher the degree of indexation is, the lower the relative losses under both CPI and WI. It should be noted however that the loss under WI increases with the degree of indexation since the higher the indexation rate, the more costly full stabilization of the wage inflation is. The loss under CPI targeting does not vary with the indexation degree since when CPI inflation is zero, the wage indexation degree is irrelevant. Hence, as the relative loss under CPI is considered, the difference between Figures 3 and 4 comes from the fact that the losses under DPI targeting are higher for higher degrees of indexation.

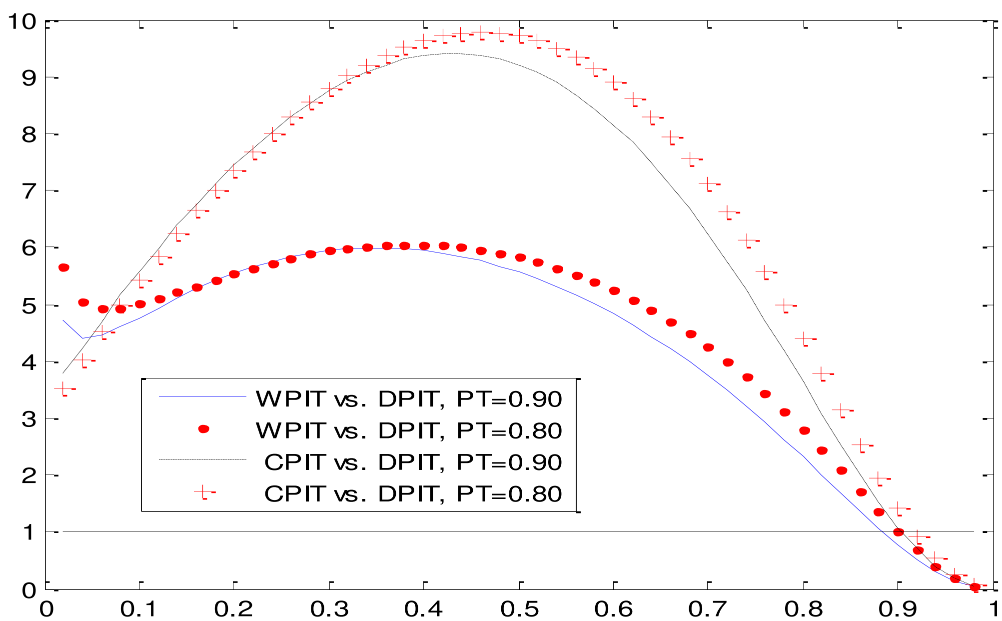

FIGURE III: The Losses under CPI targeting and Wage Inflation Targeting Relative to the Loss under DPI Targeting with Incomplete Pass-Through and Rigid Wages Indexation Degree=0.75.

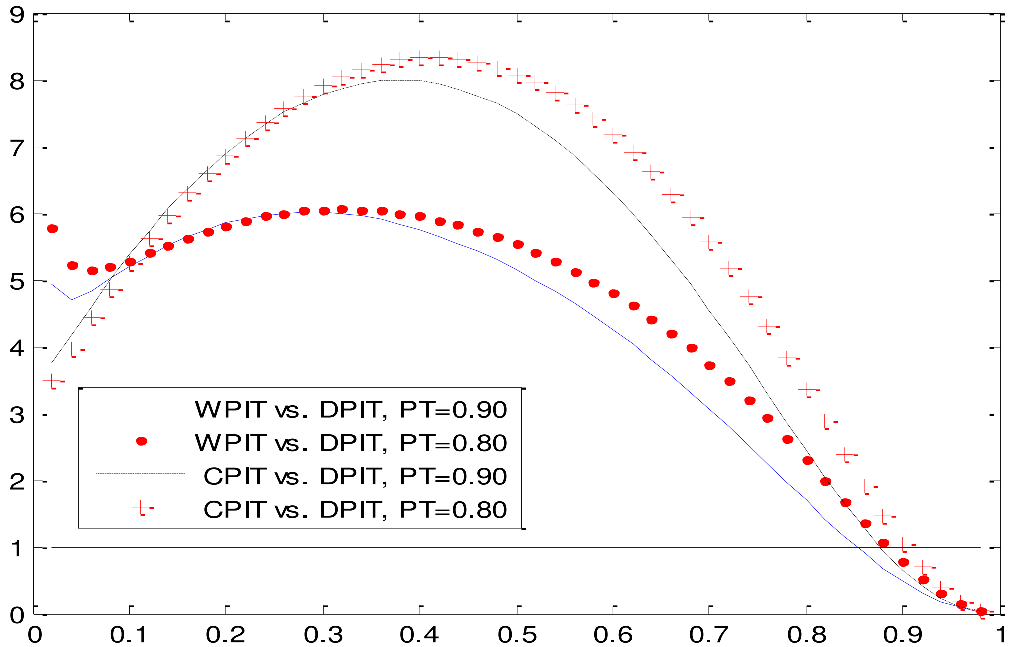

FIGURE IV: The Losses under CPI targeting and Wage Inflation Targeting Relative to the Loss under DPI Targeting with Incomplete Pass-Through and Rigid Wages Indexation Degree=0.90.

I close this subsection by considering the effect of varying the openness degree on my main results. Since I need to control for few parameters, I choose here to show the results only when the degree of openness is 0.60, but with noting that some of the results hold qualitatively for other degrees of openness (e.g. 0.50). Moreover, I assume the relatively moderate degree of indexation of 0.75 both because of its empirical plausibility since and since around which the favourability of DPI targeting may cease to hold. As for PT, I assume two different levels, 0.50 and 0.80. I choose these levels of PT for two reasons. First, they are empirically plausible; the study of Campa and Goldberg (2005a) indicates that the average PT is around 0.46 in the short run and 0.64 in the long run. Their study for the Euro area, Campa and Goldberg (2005b), shows relatively higher averages of PT (0.66 and 0.80). Second, the results above show that in the presence of wage rigidity, CPI is better to target only if PT is relatively high. Hence, it will be interesting to check whether CPI may be optimal to target for moderate levels of PT given higher openness degree. Needless to say, the main results reported below hold also in the case of higher PT and indexation degrees.

Figure D shows that, given an indexation degree of 0.75, targeting CPI is better if wage rigidity is high and PT is moderate to high. Notice that this result differs from the result above where, for the same indexation degree, DPI is always favorable. Although not shown here, CPI may be optimal to target in the case of indexation degree of 0.65 given high degrees of wage rigidity. In short, the results found in my calibration regarding the optimality of CPI targeting are only supported and even strengthened for more open economies.

IV SENSITIVITY ANALYSIS

This section presents some sensitivity analysis by changing some of the benchmark parameters. As for the case with Openness, I do not show the effects of different parameterization on the optimality of wage inflation targeting and hence focus on the comparison between CPI and DPI targeting. The first parameter to change is the elasticity of substitution between home and foreign goods (η) assumed to be 1.5 in my benchmark calibration (and 1.0 in GM). Next, I will change the degree of domestic price rigidity (assumed above to be 0.75). Finally, the elasticities of substitution between domestic goods (ε_H), foreign goods (ε_F) as well as between labor inputs (ε_W) will be varied. This basically allows for different levels of markup in each of these markets.

IV.A. Changing the Elasticity of Substitution between home and foreign goods (η):

I assume that η can take any level between 0.3 and 2.25. In addition, I assume the more relevant levels of indexation (set to be 0.75), wage rigidity (0.75 and 0.80) as well relatively high degree of PT (0.80). The results are presented in Figure E.

When wage rigidity is 0.75, CPI targeting leads to lower loss given that η falls below 0.70. for higher levels of η, DPI seems to be better to target. Increasing the wage rigidity degree only slightly (to 0.80) shows that CPI is favorable when η is less than 1.0. Hence, as the degree of wage rigidity increases, CPI yields lower losses for a wider range of η. Also, given some wage rigidity degrees, he higher the indexation rate, the wider the range under which CPI targeting is optimal. Increasing the degree of PT in this case will also support CPI as the favourable index to target for more values of η.

IV.B. Changing the Degree of Domestic Price Rigidity (θ_H):

So far, the study assumed a degree of domestic price rigidity of 0.75 for the case of CPI targeting. In this subsection I check whether the results can be altered once different levels of domestic price rigidities are assumed. Notice that since, by definition, DPI targeting corresponds to θ_H being 1, the only effects to consider are on the loss under CPI targeting. Moreover, I have chosen the more relevant degrees of wage indexation and pass-through (both set to 0.75).

I first change θ_H to 0.50. The results (not reported here) show that in this case the loss under CPI is even larger than under θ_H of 0.75, reflecting highly variable domestic prices. Next, I increase θ_H to 0.90 and found lower loss under CPI compared to the benchmark case. In all of these occasions however, the loss under CPI is higher than the loss under DPI. Hence, the benchmark calibration level of θ_H has no effect on the qualitative results.

IV.C. Changing the Elasticities of Substitution between Domestic Goods (ε_H), Foreign Goods (ε_F) and between Workers (ε_W):

This subsection conducts the last sensitivity analysis of the study. Since there are 3 different parameters to vary, I do not go into details here and only report the basic results qualitatively. The whole analysis is done assuming pass-through, wage rigidity and indexation degrees of 0.75. The main outcome of this exercise is that changing the three parameters in the more relevant range (between 4 and 11) do not change the basic results of the paper.

V. Conclusion

This paper studies optimal monetary policy in the era of Inflation Targeting in an economy with multiple nominal rigidities. Particularly, the paper assumes domestic price rigidity, import price rigidity (incomplete pass-through) and nominal wage rigidity. The study then contrasts welfare losses under two different inflation targeting regimes (of the domestic price index and the consumer price index) as well as the losses under fully stable nominal wages (to which we refer as wage inflation targeting). Wage inflation targeting basically examines the optimality of targeting an intermediate goal for monetary policy. The main focus however remains on comparing the optimality of CPI targeting versus DPI targeting.

Allowing for rigid import prices, but fully flexible wages, the study shows that targeting CPI is better when pass-through is relatively low to moderate (around 0.40 or lower). This degree of PT has been reported to be the case of few Inflation Targeting economies and hence the significance of the result. This finding is robust to changing the degree of openness.

When complete pass-through is restored and wage rigidity is assumed instead, CPI targeting turns to be better than DPI targeting for relatively high degrees of both wage rigidity and wage indexation to CPI inflation. Particularly, when the indexation degree and the wage rigidity degree are both around 0.75, the economy better target its CPI in order to avoid large fluctuations in marginal costs (through fluctuating nominal wages) and hence in both domestic prices and the output gap. The study also points that fully stabilizing nominal wages in such an environment (in which nominal wages are very rigid by nature) may even be the superior choice.

The key results for the case of both rigid wages and import prices are similar to the case of only rigid wages. Having high degrees of both wage rigidity and indexation, CPI tends to be a better index to target given high degrees of PT. This result is undoubtedly important since it suggests a different conclusion from GM's even for high pass-through. When PT is low however, CPI ceases to be favorable even if wages are relatively rigid and highly indexed to CPI inflation. However, increasing the degree of openness reveals that CPI is better to target also in moderate PT environments (around 0.50). Moreover, the study points to the favorability of targeting nominal wages in this economic environment.

In overall, the paper suggests that the right index to target depends on the specific structure of the individual economy. Countries with low flexible nominal wages, high degrees of wage indexation and high pass-through should target their CPI. The same conclusion holds for countries with low degrees of pass-through and highly flexible wages. Relatively open countries with moderate to high indexation degrees and rigid wages should also target their CPIs. Economies with high degrees of wage rigidity may also consider the possibility of full stabilization of nominal wages. Other countries better target their Domestic Price Index. In this regard, some countries may not be conducting monetary policy optimally once committing to a common policy.

This study can also be further extended. One possible extension is adding imported inputs and then considering the ranking of the different indices. Allowing for rigid export prices or incomplete pass-through in the foreign economy is another modification to consider. Finally, it would also be interesting to rank the indices according to some Taylor-Type Rules, which are believed to be the rules guiding monetary policy making in several countries.

APPENDIX A:

Figure A: Volatilities of Main Variables

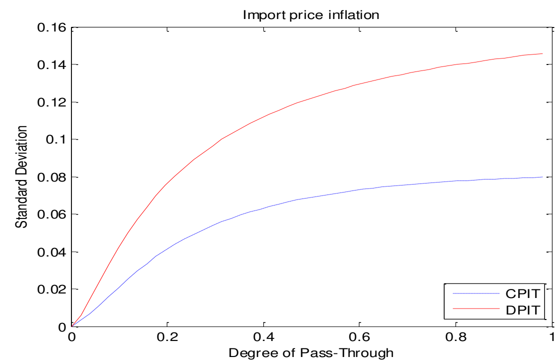

FIGURE A.1: Import Price Inflation

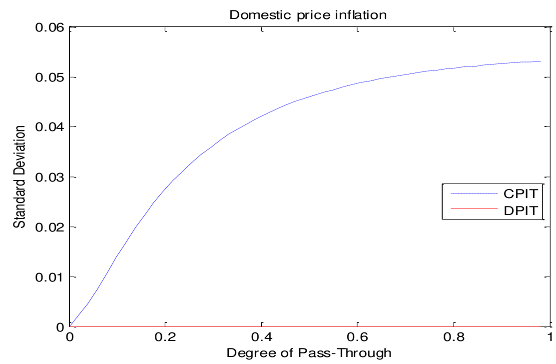

FIGURE A.2: Domestic Price Inflation

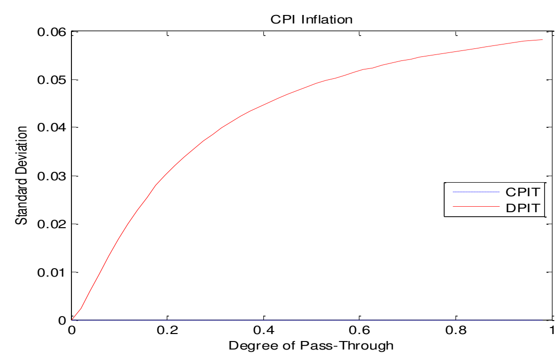

FIGURE A.3: CPI Inflation

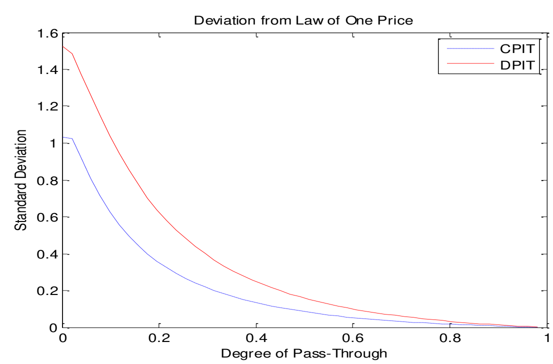

FIGURE A.4: LOP

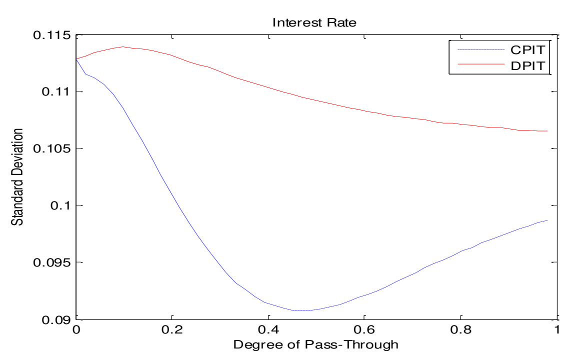

FIGURE A.5: Nominal Interest Rate

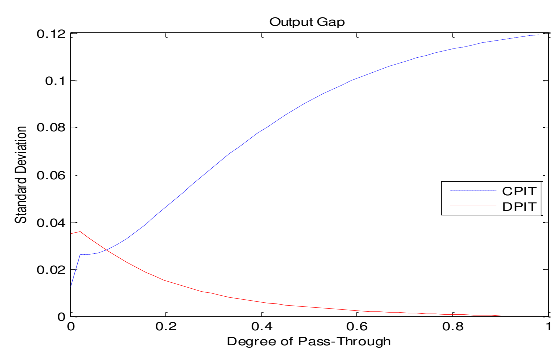

FIGURE A.6: Output Gap

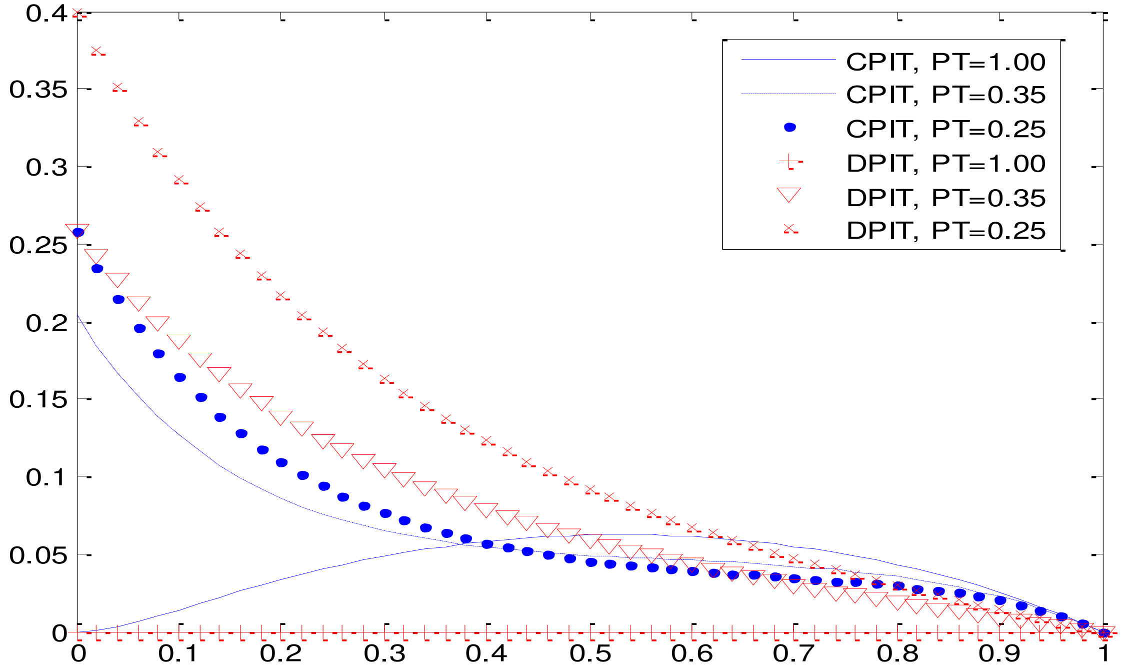

FIGURE B.1: Welfare Losses under CPI and DPI targeting (as a percentage of SS consumption) and for various openness values and for given degrees of PT.

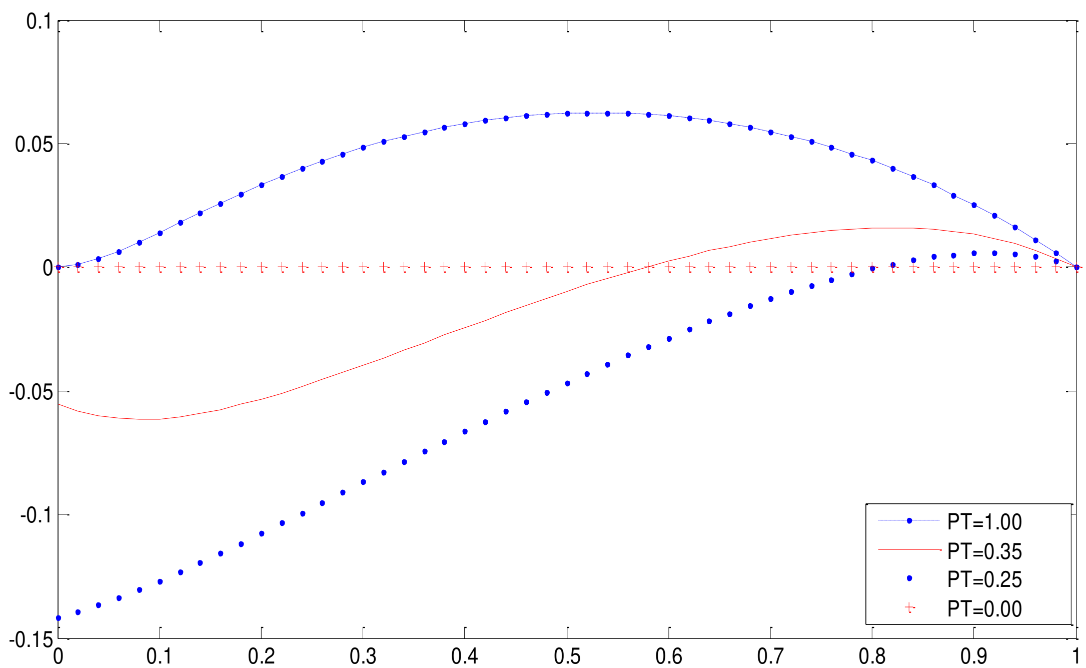

FIGURE B.2: Differences in Welfare Losses under CPI and DPI targeting (as a percentage of SS consumption) for various openness values and for given degrees of PT.

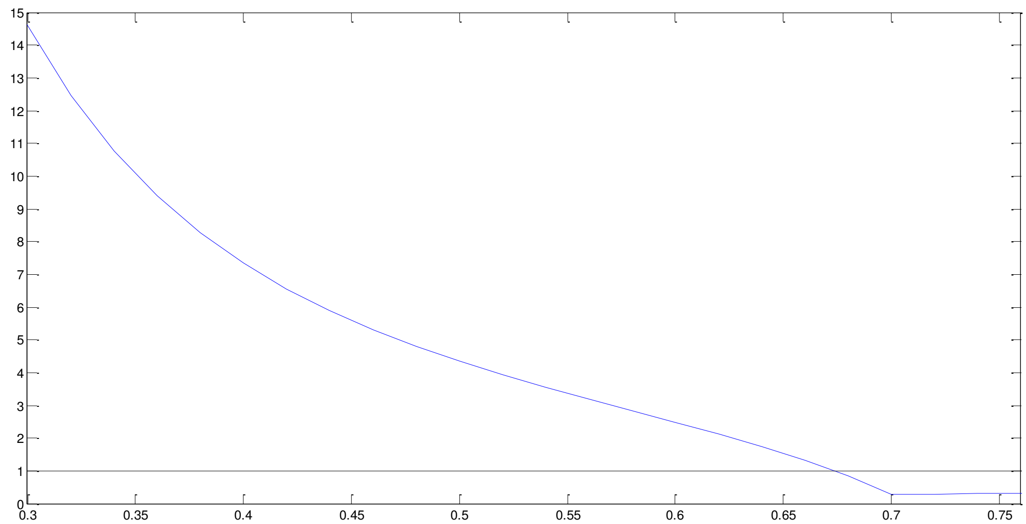

FIGURE C: The loss under CPI Targeting relative the loss under DPI Targeting for various openness values. Degrees of wage rigidity=0.75; Indexation degree= 0.50.

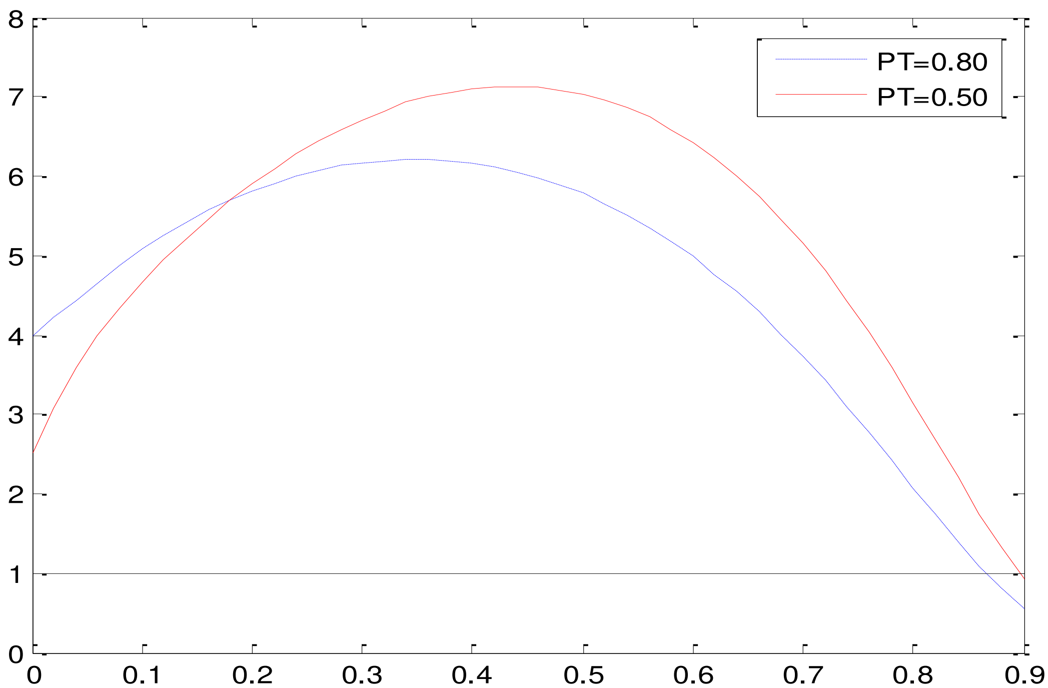

FIGURE D: The Losses under CPI targeting and Wage Inflation Targeting relative to the loss under DPI Targeting with incomplete pass-through and rigid wages. Indexation degree=0.75; Openness degree=0.60.

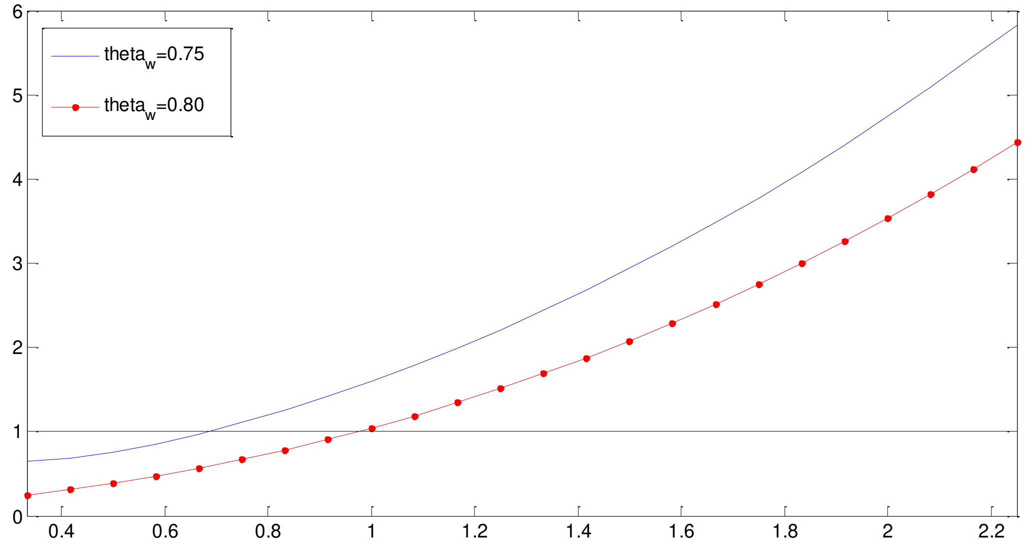

FIGURE E: The loss under CPI Targeting relative to the loss under DPI Targeting for various values the elasticity of substitution between home and foreign goods. Pass-Through=0.80.

APPENDIX B: THE OPTIMAL MONETARY POLICY PROBLEM:

In the general case where the economy features rigidities in domestic prices, import prices and nominal wages, the problem of the Monetary Authority is to choose allocations $\{x_t, \pi_t, \pi_{H,t}, \pi_{F,t}, \pi_{w,t}, \psi_{F,t}, w_t, r_t\}$ to maximize

$$W = -\frac{(1-\alpha)}{2\omega_s}\sum_{t=0}^{\infty}\beta^t[(1+\varphi)x_t^2 + \frac{\varepsilon_H}{\lambda_H}\pi_{H,t}^2 + \frac{\varepsilon_w}{\lambda_w}\pi_{w,t}^2 + \beta\gamma_w^2\frac{\varepsilon_w}{\lambda_w}\pi_t^2 + \frac{\varepsilon_F}{\lambda_F}\pi_{F,t}^2]$$

Subject to,

$$\pi_{H,t} = \beta E_t\pi_{H,t+1} + \kappa_x x_t + \lambda_H\left[w_t + \frac{1-\alpha-\omega_s}{\omega_s}y_t^* + (\frac{1-\alpha}{\omega_s}+\varphi)(x_t + \frac{\log(1-\alpha)}{1+\varphi}) - (\frac{1-\alpha}{\omega_s})a_t\right] - \left[\frac{\lambda_H\alpha\eta}{\omega_s} - \kappa_\psi\right]\psi_{F,t} \quad \text{(B1)}$$

$$\pi_{F,t} = \beta E_t\pi_{F,t+1} + \lambda_F\psi_{F,t} \quad \text{(B2)}$$

$$\psi_{F,t+1} - \psi_{F,t} = r_t - r_t^* + \pi_{t+1}^* - \pi_{F,t+1} \quad \text{(B3)}$$

$$\pi_t = \alpha\pi_{F,t} + (1-\alpha)\pi_{H,t} \quad \text{(B4)}$$

$$\pi_t - \pi_t^w = w_t - w_{t-1} \quad \text{(B5)}$$

$$\pi_{w,t} = \beta E_t\pi_{w,t+1} - \lambda_w\left[w_t + \frac{1-\alpha-\omega_s}{\omega_s}y_t^* + (\frac{1-\alpha}{\omega_s}+\varphi)(x_t + \frac{\log(1-\alpha)}{1+\varphi}) - (\frac{1-\alpha}{\omega_s})a_t\right] + \frac{\lambda_w\alpha\eta}{\omega_s}\psi_{F,t} - \beta\theta_w\gamma_w\pi_t + \gamma_w\pi_{t-1} \quad \text{(B6)}$$

$$x_t = E_t x_{t+1} - \frac{\omega_s}{\sigma}\left(r_t - \pi_{H,t+1} - rr_t\right) + \Gamma_x E_t(\psi_{F,t+1} - \psi_{F,t}); \quad \text{(B7)}$$

where,

$$rr_t = \frac{\sigma\varphi(\omega_s - 1)}{\sigma+\varphi\omega_s}E_t\Delta x_{t+1}^* - \frac{\sigma(1-\rho_a)(1+\varphi)}{\sigma+\varphi\omega_s}a_t + \rho$$

$$\Gamma_x = \frac{\alpha(1-\alpha)(\sigma\eta-1)}{\sigma}$$

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