The effects of capital market openness on exchange rate pass-through and welfare in an inflation targeting small open economy

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Abstract

This paper analyzes the impact of capital market openness on exchange rate pass-through and subsequently on the social loss function in an inflation targeting small open economy under a pure commitment policy. Applying the intuition behind the macroeconomic trilemma, I examine whether a more open capital market in an inflation targeting country improves the credibility of the central bank and consequently reduces exchange rate pass-through. First, I empirically examine the effect of capital openness on exchange rate pass-through using a New Keynesian Phillips curve. The empirical investigation reveals that limited capital openness leads to greater pass-through from the exchange rate to domestic inflation, which raises the marginal cost of deviation from the inflation target. This subsequently worsens the inflation output-gap trade-off and increases the social loss of the inflation targeting central bank under pure commitment. However, the calibration results suggest that the inflation output-gap trade-off improves and the social loss decreases even in the presence of larger exchange rate pass-through if the capital controls are effective at insulating the exchange rate from interest rate and risk-premia shocks.

Keywords: Monetary policy, Inflation Targeting, Exchange rate pass-through, Capital account openness, Small open economy

JEL Classification Numbers: F41, F47, E44, E52, E58

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1 Introduction

The relationship between optimal monetary policy and exchange rate pass-through (ERPT) has gained significant attention in theoretical and empirical research over the last decade. Much of the interest has been driven by the apparent decline in the pass-through of exchange rate changes to domestic prices in low inflation environments (McCarthy (2007), Gagnon and Ihrig (2004), Bailliu and Fujii (2004)) over the last two decades. To date, the literature on ERPT suggests that the risk to inflation of a depreciating domestic currency depends on how much of the falling value of the currency is passed through to import prices, and then to overall consumer prices. Taylor (2000) and Mishkin (2008) argue that a monetary stance that is sufficiently reactive to inflation can insulate consumer prices from the effects of a shock that causes the exchange rate to depreciate. They point out that ERPT is primarily a function of the persistence of exchange rate and price shocks, which tend to be reduced in an environment where inflation is low and monetary policy is more credible. Further, some of the implications of incomplete ERPT on monetary policy associated with the local currency pricing (Devereux and Engel (2002), Corsetti and Pesenti (2005), Bacchetta and van Wincoop (2003)), sticky import price behavior (Smets and Wouters (2002)) and the deviation from the law of one price (Monacelli (2005)) have already been analyzed.

One feature that characterizes all the models discussed above is the assumption of a fully developed and perfectly open capital market. In Figure 1, I have plotted the average capital market openness in nine inflation targeting developed countries, Australia, Canada, Iceland, Israel, New Zealand, Norway, Sweden, Switzerland and U.K. Here I have used a capital openness index developed by Chinn and Ito (Chinn and Ito (2008)) as a measure of capital market openness where the index ranges from (-1.83) to 2.50, and higher values indicate a more financially open economy. Since the value 2.50 indicates a perfectly open capital market, Figure 1 indicates that the assumption of a perfect capital mobility does not hold for the developed IT countries.

Under flexible inflation targeting, the monetary authority adjusts the short-term nominal interest rate to stabilize inflation to its target level and the real economy, represented by the output-gap (Svensson (2000), Taylor (2001), Giannoni and Woodford (2003), Walsh (2009)), and let the exchange rate float freely under the assumption of perfect capital mobility. This is consistent with Mundell's Macroeconomic Trilemma, which states that the monetary authority can choose at most two of the following three conditions,

- Autonomous monetary policy in the sense of different domestic and foreign interest rates
- A fixed exchange rate
- Perfect capital mobility

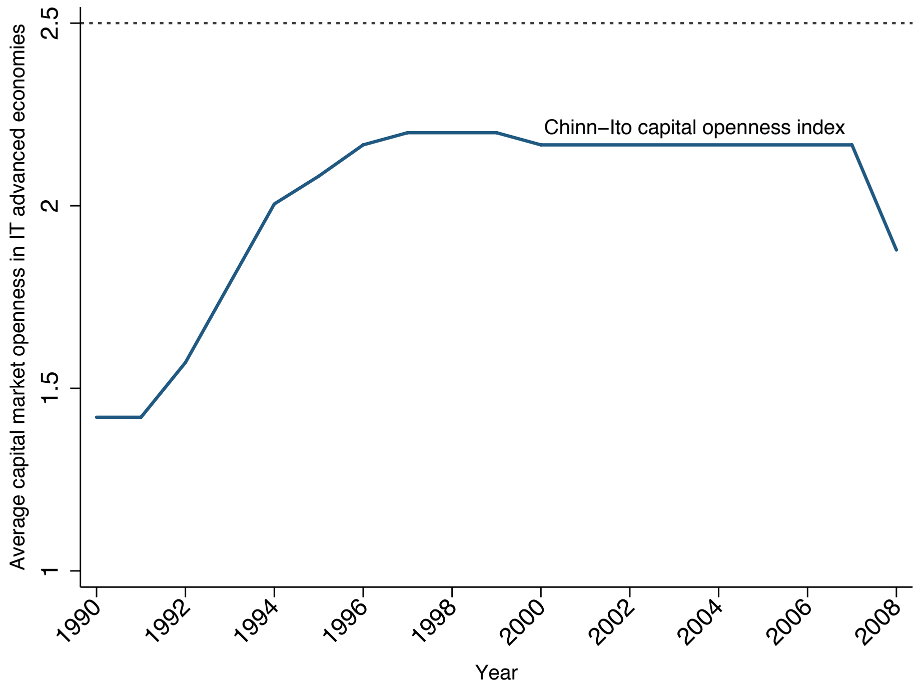

Figure 1: **Average capital openness in developed IT countries**

Because the goal of central banks following a flexible inflation targeting regime is the stabilization of domestic inflation and the output-gap, they need to be able to adjust domestic interest rates independent of foreign interest rates. For this reason, central banks need monetary independence. The developed IT countries gave up on a fixed exchange rate regime after the collapse of the Bretton Woods system. However, imposition of capital controls indicate an inclination towards exchange rate management. When the countries claim that they follow a flexible exchange rate system, but allow for limited capital openness, it might have an adverse impact on the transparency of the monetary policy and central bank's commitment to its policy target, which is inflation stabilization. This may raise the inflationary expectations and have an impact on exchange rate pass-through.

Therefore, the objective of this paper is to estimate the effect of capital openness on exchange rate pass-through to domestic inflation in a flexible inflation targeting small open economy and assess the welfare implications of incomplete ERPT. Accordingly, the purpose of this paper is to answer the following questions:

- Does the pass-through from the exchange rate to domestic inflation vary with the degree of capital openness?
- If there is any effect of the capital openness on exchange rate pass-through, what implications does it have on inflation output-gap trade-off and the social loss function in an inflation targeting small open economy?

This study is important because ERPT determines the impact of exchange rate movements on the domestic rate of inflation and consequently, the degree to which exchange rate fluctuations interfere with the main task of the central banks, inflation stabilization. Moreover, over the years, emerging markets and developing countries have also begun to adopt inflation targeting regime, and most of these countries do not have a perfectly open capital market. A study estimating the welfare cost of the capital market imperfections could be helpful to the potential inflation targeters for the insight it can bring through their policy formulation.

To answer the aforementioned questions, I consider a typical small open economy, which is following a flexible inflation targeting regime, in a New Keynesian set up. I use the reduced form equations from Monacelli (2005), Walsh (2009) and Walsh (2010). I assume that the central bank follows an inflation targeting regime by minimizing a standard quadratic loss function subject to aggregate demand, aggregate supply and the interest rate parity conditions under a pure commitment policy.[1] The aggregate demand function or the forward looking (open economy) IS equation is derived from the consumption Euler equation, taking into account that households consume both domestically produced and imported goods. The aggregate supply curve or the forward looking New Keynesian Phillips curve is obtained from the optimal price setting decisions of domestic producers. Moreover, the exchange rate is introduced in terms of the uncovered interest rate parity

[1]The central bank that follows a flexible inflation targeting regime is committed to stabilize inflation to its target level and the output-gap.

(UIP) condition. Taking into consideration the deviations from purchasing power parity,[2] it is assumed that the real exchange rate can vary over time, and the exchange rate pass-through is incomplete.

First I estimate the effect of capital market openness on exchange rate pass-through. Then I impose parameter restrictions to the reduced form equations to examine how the inflation and output-gap trade-off and the social loss vary with capital openness.

The calibration results suggest that in the presence of capital controls, the inflation and output-gap trade-off deteriorates in the face of demand, cost-push and risk-premia shocks. The deteriorating trade-off between inflation and the output-gap implies that the IT central bank has to suffer a greater loss in terms of a reduction in real activity when inflation is above its target rate. Since the primary objective of the IT central bank is to stabilize the deviation of inflation from its target and the output-gap, imposition of capital controls is welfare reducing. However, as the transmission of interest rate and risk-premia shocks to exchange rate declines in the presence of capital controls, the inflation output-gap trade-off and the social loss improves even in the presence of greater exchange rate pass-through.

The paper is organized as follows: Section 2 presents the simple model of a small open economy. Section 3 empirically examines the effect of capital openness on the pass-through from the exchange rate to inflation and formulates the central bank's problem. Section 4 presents the calibration results and the estimation of social loss under a commitment strategy. Finally, section 5 describes the future research ideas and concludes.

2 Simple model of a small open economy

Here I use a simplified version of a small open economy model that is based on the reduced form equations from Monacelli (2005), Walsh (2009) and Walsh (2010)[3]. This approach is consistent with Walsh (1999).

The demand side of the economy is given by the following open economy forward looking IS equation:

$$x_t = -\sigma r_t + E_t x_{t+1} + \eta^y e_t + u_t, \tag{2.1}$$

[2] See Rogoff (1996), Goldberg and Knetter (1997), Engel (1993), Engel (1999), Engel (2002), Rogers and Jenkins (1995)

[3] Walsh (2010) : Monetary Theory and Policy, 3rd ed. Chapter 9.

where x is the output-gap, r is the real interest rate, e is the real exchange rate, E_t denotes the market expectations based on the information at time t, and u is a demand shock that follows a first order autoregressive process (AR(1)) given by

$$u_t = \rho_u \, u_{t-1} + s_t,$$

where $\rho_u > 0$ and $s_t \sim iid\,(0, \sigma_s^2)$. In equation (2.1), the output-gap (x_t) depends negatively on the real interest rate, where the parameter σ (> 0) is the inverse of the coefficient of relative risk aversion. Also, x_t depends positively on the expected future output-gap[4] and on real depreciation. Taking the domestic currency as the numeraire, the real exchange rate is defined as the relative price of the foreign currency where an increase in e is given by a real depreciation of the domestic currency. Moreover, following the empirical evidence that purchasing power parity need not hold, this model assumes that the real exchange rate can vary. With a real depreciation, domestic products become cheaper relative to foreign products. Therefore, exports increase and imports fall, giving a boost to aggregate demand and output, and therefore, $\eta^y > 0$.

The supply side of the economy is given by the New Keynesian open economy Phillips curve (NKPC),

$$\pi_t = \pi^T + \beta E_t(\pi_{t+1} - \pi^T) + \lambda x_t + \eta^\pi e_t + \epsilon_t, \tag{2.2}$$

where π is CPI (consumer price index) inflation, and π^T is the inflation target set by the central bank, and ϵ_t is a supply shock following a first order autoregressive (AR) process given by

$$\epsilon_t = \rho_\epsilon \, \epsilon_{t-1} + \omega_t,$$

where $\rho_\epsilon > 0$ and $\omega_t \sim iid\,(0, \sigma_\omega^2)$. In a sticky price model, the pricing decision of firms depends positively on real marginal costs, and therefore, the output-gap ($\Longrightarrow \lambda > 0$) and the expected future inflation ($\Longrightarrow \beta > 0$). Also, the deviation of inflation from its target level depends on the exchange rate depreciation, as the falling value of the currency puts upward pressure on import prices, and then is passed through to overall consumer prices ($\Longrightarrow \eta^\pi > 0$).[5]

Under the assumption of perfect capital mobility, perfect capital substitutability and

[4] Indicating that current aggregate demand is a function of expected future income.

[5] Also known as exchange rate pass-through.

risk neutrality, the uncovered interest rate parity holds and is given by[6]

$$E_t e_{t+1} - e_t = r_t - {r_t}^*,$$

where r is the domestic real interest rate, r^* is the foreign real interest rate, and $(E_t e_{t+1} - e_t)$ is the expected real rate of depreciation. Interest rate parity suggests that the home interest rate on bonds, r, must equal the foreign interest rate r^*, plus the expected real depreciation, $(E_t e_{t+1} - e_t)$. In other words, if home and foreign bonds are perfect substitutes, and the international capital is fully mobile, the two bonds pay different interest rates only if agents expect that there will be a compensating movement in the exchange rate. However, the empirical evidence in favor of uncovered interest rate parity (UIP) is very weak. Therefore, I relax the assumption of risk neutral agents and introduce a shock reflecting a risk-premium demanded by risk averse investors for foreign bonds.[7] Thus, the UIP condition is given by

$$E_t e_{t+1} - e_t = r_t - {r_t}^* - \zeta_t, \tag{2.3}$$

where ζ_t is an AR(1) risk-premium shock.[8]

Since it is assumed that the country is small in world capital markets, it takes the foreign real interest rate, r^*, as given. Also, the real interest rate is defined as[9]

$$r_t = i_t - E_t(\pi_{t+1} - \pi^T)$$

where i is the nominal interest rate (the central bank's policy instrument). All the variables, except inflation, are expressed in terms of their deviation from the respective steady state values where the steady state inflation is assumed to be π^T.[10]

Subsequently, following the standard literature, it is assumed that the monetary authority minimizes a quadratic loss function, which depends on the variability of inflation from its target and the output-gap,[11] subject to equations (2.1) through (2.3). Thus, the

[6] Assuming that the forward rate $(F_{t,t+1})$ is equal to the future spot rate (E^e_{t+1}).

[7] The assumption of perfect capital mobility still holds.

[8] $\zeta_t = \rho_\zeta \, \zeta_{t-1} + \phi'_t$ where $\rho_\zeta > 0$ and $\phi'_t \sim iid\,(0, \sigma^2_{\phi'})$.

[9] From the Fisher's condition, the real interest rate (r_t) can be written as, $r_t = i_t - E_t \pi_{t+1}$. Also, the steady state real interest rate can be written as $r^{ss} = (r^{ss} + \pi^T) - \pi^T$, where $(r^{ss} + \pi^T) = i^{ss}$. Therefore, $r_t - r^{ss} = (i_t - E_t \pi_{t+1}) - (i^{ss} - \pi^T)$, which can be also written as $r_t - r^{ss} = (i_t - i^{ss}) - (E_t \pi_{t+1} - \pi^T)$. If we assume that $r^{ss} = i^{ss} = 0$, then $r_t = i_t - (E_t \pi_{t+1} - \pi^T)$.

[10] The steady state values for the rest of the variables are assumed to be zero.

[11] Under the assumption of flexible inflation targeting, the natural rate of output is assumed to be the

loss function (L) is the following:

$$L = \frac{1}{2}\left\{\sum_{i=0}^{\infty}\beta^i\left[\alpha x_{t+i}^2 + \left(\pi_{t+i} - \pi^T\right)^2\right]\right\}. \tag{2.4}$$

3 Effect of capital openness on exchange rate pass-through and the UIP condition

3.1 Capital market openness and exchange rate pass-through

In this section, I empirically examine the effect of capital openness on ERPT, and to do that I use equation (2.2), the reduced form equation of the forward looking aggregate supply curve from section 2. However, in order to empirically examine this effect in the inflation targeting countries, I modify the aggregate supply curve. Instead of assuming a zero steady state for the real exchange rate, the real rate of depreciation is defined in the following way

$$\Delta e_t = \Delta s_t + \pi_t^* - \pi_t,$$

where Δs is the deviation of the nominal exchange rate from its trend level,[12] π^* is the world CPI inflation rate, and π is the domestic CPI inflation rate.

I include several control variables that have been found to be important determinants of inflation in the literature such as the output-gap (log difference between actual and trend[13] real GDP), and trade openness. In New Keynesian literature, a higher output-gap reflects higher cost of production (higher marginal cost), which in turn leads to increase in the prices, and as a result higher inflation. Moreover, Romer (1993) demonstrates that countries with greater trade openness experience lower average rates of inflation. He explains that an unanticipated monetary expansion causes exchange rate depreciation, and as this depreciation is greater in more open economies, the benefits of a surprise expansion are a decreasing function of the degree of trade openness. Therefore, the monetary author-

implicit target for the actual output.

[12]In a flexible inflation targeting environment, assuming that the trend exchange rate is the implicit target of the actual exchange rate. Also, measuring the exchange rate deviation from its trend level will remove the non-stationarity in the exchange rate.

[13]HP filtered trend where the smoothing parameter is 1600.

ities in a more open economy expand less and achieve lower average rates of inflation.[14] Since I use an interaction term between exchange rate deviation and capital openness in the regression equation, I also control for capital openness (ko) in order to avoid omitted variable bias. Therefore, the estimating equation is the following:

$$\begin{aligned}(\pi_{j,t} - \pi^T) = \alpha_j + \beta\,(E_t\pi_{j,t+1} - \pi^T) + \lambda\, x_{j,t} + \eta^{\pi}\,\Delta e_{j,t} + \eta^{\pi}_{ko}\,(\Delta e_{j,t} * ko_{j,t}) \\ + \eta_{ko}\, ko_{j,t} + \eta_{to}\, to_{j,t} + \epsilon'_{j,t},\end{aligned} \tag{3.1}$$

where j refers to the country, t refers to the time period, π is the rate of inflation, x is the output-gap, Δe is the real exchange rate depreciation, E_t denotes the market expectations based on information available at time t, ko is a measure of capital openness, to is a measure of trade openness, and ϵ'_{it} is a supply shock. The CPI inflation target is assumed to be fixed at 2.5%, since the developed inflation targeting countries have a constant inflation target between 2-3%. Thus, I examine whether the ERPT in 8 IT developed countries,[15] Australia, Canada, Iceland, New Zealand, Norway, Sweden, Switzerland, and UK, has declined with a more open capital account.[16] The date of the adoption of IT for each country is summarized in Table 1.

Table 1: Countries in study

Country	Time of Adoption of IT
1. Australia	1993Q2
2. Canada	1991Q1
3. Iceland	2001Q1
4. New Zealand	1989Q4
5. Norway	2001Q1
6. Sweden	1993Q1
7. Switzerland	2000Q1
8. UK	1992Q4

[14] Monetary expansion is an important determinant of inflation in the long run.
[15] Countries that have adopted IT until 2008 (central banks' websites).
[16] Israel is not included due to some data unavailability.

3.1.1 Data description

The macroeconomic data set used in this estimation is taken from the IMF's International Financial Statistics (IFS) database. The data set for each country begins when it started targeting inflation and extends through 2008Q4, and the frequency of the data is quarterly.

The world CPI inflation data is taken from the IMF's IFS database. Inflation deviation data is constructed by subtracting the monetary authority's target inflation rate (2.5%) from actual inflation. Since, for most of the countries in the sample, data for their inflation forecasts is not available, I use the average value of current and last period's inflation as a proxy for one period ahead expected inflation. The output-gap is constructed by subtracting the real GDP trend (using a Hodrick-Prescott filter (smoothing parameter 1600)) from actual real GDP for each country. The nominal exchange rate deviation is measured by the log difference of the nominal exchange rate with respect to US dollars from a smoothed series, which is constructed using Hodrick- Prescott filter with a smoothing parameter of 1600. Moreover, the degree of trade openness is calculated as the share of $(imports + exports)$ in GDP.

The Chinn-Ito (2008) index is used as the measure of capital account openness. This index is based on the binary variables, which capture the presence of cross-border financial restrictions reported in the *IMF's Annual Report on Exchange Arrangements and Exchange Restrictions*. Chinn and Ito compile the index by considering four major categories of restrictions on external accounts: (i) the presence of a multiple exchange rate regime, (ii) the presence of restrictions on current account transactions, (iii) the presence of restrictions on capital account transactions, and (iv) the presence of a requirement of the surrender of export proceeds. Since these categories reflect capital controls instead of capital openness, they take the inverse of the values of the binary variables, and construct an index based on the standardized principal components. The index ranges from (-1.83) to 2.50,[17] where higher values indicate a more financially open economy. By the nature of its construction, this is a de-jure measure of financial openness, as it attempts to measure the regulatory restrictions on capital account transactions. Since I am interested in finding out the signaling and disciplinary effect of capital account openness on ERPT, the use of a de-jure measure is appropriate. Table 2 presents the summary statistics for the variables.

[17] For the 8 IT developed countries, it ranges from -1.13 through 2.50.

Table 2: Summary statistics of the variables

Variable	Observations	Mean	Std. Dev.	Min	Max
$(\pi_t - \pi^T)$	440	0.024	0.018	-0.014	0.171
$(E_t\pi_{t+1} - \pi^T)$	440	0.024	0.014	-0.0019	0.111
x_t	431	8.12e-08	0.024	-0.09	0.083
e_t	440	0.049	0.099	-0.188	0.333
ko	440	2.22	0.585	-1.13	2.50
to	410	1.93	0.245	1.24	3.07

3.2 Stationarity test results

Before estimating equation (3.1), I test for non-stationarity of the variables applying Augmented Dickey Fuller test with a lag term, where the optimal lag length for each variable was selected using the Schwarz Criterion (SC). The null hypothesis (H_0) for the stationarity test results is that the variable is non-stationary (has a unit root), and the alternative hypothesis (H_A) suggests that the variable is stationary (with no unit root). The ADF test results are summarized in Table 3 and reject the null hypothesis of a unit root for all of the variables, suggesting that they are all stationary.

Table 3: Stationarity test results

Variable	**Symbol**	**ADF test statistic (No. of lags)**
Inflation deviation	$(\pi_t - \pi^T)$	$-4.075^{***}(2)$
Output-gap	x_t	$-9.365^{***}(8)$
Exchange rate deviation	Δe_t	$-4.628^{***}(1)$
Capital market openness	ko_t	$-2.970^{**}(4)$
Trade openness	to_t	$-4.965^{***}(1)$

(*** significant at 1% level, ** significant at 5% level)

3.2.1 Estimation technique

To estimate exchange rate pass-through in the 8 IT countries either one of the two types of estimation techniques can be used, the time series estimation technique separately for the 8 countries, or a panel regression. The time series analysis suffers from a limitation in this case. Since the study focuses on the period in which these countries have followed inflation targeting, its duration is not very long. As a result, there are only a small number of observations for each country, which may give biased estimates. However, this shortcoming can be addressed with a panel regression. The greater number of observations in a panel study will give more precise estimates. Also because this study focuses on inflation targeting developed countries rather than a random sample of a very large number of countries, the coefficients are expected to be similar. Moreover, the use of a panel regression will allow for the identification of country-specific effects in the estimation of the cross-country pass-through equation. However, here two aspects need to be addressed. First, in this model, the problem of endogeneity can be expected to arise as the exchange rate and the output-gap are affected by the deviation of current inflation from its target. This endogeneity makes the estimation using pooled ordinary least squares inconsistent. Second, the Breusch-Pagan test for heteroskedasticity suggests that the error term is heteroskedastic[18] rendering the fixed effects estimates inconsistent. The problem of endogeneity can be addressed by using the lagged values of output, inflation and exchange rate deviations as instruments. However, in this particular case, the number of instrumental variables and hence the orthogonality conditions will exceed the number of regressors, which will lead to over-identification. Hansen (1982), in his seminal work, introduced the generalized methods of moments (GMM) estimation. One important feature of the generalized methods of moments (GMM) is that it allows for more moment conditions than the number of parameters that need to be estimated, which means it allows the parameters to be over-identified and can obtain an optimal weighting matrix. Therefore, to overcome the problem of endogeneity and heteroskedasticity, I use the IV-GMM (Instrumental variable general method of moments) estimation technique that generates coefficient estimates robust to heteroskedasticity and autocorrelation. Further, I test the validity of the instruments applying Hansen J test.

[18] Breusch-Pagan test statistic, a lagrange multiplier (LM) measure, is distributed Chi-squared(p) under the null hypothesis of homoskedasticity. For the aggregate supply function, the Breusch-Pagan LM statistic: 127.18, with Chi-sq P-value 2.4e-24. This test statistic suggests the rejection of the null hypothesis of homoskedasticity in favor of the alternative hypothesis of heteroskedasticity.

3.2.2 Empirical results

In this section, I present the results from estimating the aggregate supply function using pooled ordinary least squares (OLS), fixed effects and IV-GMM. They capture how the cross-country ERPT changes depending on the openness of the capital market. The coefficients from pooled OLS and fixed effects suffer from endogeneity and heteroskedasticity bias. The coefficient estimates from panel IV-GMM estimation are efficient as the estimates are robust to endogeneity, heteroskedasticity and autocorrelation. To address the endogeneity problem, I have used lagged values of the endogenous variables as instruments. To examine the validity of the instrument set, I apply Hansen's J test, where the null hypothesis is that the instruments as a group are exogenous. The p-value of Hansen J statistic (0.77) fails to reject the null hypothesis, implying that the instruments are valid.

The estimating equation is the following:

$$\begin{aligned}(\pi_{j,t} - \pi^T) = \alpha_j + \beta\,(E_t\pi_{j,t+1} - \pi^T) + \lambda\, x_{j,t} + \eta^{\pi}\,\Delta e_{j,t} + \eta^{\pi}_{ko}\,(\Delta e_{j,t} * ko_{j,t}) \\ +\eta_{ko}\, ko_{j,t} + \eta_{to}\, to_{j,t} + \epsilon'_{j,t},\end{aligned} \tag{3.2}$$

Table 4 presents the estimation results. I have reported the coefficient estimates from pooled OLS in column 1, fixed effects in column 2, and IV-GMM in column 3.[19]

The results from the panel estimation suggest that higher expected inflation puts upward pressure on current inflation, as indicated by a value for β that is significantly different from zero and positive. In optimal monetary policy analysis, the coefficient attached to expected future inflation, β is assumed to be greater than 0.9 in equation (3.2). However, the empirical analysis suggests that it is close to 0.6. This could be due to the fact that the average value of last period's inflation and current inflation is used as a proxy for expected future inflation, $E_t\pi_{t+1}$, since the data for the forecast inflation is not available. Further, a higher marginal cost of production (reflected in the output-gap) also increases inflation, $\lambda > 0$ and statistcially significant. On the other hand, higher capital mobility significantly reduces inflation as $\eta_{ko} < 0$.

The effect of real depreciation on inflation or ERPT is determined by the coefficient $(\eta^{\pi} + \eta^{\pi}_{ko} * ko)$. Real depreciation puts upward pressure on inflation, as $\eta^{\pi} > 0$. However, the positive effect of real depreciation on inflation declines significantly with greater capital

[19] Robust standard errors in parenthesis (*** significant at 1% level, ** significant at 5% level, * significant at 10% level)

Table 4: Effect of capital openness on ERPT

Coefficient	Pooled OLS	Fixed Effects	IV-GMM
	(I)	(II)	(III)
β	0.549***	0.523***	0.584***
	(0.048)	(0.058)	(0.069)
λ	0.003	0.002	0.134**
	(0.018)	(0.016)	(0.060)
η^{π}	0.066**	0.097***	0.228***
	(0.020)	(0.022)	(0.101)
η^{π}_{ko}	−0.032***	−0.046***	−0.091**
	(0.008)	(0.009)	(0.036)
η_{ko}	−0.003**	−0.004**	−0.004***
	(0.001)	(0.002)	(0.001)
η_{to}	−0.012***	−0.015***	−0.010***
	(0.002)	(0.003)	(0.002)
N	407	407	392
No. of Countries	8	8	8
R^2	0.54	0.52	0.50
p value for Hansen J statistic			0.77

openness, as the coefficient on $(\Delta e_{j,t} * ko_{j,t})$, η^{π}_{ko}, is significantly less than zero.

Since the capital openness index is variable over time, the effect of capital openness on ERPT is shown in Figure 2 along with the Chinn-Ito capital openness index. The solid line in the middle shows the effect of capital openness on ERPT $(\eta^{\pi} + \eta^{\pi}_{ko} * ko)$, and the two lines on either side of the solid line show the 95% confidence interval. The 95% confidence interval around the solid line allows us to determine the conditions under which capital openness has a statistically significant effect on ERPT. When the capital market is completely closed (that is $ko = 0$), 1% real depreciation raises inflation by 0.23%. However, as the capital market opens up gradually, the effect of real depreciation on inflation (ERPT) declines significantly. Figure 2 suggests that ERPT in IT countries remains significantly positive, but declines as capital market openness increases. Further, as the capital market

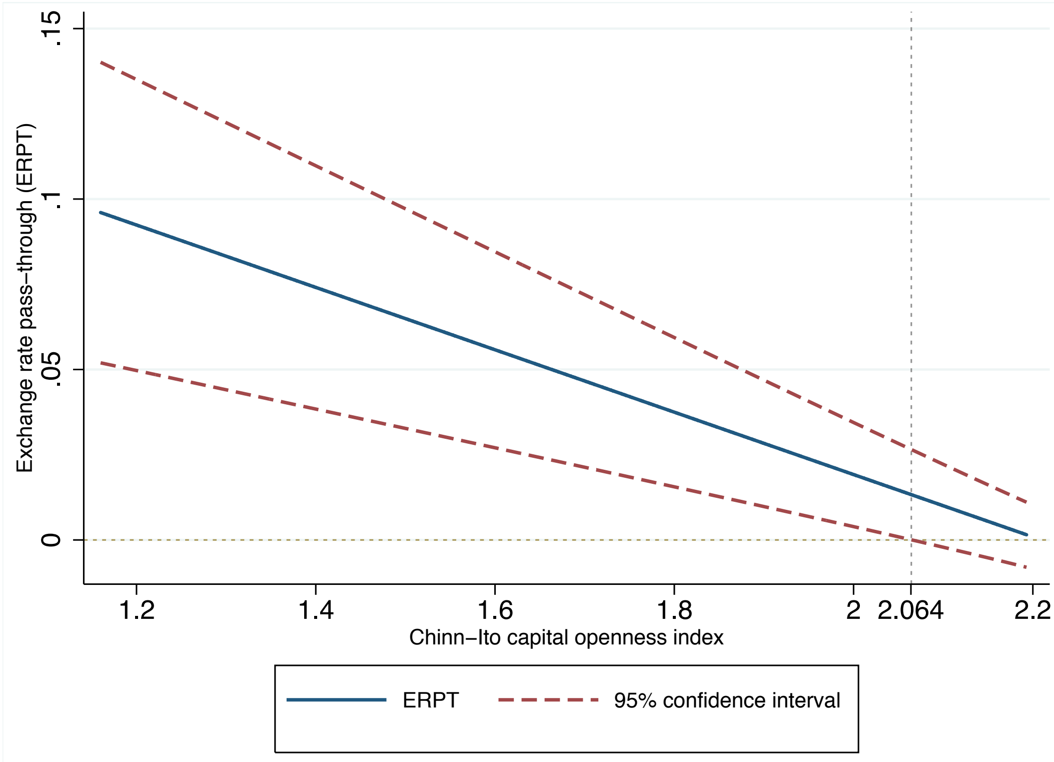

Figure 2: **The effect of capital openness on the exchange rate pass-through**

openness is large enough (rises above 2.06), the pass-through becomes insignificant.

To explain the decline in ERPT in a low inflation environment, Taylor (2000) has argued that in the presence of staggered price setting, in which pricing decisions are optimally made in a monopolistically competitive environment, the pricing power and the persistence of costs are directly related. Therefore, low inflation may be associated with less persistent changes in costs, and lower persistence of costs will result in smaller pass-through. In line with Taylor's argument, the Bank of Canada reports that when inflation is low, and the central bank's commitment to keeping it low is highly credible, firms are less inclined to quickly pass higher costs on to consumers in the form of higher prices, which in turn generates a low ERPT (Bank of Canada (2000)). In this paper, the decline in ERPT in the presence of perfect capital mobility can be due to the fact that for an inflation targeting country that claims to have a flexible exchange rate, an open capital market makes the commitment to a nominal anchor (inflation for IT countries) stronger and indicates a more stable monetary policy. This in turn leads to a low inflation environment and incomplete ERPT.

Moreover, although (Terra (1998)) points out that the negative relationship between trade openness and inflation is generated mainly for severely indebted countries, I find a significantly negative relationship between trade openness and inflation for developed countries, confirming Romer's (1993) prediction that monetary authorities in more open economies expand less, as the harm of a real depreciation is greater in those countries, and they experience lower average rates of inflation as a result.

3.3 Capital market imperfections and the interest rate parity condition

In the presence of capital controls, interest parity does not hold anymore. Aliber (1973) explains the departure from interest rate parity in terms of the rise in risk-premia in the presence of capital controls due to the exchange risk and the political risk. Dooley and Isard (1980) provide empirical evidence for this claim using the DM/dollar rate.[20] Aliber (1973) argues that capital controls can be imposed by offering less stringent terms on the forward contract relative to the spot contract. This type of control can generate exchange risk because speculators can buy an unlimited volume of the forward contract, but they cannot do the same for the spot market. Also, Aliber (1973) points out that a political risk may arise from differences in political jurisdiction, which can be explained by the probability that the authority might apply capital controls.[21] Moreover, in the presence of capital controls, a shock to the domestic interest rate will not be fully transmitted to exchange rate deviations.[22] Therefore, with limited capital openness the UIP is the following:

$$\gamma\left(E_t e_{t+1} - e_t\right) = r_t - {r_t}^* - \zeta'_t, \tag{3.3}$$

where ζ'_t is the AR(1) risk-premium shock[23] and $\gamma > 1$.

[20] These risk-premia apply in addition to the risk-premium charged by risk averse domestic agents on the foreign bonds.

[21] In this case, following Aliber (1973), and Dooley and Isard (1980), an effect on the level of risk-premia is considered and not on its volatility.

[22] Considering that the capital controls would be imposed to insulate exchange rate fluctuation from the interest rate shocks.

[23] $\zeta'_t = \rho_{\zeta'}\, \zeta'_{t-1} + \phi'_t$ where $\rho_\zeta > 0$ and $\phi'_t \sim iid\,(0, \sigma^2_{\phi'})$.

3.4 The central bank's problem

The problem of the central bank can be written as:

$$\text{Max.} \qquad L = -\tfrac{1}{2}\left\{\sum_{i=0}^{\infty}\beta^i\left[\alpha x_{t+i}^2 + (\pi_{t+i}-\pi^T)^2\right]\right\} \tag{3.4}$$

$$\text{Subject to,} \qquad x_t = -\sigma(i_t - (E_t\pi_{t+1}-\pi^T)) + E_t x_{t+1} + \eta^y e_t + u_t \tag{3.5}$$

$$(\pi_t - \pi^T) = \beta(E_t\pi_{t+1}-\pi^T) + \lambda x_t + \eta^{\pi\prime} e_t + \epsilon_t \tag{3.6}$$

$$\gamma\,(E_t\, e_{t+1} - e_t) = (i_t - E_t(\pi_{t+1}-\pi^T)) - (i_t^* - (E_t\pi_{t+1}-\pi^T)^*) - \zeta_t' \tag{3.7}$$

where $\eta^{\pi\prime} > \eta^{\pi}$, $\gamma > 1$, and ζ_t' denotes the exchange plus political risk-premia shocks following an AR(1) process:

$$\zeta_t' = \rho_{\zeta'}\,\zeta_{t-1}' + \phi_t',$$

where $\rho_{\zeta'} > 0$, and $\phi_t' \sim iid\,(0, \sigma_{\phi'}^2)$. The Lagrangian is of the following form:[24]

$$\begin{aligned}
\ell = -\frac{1}{2}\left[\alpha {x_t}^2 + (\pi_t-\pi^T)^2\right] &+ \psi_1[x_t + \sigma(i_t - E_t\pi_{t+1}) - E_t x_{t+1} - \eta^y e_t - u_t] \\
&+\psi_2[(\pi_t-\pi^T) - \beta E_t(\pi_{t+1}-\pi^T) - \lambda x_t - \eta^\pi e_t - \epsilon_t] \\
&+\psi_3[E_t e_{t+1} - (i_t - E_t(\pi_{t+1}-\pi^T)) + (i_t^* - (E_t\pi_{t+1}-\pi^T)^*) + \zeta_t'] \\
&+E_t\left\{\sum_{i=1}^{\infty}\beta^i\left[-\frac{1}{2}\left(\alpha x_{t+i}^2 + (\pi_{t+i}-\pi^T)^2\right)\right]\right\} \\
&+\psi_{1t+i}[x_{t+i} + \sigma(i_{t+i} - E_t\pi_{t+1+i}) - E_t x_{t+1+i} - \eta^y e_{t+i} - u_{t+i}] \\
&+\psi_{2t+i}[(\pi_{t+i}-\pi^T) - \beta E_t(\pi_{t+1+i}-\pi^T) - \lambda x_{t+i} - \eta^\pi e_{t+i} - \epsilon_{t+i}] \\
+\psi_{3t+i}[\gamma E_t e_{t+1+i} - \gamma e_{t+i} &- (i_{t+i} - E_t(\pi_{t+1+i}-\pi^T)) - (i_{t+i}^* - (E_t\pi_{t+i+1}-\pi^T)^*) + \zeta_{t+i}']
\end{aligned} \tag{3.8}$$

Also, we have the demand shock, the cost-push shock and the risk-premia shocks following the respective AR(1) processes with independent innovations:

$$u_{t+1} = \rho_u\, u_t + s_{t+1} \tag{3.9}$$

$$\epsilon_{t+1} = \rho_\epsilon\, \epsilon_t + \omega_{t+1} \tag{3.10}$$

$$\zeta_{t+1} = \rho_\zeta\, \zeta_t + \phi_{t+1} \tag{3.11}$$

[24] Minimization of the loss function can be written as the negative of the maximization of the loss function.

For simplicity, assuming the foreign interest rate, i_t^*, and the deviation of foreign expected inflation from its target $(E_t\pi_{t+1} - \pi^T)^*)$ are equal to zero, the shock processes ((3.9)-(3.11)) and the first-order conditions from the Lagrangian (3.8) can be written in the following state-space form:

$$CE_t \begin{bmatrix} u_{t+1} \\ \epsilon_{t+1} \\ \zeta_{t+1} \\ x_{t+1} \\ E_t(\pi_{t+1} - \pi^T) \\ e_{t+1} \end{bmatrix} = D \begin{bmatrix} u_t \\ \epsilon_t \\ \zeta_t \\ x_t \\ (\pi_t - \pi^T) \\ e_t \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \sigma \\ 0 \\ 1 \end{bmatrix} i_t + \begin{bmatrix} \sigma_s & 0 & 0 \\ 0 & \sigma_\omega & 0 \\ 0 & 0 & \sigma_\phi \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} s_{t+1} \\ \omega_{t+1} \\ \phi_{t+1} \end{bmatrix}$$

where

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & \sigma & 0 \\ 0 & 0 & 0 & 0 & \beta & 0 \\ 0 & 0 & 0 & 0 & 1 & \gamma \end{bmatrix};$$

$$D = \begin{bmatrix} \rho_u & 0 & 0 & 0 & 0 & 0 \\ 0 & \rho_\epsilon & 0 & 0 & 0 & 0 \\ 0 & 0 & \rho_\zeta & 0 & 0 & 0 \\ -1 & 0 & 0 & 1 & 0 & -\eta^y \\ 0 & -1 & 0 & -\lambda & 1 & -\eta^\pi \\ 0 & 0 & -1 & 0 & 0 & \gamma \end{bmatrix}.$$

Premultiplying the system with the inverse of C we can write the system in the following way,

$$E_t Z_{t+1} = K Z_t + G\, i_t + \chi_{t+1}. \tag{3.12}$$

Moreover, i is the policy instrument to minimize the objective function that can be expressed as

$$L = E_t \left\{ \sum_{i=0}^{\infty} \beta^i Z'_{t+i}\, Q\, Z_{t+i} \right\}, \tag{3.13}$$

where Q depends on the specification of a single-period loss function under commitment, and Q can be written as the following:

$$Q = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

Following numerical methods developed by Soderlind (1999), the endogenous variables, x_t, $(\pi_t - \pi^T)$ and e_t are obtained in terms of the shocks (u_t, ϵ_t, ζ_t). Moreover, the social loss is calculated from equation (3.13).

4 Welfare implications of capital market imperfections under commitment

In this section, I present some quantitative results based on a calibrated version of the small open economy. The unknown parameters in the model are β, α, σ, λ,, η^y, η^π, $\eta^{\pi\prime}$ and γ. The parameter values are standard and most of them are taken from Gali and Monacelli (2005).[25] The discount factor $\beta = 0.99$, implying a steady state interest rate of $i = 0.01$ at a quarterly rate.[26] The weight on the output-gap in the central bank's loss function (α) is set at 0.25. Parameter σ, which is the inverse of the coefficient of risk aversion, is assumed to be 1. Parameter λ, which captures the effect of the output-gap on inflation, is set at 0.05. η^y is calculated using the values of structural parameters from the small open economy model of Gali and Monacelli (2005), where $\eta^y = 0.4$. It is assumed that the pass-through parameter η^π varies between 0 (no pass-through) and 1 (complete pass-through) where the value of η^π rises with capital market imperfections. The coefficient attached to expected real depreciation, γ, in the UIP condition is set equal to one in the presence of perfect capital mobility such that the UIP represents the typical UIP condition for a small open economy. However, in the presence of limited capital openness $\gamma > 1$ and it is set at 1.5, implying that when capital controls are in place and effective, interest rate changes

[25]The model is calibrated on a quarterly basis.
[26]The interest rate is 4%per annum.

will not be transmitted entirely to the exchange rate.

Figures 3, 4 and 5 show the response of an inflation deviation $(\pi_t - \pi^T)$, the output-gap (x_t) and the real exchange rate (e_t) to a positive and temporary $(\rho_u = 0)$ aggregate demand shock, a cost-push shock $(\rho_\epsilon = 0)$ and risk-premia shocks $(\rho_\zeta = 0)$. Following the empirical evidence in section 3.1, the pass-through coefficient (η^π) rises with capital market imperfections, and here I have plotted the impulse responses for $\eta^\pi = 0.2$ and $\eta^\pi = 0.4$. Further, to assess the effect of γ on the impulse response functions, I compare two cases, $\gamma = 1$ and $\gamma = 1.5$ where η^π is set at 0.4.

Figure 3 shows the responses of an inflation deviation $(\pi_t - \pi^T)$, the output-gap (x_t) and the real exchange rate (e_t) to a temporary $(\rho_u = 0)$ aggregate demand shock. The positive demand shock increases the output-gap and requires monetary tightening. The rise in the interest rate causes the exchange rate to appreciate making imports cheaper, and as a result, inflation declines below its target level. However, clearly the deflation required to bring output back to its trend level rises with capital market imperfections. One interesting aspect of the impulse response function is that although the demand shock is temporary, the figure shows a strong positive correlation in the output-gap over time under commitment.

Figure 4 displays the impact of a temporary cost-push shock on $(\pi_t - \pi^T)$, x_t and e_t. In response to a positive cost-push shock, the production cost increases, and as a result, inflation rises above its target. The central bank finds it optimal to engineer a temporary reduction in the output-gap, thus dampening the effect of the shock on inflation. Also, due to the rise in domestic prices, the real exchange rate appreciates. To stabilize prices, the central bank raises the interest rate, and the rise in the interest rate is greater in the presence of greater capital openness (smaller pass-through). One interpretation for this could be that under an inflation targeting framework, greater capital openness makes the central bank's commitment to stabilizing inflation more credible. This in turn leads to a greater response of the nominal interest rate in the face of a cost-push shock. Moreover, it is evident from Figure 4 that the output loss required to bring inflation to its target is greater in the presence of capital market imperfections, suggesting a deterioration in the inflation output-gap trade-off in the presence of capital market imperfections.

Figure 5 presents the effect of positive and temporary risk-premia shocks on $(\pi_t - \pi^T)$, x_t and e_t. Positive risk-premia shocks cause the exchange rate to depreciate, and therefore raise inflation. The pass-through from the exchange rate to inflation is more complete with limited capital openness, and consequently, the rise in inflation is greater when $\eta^{\pi} = 0.4$, compared to when $\eta^{\pi} = 0.2$. In response to a real depreciation, the central bank raises the interest rate. However, limited capital openness leads to a greater interest rate response to positive risk-premia shocks. This could be due to the fact that in the presence of capital market imperfections, the pass-through rate is greater, which raises inflation more when there is a depreciation resulting from a positive risk-premium shock. As a result, the monetary authority raises the interest rate more to influence the exchange rate. The behavior of macroeconomic variables in response to the risk-premia shocks in turn indicates that in an inflation targeting environment, the central bank has less control over exchange rates in the presence of greater capital openness. Further, in the face of risk-premia shocks, greater output loss is needed to reduce inflation to its target level in the presence of capital controls.

Further, I plot the impulse response functions of $(\pi_t - \pi^T)$, x_t and e_t for $\gamma > 1$, keeping $\eta^{\pi} = 0.4$ and compare these to those when $\gamma = 1$, in response to demand, cost-push and risk-premia shocks, respectively. Figure 3, Figure 4, and Figure 5 show that in response to demand, cost-push and risk-premia shocks, the reaction of the exchange rate (blue line) under limited capital openness ($\eta^{\pi} = 0.2$) is less when $\gamma > 1$ (more specifically $\gamma = 1.5$). This reduced reaction of the real exchange rate to macroeconomic shocks improves the inflation output-gap trade-off and reduces social loss.

The social loss calculated from equation (3.13) (for different values of η^{π} and γ) is summarized in Table 5. The top two rows in Table 5 describe the parameter values of β, σ, η^{y}, α and λ and the persistence parameters ρ_u, ρ_{ϵ} and ρ_{ζ}. The first column presents the values of η^{π}, which vary from 0.00 (no pass-through) to 1.00 (complete pass-through). The second and third columns denote the coefficient γ, which is attached to the exchange rate deviation in the UIP condition. First, γ is set to 1 and then to 1.5, indicating that the variation in the interest rate is first transmitted entirely and then only partially to exchange rate deviations. The conjecture is that in the presence of perfect capital mobility there is a one-to-one relation between exchange rate deviation and the interest rate through the UIP condition, and therefore, $\gamma = 1$. However, when capital controls are effectively in place, they would insulate the exchange rate deviations from the interest rate fluctuations, and consequently $\gamma > 1$. Fourth and fifth columns present the values of the central bank's loss function for corresponding values of η^{π} and γ.

The values of the parameters and the central bank's loss function in Table 4 suggest that

Table 5: Calibrated parameter values and social loss

$\beta = 0.99$	$\sigma = 1$	$\eta^y = 0.4$	$\alpha = 0.25$	$\lambda = 0.05$	
$\rho_u = 0.0$	$\rho_\epsilon = 0.0$	$\rho_\zeta = 0.0$			
η^π	γ	γ'		$Loss(L)$	$Loss'(L')$
				$\gamma = 1$	$\gamma' = 1.5$
0.00	1	1.5		39.38	39.38
0.20	1	1.5		73.09	64.42
0.40	1	1.5		102.33	87.18
0.60	1	1.5		121.43	103.62
0.80	1	1.5		134.79	116.00
0.90	1	1.5		140.13	121.20
1.00	1	1.5		144.81	125.91

as the ERPT rises with capital market imperfections, keeping everything else unchanged, social loss rises under commitment, implying that a greater pass-through is welfare reducing under a commitment strategy. However, as the value of γ is set to greater than one in the presence of limited capital openness, the social loss rises with greater pass-through, but is less than in previous respective cases, when γ was kept constant at one. For example, when $\gamma = 1$, a 20% rise in the pass-through (as η^π rises from 0.00 to 0.20), raises the social loss by 85% (from 39.38 to 73.09). However, when the capital controls effectively insulate the exchange rate from external shocks that is when $\gamma = 1.5 > 1$, a 20% rise in the pass-through raises social loss by 63% (from 39.38 to 64.42). Thus, when capital controls are in place and effective in the sense that they can insulate the exchange rate from the fluctuations in interest rates, then even in the presence of large exchange rate pass-through, social loss can be reduced.

5 Conclusions and future research

To the best of my knowledge, the existing literature has analyzed imperfect exchange rate pass-through under the assumption of perfect capital mobility. In this paper, I estimate the effect of limited capital openness on exchange-rate pass-through, and further analyze the inflation output-gap trade-off and the social loss function of a central bank following an inflation targeting regime under a commitment strategy. The approach used in the theoretical part of the paper is consistent with Walsh (1999) and Adolfson (2007), although they do not incorporate capital market imperfections in their respective models.

Using a forward looking New Keynesian model, I find that in the presence of imperfect capital mobility, the exchange rate pass-through to inflation increases and the uncovered interest parity condition does not hold. Under reasonable parameter values drawn from the recent literature, the calibration results show that with limited capital openness, these two effects raise the marginal cost of an inflation deviation from its target, and lead to a deterioration of the inflation output-gap trade-off in the face of demand, cost-push and risk-premia shocks. Also, with limited capital openness, the nominal interest rate response to positive demand (increases the output-gap) and cost-push shocks (raises inflation above its target) are less, while the response to the risk-premia shocks (cause exchange rate depreciation) are greater in magnitude. Further, the social loss under an optimal commitment policy rises with greater exchange rate pass-through. However, the social loss can be reduced by insulating the exchange rate deviations from the transmission of interest rate shocks.

The implication of these findings is that under an optimal commitment strategy, an inflation targeting country has to suffer greater loss in terms of real activity to keep inflation at its target in the presence of capital controls, and thus imposing capital controls when the country is targeting inflation is welfare reducing. For example, when an inflation targeting economy experiences a positive risk-premium shock, the exchange rate depreciates. Due to a greater pass-through from exchange rates to inflation in the presence of an imperfect capital market, inflation rises more. Consequently, the central bank suffers from a larger output loss to bring the inflation back to its target. As a result, the social loss in the presence of capital market restrictions rises. However, if the capital controls are effective at reducing the transmission of interest rate and risk-premia shocks to the real exchange rate, then the social loss can be reduced even in the presence of greater exchange rate pass-through. Also, under an inflation targeting framework, limited capital openness makes the central bank's commitment of inflation stabilization less credible and reduces the interest rate response in the face of cost-push shocks. At the same time, greater capital mobility (limited capital mobility) leads to a lower (greater) response of the interest rate to risk-premia shocks that directly affect the exchange rate, indicating that under an inflation targeting framework a central bank has less (greater) control over exchange rate movements in the presence of greater (limited) capital openness.

For future research, one interesting extension would involve examining the effect of a time-varying inflation target on the model instead of assuming a constant inflation target. Such an extension will help to incorporate developing countries into the empirical analysis. Finally, it is worth noting that this paper allows for incomplete exchange rate pass-through to inflation. Some of the implications of incomplete exchange rate pass-through on monetary policy associated with the local currency pricing (Devereux and Engel (2002), Corsetti and Pesenti (2005), Bacchetta and van Wincoop (2003)) and the deviation from the law of one price (Monacelli (2005)) have already been analyzed. At the same time, from the empirical study in this paper (section 3.1), it is evident that monetary policy also affects the level of exchange rate pass-through by anchoring inflation expectations more solidly with greater openness of the capital market. Therefore, it would be interesting to further explore the implications of alternative monetary policies on ERPT in the presence of capital market imperfections.

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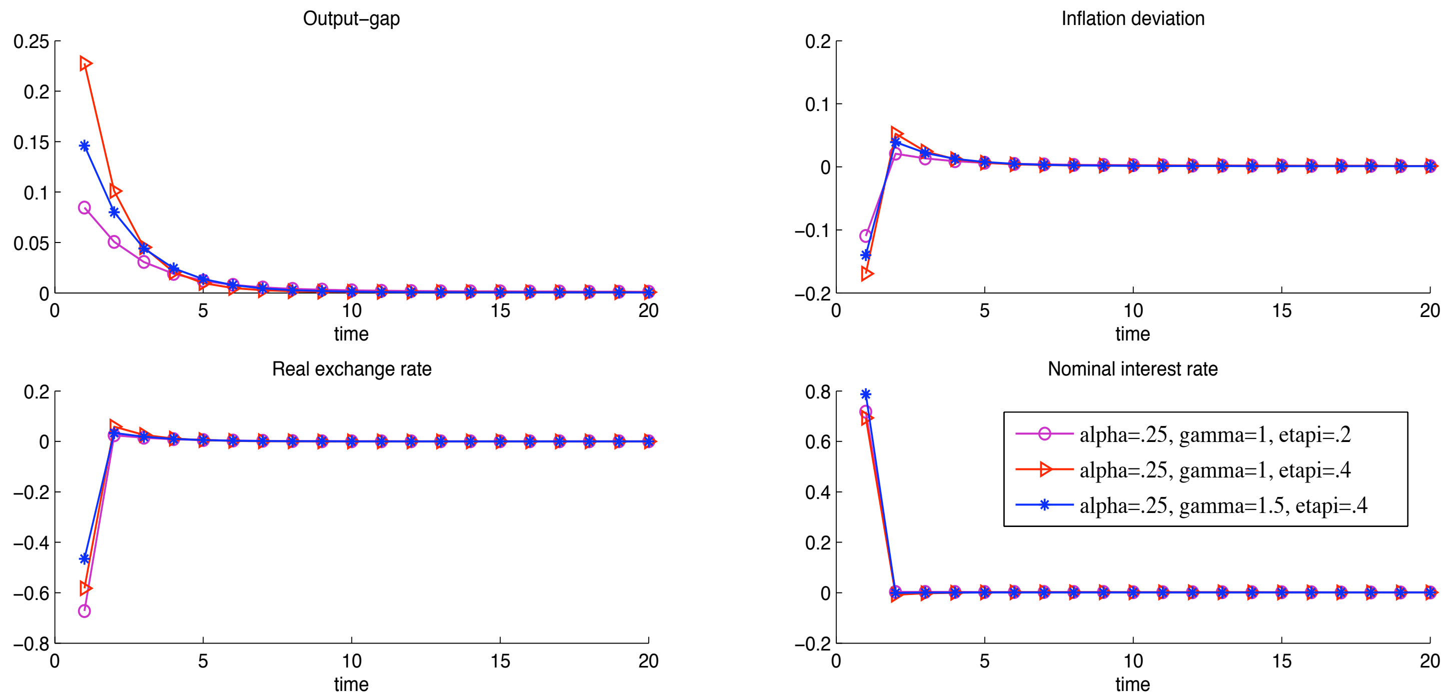

Figure 3: **Impact of demand shock on the endogenous variables**

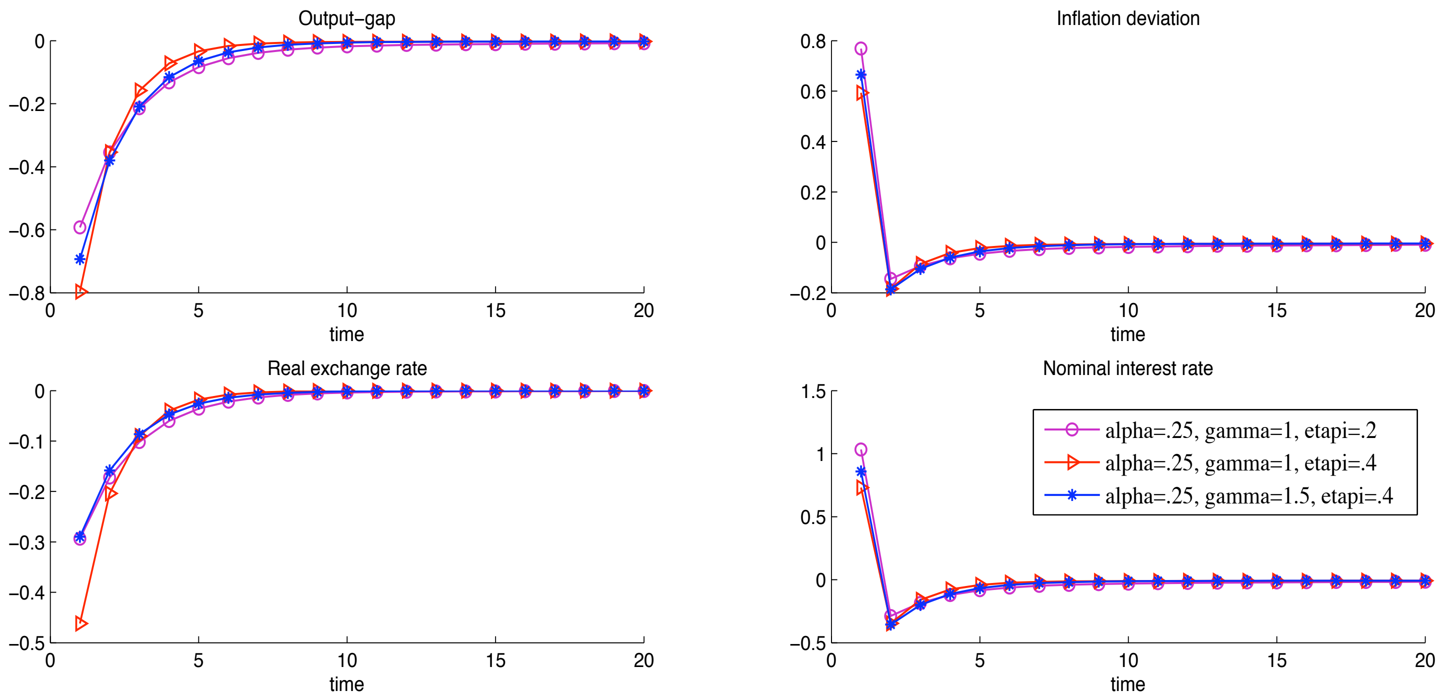

Figure 4: **Impact of cost-push shock on the endogenous variables**

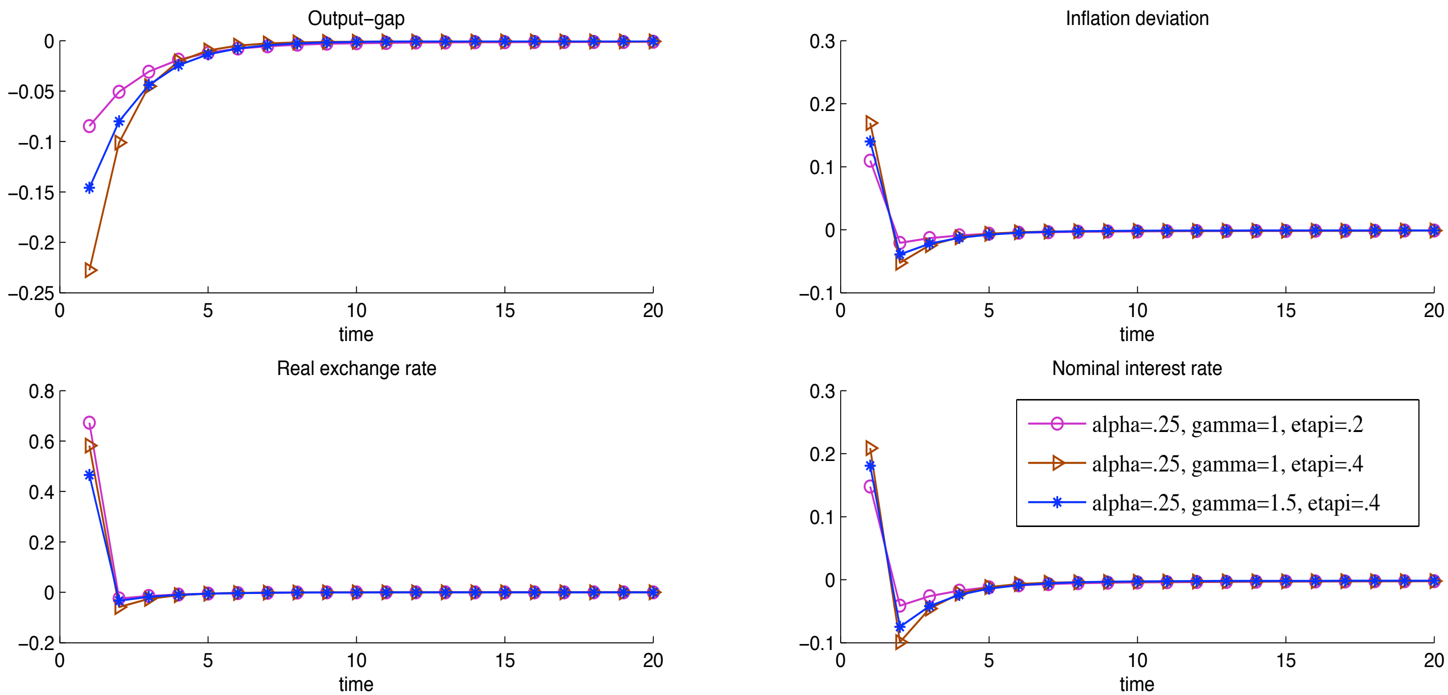

Figure 5: **Impact of risk-premia shocks on the endogenous variables**