Exchange Rate Pass-Through, Monetary Policy, and Currency Invoicing: An Analysis within a DSGE Framework for India

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Abstract

This paper employs a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) framework to explore the dynamic interaction among Exchange Rate Pass-Through (ERPT), monetary policy, and the phenomenon of currency of invoicing for tradable commodities. Diverging from single-equation methodologies, this approach demonstrates that diverse shocks exert uneven impacts on pivotal economic indicators. Notably, the responsiveness of tradable goods to ERPT surpasses that of non-tradable goods due to the greater flexibility in pricing. While monetary shocks lead to near-complete ERPT for tradable goods, foreign inflation shocks result in incomplete ERPT. Shocks in global interest rates and trade endowments prominently influence ERPT in non-tradable goods. Moreover, a heightened persistence in monetary shocks corresponds to a reduced CERPT. The paper also delves into the consequences of currency-specific invoicing strategies, revealing that CERPT is minimized under the Local Currency Pricing (LCP) approach and maximized under the Dominant Currency Pricing (DCP) approach. Consequently, policy measures should be oriented towards bolstering the economy's resilience against diverse shocks while upholding overall stability.

JEL classifications: E31, F31, E52, F41

Keywords: Exchange Rate Pass Through, Inflation, Monetary policy, Currency of invoice, Dynamic Stochastic General Equilibrium (DSGE).

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1. Introduction

This paper integrates three key components – Exchange Rate Pass-Through (ERPT), monetary policy, and considerations regarding the currency of invoice – into a medium-scale New Keynesian Dynamic Stochastic General Equilibrium (DSGE) framework. The primary objective is to gain a deeper understanding of how fluctuations in exchange rates influence domestic prices, overall economic performance, and the effectiveness of monetary policy. Theoretically, ERPT specifically pertains to the process by which alterations in the nominal exchange rate (NER) lead to adjustments in prices. This process unfolds in two stages: initially, shifts in the NER cause price fluctuations in tradable goods, which subsequently drive changes in inflation rates. While some studies have indicated complete pass-through[3], the majority of empirical investigations assert that Exchange Rate Pass-Through is incomplete, as evidenced by the works of Taylor (2000), Otani et al. (2003), Marazzi et al. (2005), Takhtamanova (2010), Shioji (2012); Sengupta & Sinha Roy (2023).

Existing literature has extensively explored Exchange Rate Pass-Through using methodologies such as single equation models (Bailliu & Fujii, 2004; Ca'Zorzi et al., 2007; Takhtamanova, 2010) or Vector Auto Regression (VAR) models (Devereux and Engel, 2002; Campa and Goldberg, 2005; Choudhuri and Hakura, 2006; Ito and Sato, 2008; Gopinath et al., 2010; Aron et al., 2014; Aleem and Lahiani, 2014; Tunc and Kilinc, 2018). However, these empirical approaches exhibit certain limitations (Cicco and Schmidt, 2020). They assume symmetric effects of shocks on the NER and prices and lack the capability to distinguish between the impacts of current and anticipated monetary policies on Exchange Rate Pass-Through. To overcome the shortcomings of these methods, recent studies have shifted their focus on structural modelling within the framework of a Dynamic Stochastic General Equilibrium (DSGE) model. This framework amalgamates the

[3] Complete Exchange Rate Pass-Through (ERPT) refers to the situation where a change in the exchange rate directly and entirely translates into an equivalent change in the prices of tradable goods or services. Incomplete Exchange Rate Pass-Through (ERPT), on the other hand, occurs when a portion of the exchange rate movement is passed on to domestic prices, while the remaining part may be absorbed by other factors such as production costs, market competition, or pricing strategies.

dynamics of economic variables – encompassing aspects such as output, inflation, and interest rates – with the inherent uncertainty and shocks that shape economies over time. DSGE models offer an all-encompassing depiction of the behaviour of economic agents, including households, firms, and policymakers. This allows for the exploration of various policy scenarios and external shocks.

Of late, the topic of Exchange Rate Pass-Through has garnered increased attention in the literature on open economy macroeconomics. This attention is particularly pronounced within the context of Dynamic Stochastic General Equilibrium models (Lane, 2001; Bowman & Doyle, 2003; Corsetti,2005; Bache, 2007; Razafindrage,2016; Ca'Zorzi, 2017; Garcia-Smidth,2018; Gorazki,2023). Many of these models amalgamate elements from the New Keynesian and real business cycle paradigms. The real business cycle (RBC) model is grounded in the neoclassical framework, assuming rational behaviour among economic agents and flexible pricing. This model posits that fluctuations in real quantities exclusively result from real shocks, such as government interventions or alterations in real exchange rates. Later iterations of DSGE models introduce Keynesian features pertinent to short-term macroeconomics. These features encompass nominal rigidities like staggered pricing behaviour (Calvo, 1983) and wage contracts (Taylor, 1980). This integrated approach merges the micro foundations of both households and firms with a variety of nominal and real rigidities, culminating in plausible short-term macroeconomic fluctuations and a comprehensive portrayal of the mechanisms underpinning the transmission of monetary policy. Within the DSGE framework, the effects of monetary policy actions – including changes in interest rates or money supply – can be meticulously examined. These actions exert an influence on the conduct of economic agents, shaping their decisions regarding consumption and investment, and subsequently impacting broader economic outcomes. Hence, understanding the intricate interplay among monetary policy, Exchange Rate Pass-Through, and the movements of exchange rates, within the flexilibily of DSGE framework, helps in devising effective policy strategies, particularly in an increasingly interconnected global economic landscape.

Furthermore, the choice of currency in which goods are invoiced – commonly referred to as the currency of invoice – introduces an additional layer of complexity in the context of international trade and monetary policy. Varied pricing strategies, such as Local Currency Pricing (LCP), Producer Currency Pricing (PCP), and Dominant Currency Pricing (DCP), lead to diverse effects on how changes in exchange rates propagate to alterations in the prices of tradable goods. The DSGE framework serves as a robust platform for analyzing the implications of these distinct pricing strategies on Exchange Rate Pass-Through and broader macroeconomic outcomes.

Despite the extensive literature on DSGE models analysing economic issues in developed and developing economies, very few studies have explicitly examined ERPT within a DSGE framework in the context of India, apart from the work by Patra, Khundrakpam, and John (2018). This study aims to address this gap and contribute to the litearure by investigating ERPT variability under specific shocks and different currencies used for pricing tradable goods.

The study commences by specifying a simple DSGE model, calibrated to Indian data. This model captures the micro behaviour of households and firms in a small open economy with nominal rigidities, making it susceptible to policy-induced or other external shocks. Further, the study also analyses the ERPT in context to alternative monetary policy paths. The study then introduces distinct pricing strategies—Local Currency Pricing (LCP), Producer Currency Pricing (PCP), and Dominant Currency Pricing (DCP)—to explore varying degrees of ERPT under alternative pricing approaches. Further the study highlights the changes in the degree of ERPT under different monetary policy parameter.

The rest of the paper is organized as follows: Section 2 outlines the baseline model, while Section 3 discusses the results and their interpretations related to CERPT. Section 4 highlights the role of different monetary policy paths that influence CERPT Section 5 presents the model describing currency-specific invoicing and its outcomes. Finally, Section 5 provides conclusions drawn from the study.

2. Model:

This section presents a medium scale DSGE model, based on Schmitt-Grohé and Uribe (2017), which has the important elements to present our results. The model incorporates four major shocks to observe the impulse response functions and analyse the Conditional

Exchange Rate Pass Through (CERPT)[4]. This model includes a tradable sector, *T*, and a non-tradable sector, *N*. The central bank follows an inflation targeting regime and sets the interest rate using a Taylor rule in the baseline and then with other alternatives to evaluate the effects of different policy paths. The price stickiness in New Keynesian framework has been incorporated using Calvo pricing rule which helps in finding out transmission channel of exchange-rate movements to internal prices.

2.1 Households

The representative household consumes a basket of tradable and non-tradable goods, works to earn wages W and intends to maximize the presented discounted value of the life time utility,

$$Max\ E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \eta \frac{{L_t}^{1+\varphi}}{1+\varphi} \right\} \tag{2.1}$$

where C_t is consumption and L_t are hours worked, β is the discount factor, σ is the risk aversion parameter, φ is the inverse of the Frisch elasticity of labor supply and η is a scale parameter. The household is assumed to maximize its utility subject to the budget constraint,

$$P_t C_t + e_t B_t^* + B_t = L_t W_t + e_t R_{t-1}^* B_{t-1}^* + R_{t-1} B_{t-1} + \pi_t \tag{2.2}$$

Here P_t is the price of final consumption, e_t is the nominal exchange rate, B^*_t and B_t are holdings of foreign and domestic bonds respectively (with R^* and R being the return on bonds), W is the wage rate, and Π adds exogenous profits from all firms.

The consumption good C_t is a composite of tradable consumption good, C^T, and non-tradable consumption good, C^N, expressed in the form Constant elasticity of substitution

[4] Conditional exchange rate pass-through (ERPT) refers to the responsiveness of domestic prices to changes in the nominal exchange rate (NER) under specific conditions, shocks, or policy paths. For instance, conditional ERPT might investigate how a change in monetary policy stance, such as an interest rate adjustment, affects the pass-through of exchange rate fluctuations to consumer prices. It could also explore how different pricing strategies, such as currency of invoice choices or producer pricing behaviors, interact with exchange rate movements and impact the magnitude of ERPT.

function.

$$C_t = \left[\gamma^{\frac{1}{\theta}}(C_t^N)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}}(C_t^T)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{1-\theta}} \quad (2.3)$$

where γ is the share of nontradables in the total consumption and θ is the constant elasticity of substitution between tradable and non-tradable goods.

Additionally, non-tradable consumption is expressed as a Dixit-Stiglitz aggregate of non-tradable differentiated varieties, $C^N(j)$ with ε being the constant elasticity of substitution across the varieties of goods.

$$C_t^N = \left[\int_0^1 \left(C_t^n(j)\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (2.4)$$

The representative household exhibit an expenditure minimizing habit and we derive the Consumer Price Index P[5] as a combination of prices of tradable and non-tradable consumption good.

$$P_t = \left[(1-\gamma)(P_t^T)^{1-\theta} + \gamma(P_t^N)^{1-\theta}\right]^{\frac{1}{1-\theta}} \quad (2.5)$$

2.2 Firms

2.2.1 Production Technology

The tradable *sec*tor is assumed to have a homogenous stochastic endowment of the tradable good, Y^T, with existence of Purchasing Power Parity (PPP)

$$P^T = \mathrm{e}P^{T,*} \quad (2.6)$$

where $P^{T,*}$ is the price of the trade good in the foreign country.

On the contrary, in the non-tradable sector, each firm produces goods which are differentiated across varieties $j \in [0, 1]$ and is produced using labour as the only factor of production.

The firms adopt a production technology,

$$Y_t^i(j) = L_t^{\alpha_N}(j) \qquad \forall j \in [0,1]\ \alpha_N = (0,1] \quad (2.7)$$

[5] The Composite price is derived using the expenditure minimising behaviour of households.

where $Y_t^i(j)$ is the quantity of output produced by firm i, $L_t(j)$ are labour hours hired for production of j varieties and $\alpha_N \in (0, 1]$ is the labour share parameter. Each firm j faces a downward sloping demand given by:

$$Y_t^N(j) = \left[\frac{P_t^N(j)}{P_t^N}\right]^{\varepsilon} Y_t^N \tag{2.8}$$

where $P^N(j)$ is the price of variety j and Y^N is the aggregate production of the non-tradable sector.

2.2.2 Pricing Strategy

It is assumed in this paper that the firms resort to *Calvo* Pricing technique. In any given period, only a fraction of firms is allowed to adjust their prices. The rest of the firms continue with their existing prices. At any given time, the firms either choose prices optimally with probability *(1-s)* or update according to past inflation data π_{t-1}, and the inflation target, $\bar{\pi}$:

$$\bar{\pi}_t = \pi_{t-1}^{\rho} \bar{\pi}^{(1-\rho)} \tag{2.9}$$

The optimisation problem solved by the firms when choosing prices is to maximise profit function *(V)*,

Max V=

$$E_t \sum_{\tau=0}^{\infty} (\beta s)^{\tau} \Lambda_{t,t+\tau} \left[\frac{\left(P_t^N(i)\right)^{1-\varepsilon}}{(P_{t+\tau}^N)^{-\varepsilon_j}}\right] Y_{t+\Lambda}^N - P_t^N(i)^{\frac{-\varepsilon}{1-\alpha_N}} W_{t+\tau} \left(\frac{y_{t+\tau}^N}{(P_{t+\tau}^N)^{-\varepsilon}}\right)^{\frac{1}{1-\alpha_N}} \prod_{S=1}^{\tau} [(\pi_{t+s-1})^{-\rho} \bar{\pi}^{1-p}]^{-\frac{\varepsilon}{1-\alpha_N}} \tag{2.10}$$

where Λ is the stochastic discount factor. Defining $p_t^{N,*}$ as the real optimal price of the non-tradable good, chosen by the firms, the FOC equation can be recursively expressed in the form,

$$U_t^N = \frac{\epsilon - 1}{\epsilon} (p_t^{N,*})^{1-\varepsilon} C_t^N + \beta s E_t \left(\frac{p_t^{N,*}}{p_{t+1}^{N,*}} . \frac{\pi_{t-1}^{\rho} \bar{\pi}^{(1-\rho)}}{\pi_{t+1}^N}\right)^{1-\varepsilon} \frac{\lambda_{t+1}}{\lambda_t} \frac{\pi_{t+1}^N}{\pi_{t+1}} U_{t+1}^N \tag{2.11}$$

$$U_t^N = \frac{1}{\alpha} (p_t^{N,*})^{\frac{-\varepsilon}{\alpha}} \frac{w_t}{p_t^{N,}} (C_t^N)^{\frac{1}{\alpha_N}} + \beta s E_t \left(\frac{p_t^{N,*}}{p_{t+1}^{N,*}} . \frac{\pi_{t-1}^{\rho} \bar{\pi}^{(1-\rho)}}{\pi_{t+1}^N}\right)^{\frac{1-\varepsilon}{\alpha}} \frac{\lambda_{t+1}}{\lambda_t} \frac{\pi_{t+1}^N}{\pi_{t+1}} U_{t+1}^N \tag{2.12}$$

2.3 The Monetary Policy

The Central bank adopts a Taylor rule where the interest rate is determined by the divergence between actual and targeted inflation rates, actual and potential GDP and some exogenous monetary policy shock (e_t^m) .

$$\left(\frac{R_t}{\bar{R}}\right) = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{GDP_t}{\overline{GDP}}\right)^{\alpha_y} \exp(e_t^m) \tag{2.13}$$

Here the values the variables without the time subscripts are the steady state values of interest rate R_t, actual inflation π_t and actual gross domestic product GDP_t respectively and α_π, α_y are non-negative constants. The specific impact of each factor on the interest rate is determined by coefficients that reflect the Central Bank's policy objectives and the prevailing economic context. The Taylor Rule dictates that when inflation and growth targets exceed expectations, the policy rate is increased; conversely, if these targets fall short, the policy rate is decreased.

2.4 The external sector

The price of the tradable goods P_t^{T*} , the external interest rate R_t^* and the foreign inflation rate π_t^* are determined abroad and are assumed to be exogenous to the system. We close this model with an interest parity condition.

$$R_t^* = R_t^w + \phi_B \left[\exp\left(\bar{b} - \frac{B_t^*}{P_t^{T*}}\right) - 1\right] \tag{2.14}$$

where R_t^w is the exogenous world interest rate and ϕ_B and $\bar{b}$ are parameters. Hence the foreign interest rate is determined by the world interest rate and the country premium obtained due to deviation from the UIP[6] condition.

[6] It states that the difference in interest rates between two countries should be equal to the expected change in the exchange rate between their currencies

2.5 The Shocks and Calibration

In this model, we incorporate four significant disturbances: uncertain tradable endowment Y^T, a shock to monetary policy represented as e_t^m, variations in the global interest rate R_t^w and changes in foreign inflation π_t^* . Each of these shocks denoted as 'sk' is governed by an autoregressive process of order one(AR(I)) with the $u_t^{sk} \sim iid\ (0, \sigma_{sk})$.

$$log\left(\frac{sk_t}{sk}\right) = \rho_{sk} log\left(\frac{sk_{t-1}}{sk}\right) + u_t^{sk} \tag{2.15}$$

For the simulation purpose we calibrate the parameters of the model to represent the Indian context. The exact descriptions of the parameters and their calibrated values have been summarized in Table 1.

Table 1: Parameterization

Parameters	Values	Description	Source
$\boldsymbol{\beta}$	0.9823	Discount Factor	Levine et.al. (2012)
$\boldsymbol{\sigma}$	1.99	Risk Aversion	Levine et.al. (2012)
φ	3	Inverse of Frisch Elasticity	Anand and Prasad(2010)
$\boldsymbol{\theta}$	1.5	Elasticity of substitution between C^T and C^N	Batini (2010)
$\boldsymbol{\gamma}$	0.46	Share of C^N in Consumption	Basu and Das (2015)
$\boldsymbol{\alpha_N}$	0.34	Labour share in non-traded sector	Economic survey (2017)
$\boldsymbol{\epsilon}$	0.97	Elasticity of substitution between non tradables varieties	Goldar(2014)
$\boldsymbol{s}$	0.75	Calvo probability	Patra and Kapur (2012)
$\boldsymbol{\rho}$	0	Index to past inflation	Patra and Kapur (2012)
$\boldsymbol{\alpha_\pi}$	1.1	Taylor rule coeff of π	Patra and Kapur (2012)
$\boldsymbol{\alpha_y}$	0.4	Taylor rule coeff of GDP	Patra and Kapur (2012)
$\boldsymbol{\varphi_B}$	0.233	Debt elastic interest rate	Schmitt-Grohe and Uribe(2017)
$\boldsymbol{\bar{\pi}}$	0.04	Inflation target	RBI
$\boldsymbol{P^T}$	1	Relative price of tradables	Normalisation
$\boldsymbol{L}$	0.56	Hours worked	0.56
$\boldsymbol{S^{TB}}$	0.42	Measure of openness(Trade/GDP)	Patra and Kapur (2012)

3. Results

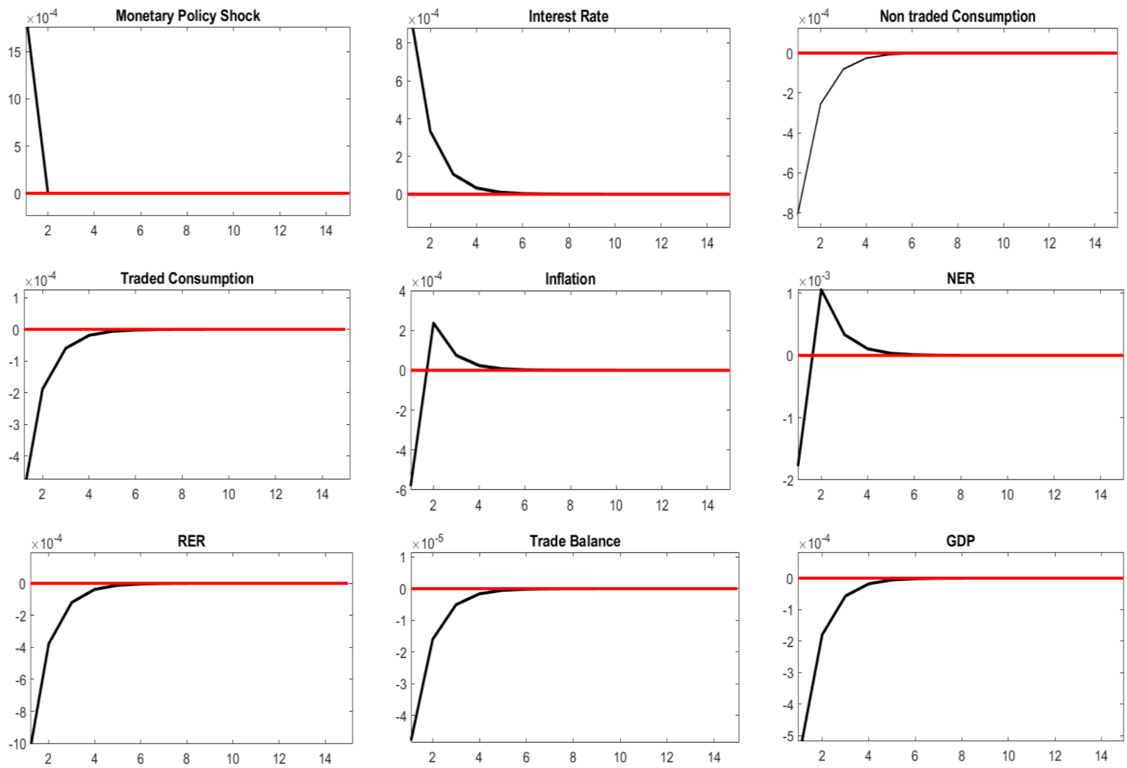
The initial subpart focuses on illuminating how individual shocks influence the principal endogenous variables within the model. The subsequent subpart examines how each of the four shocks impacts the dynamics of conditional exchange rate pass-through.

3.1 Impulse Response Analysis

3.1.1 Impact of Monetary Policy Shock

An upward shift in the Taylor rule results in a decrease in the nominal interest rate, prompting a shift towards current consumption preference. As depicted in Figure 3A, it can be seen that the demand for both tradable and non-tradable goods increases, consequently driving up the general price level and fostering inflationary tendencies. As a result of nominal and real depreciation, the trade balance experiences enhancement, ultimately contributing to a potential increase in GDP.

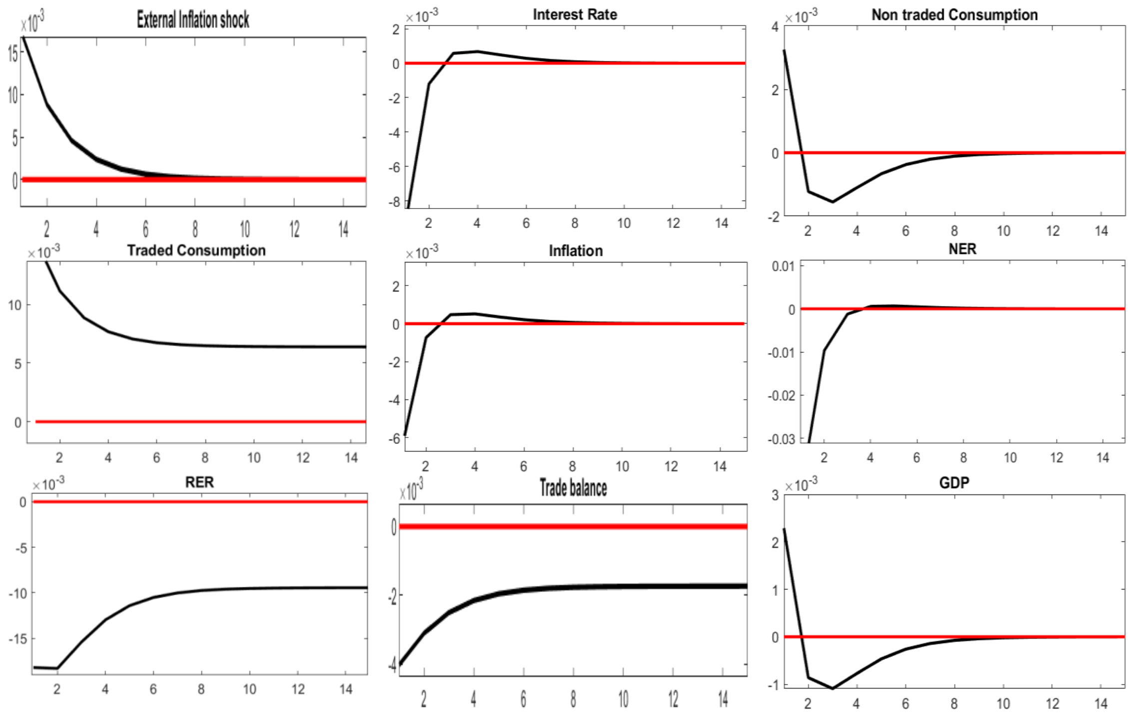
Fig 3A: IRF to monetary policy Shock



3.1.2 Impact of Foreign Inflation shock

A positive external inflation rate shock generates a favorable impact on income. Initially, we make the assumption that foreign bonds are denominated in US dollars within this model. The decline in foreign inflation magnifies the value of debt payments when assessed in real terms. This, in turn, curbs the overall demand within the economy, resulting in a reduction in the desire for both tradable and non-tradable goods. Consequently, this leads to a decline in GDP and an escalation in unemployment.

Fig 3B: IRF to external inflation shock

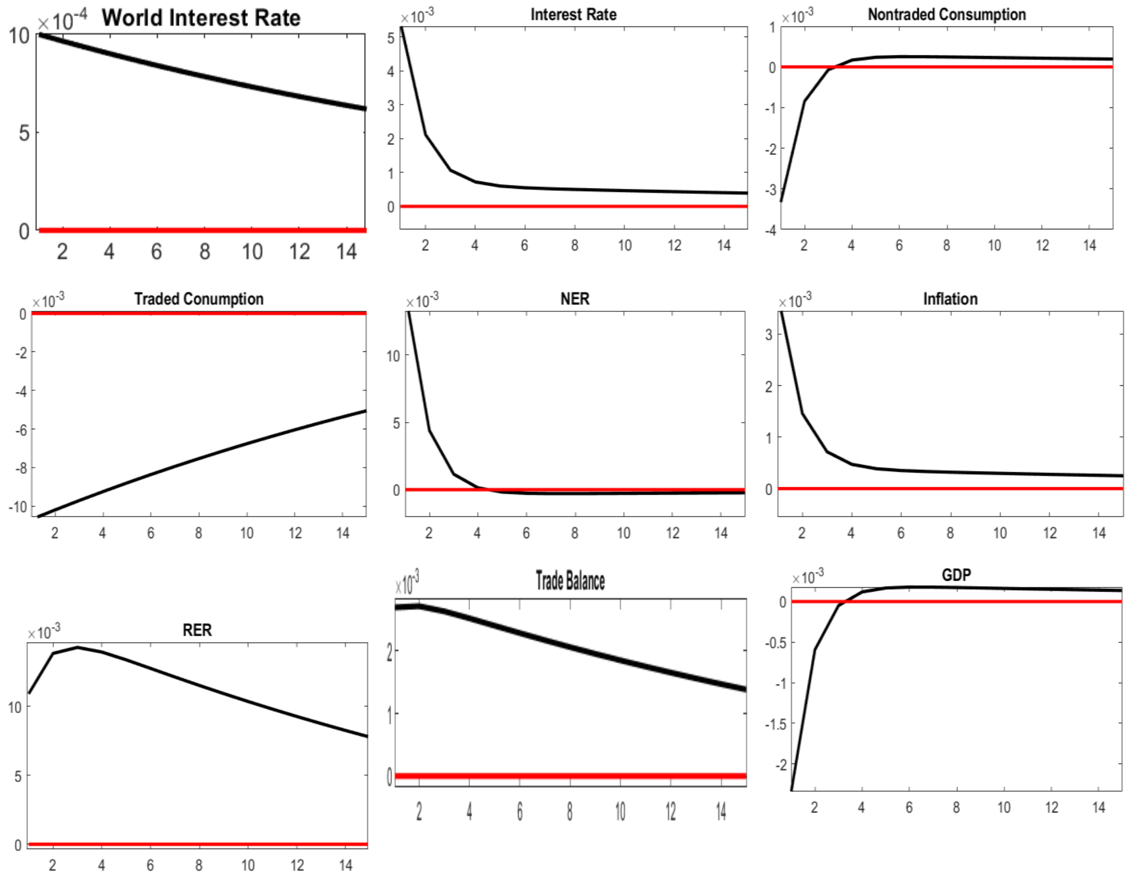


Given the necessity for equilibrium in the non-tradable sector, the absolute price of non-tradable goods experiences a decrease (see Fig 3B). This triggers both nominal and real depreciations in exchange rates, contributing to a decrease in inflation. However, this shock also raises the domestic prices of tradable goods, thereby mitigating the impacts of nominal depreciation and giving rise to inflationary pressures.

3.3 Impact of World Interest Rate Shock

The impact of a rise in the world interest rate shifts the intertemporal consumption in favour of the future leading to increased savings in the present period. This leads to an excess supply of labour and unemployment emerges. The relative price of the non-tradable goods decreases leading to depreciation of the real exchange rates. As the prices are sticky in the new Keynesian framework, the nominal exchange rate also depreciates. However since a negative income effect is created due to rise in world interest rate, a reduction in demand in the non-traded sector emerges. Hence the equilibrium impact on consumption is ambiguous.

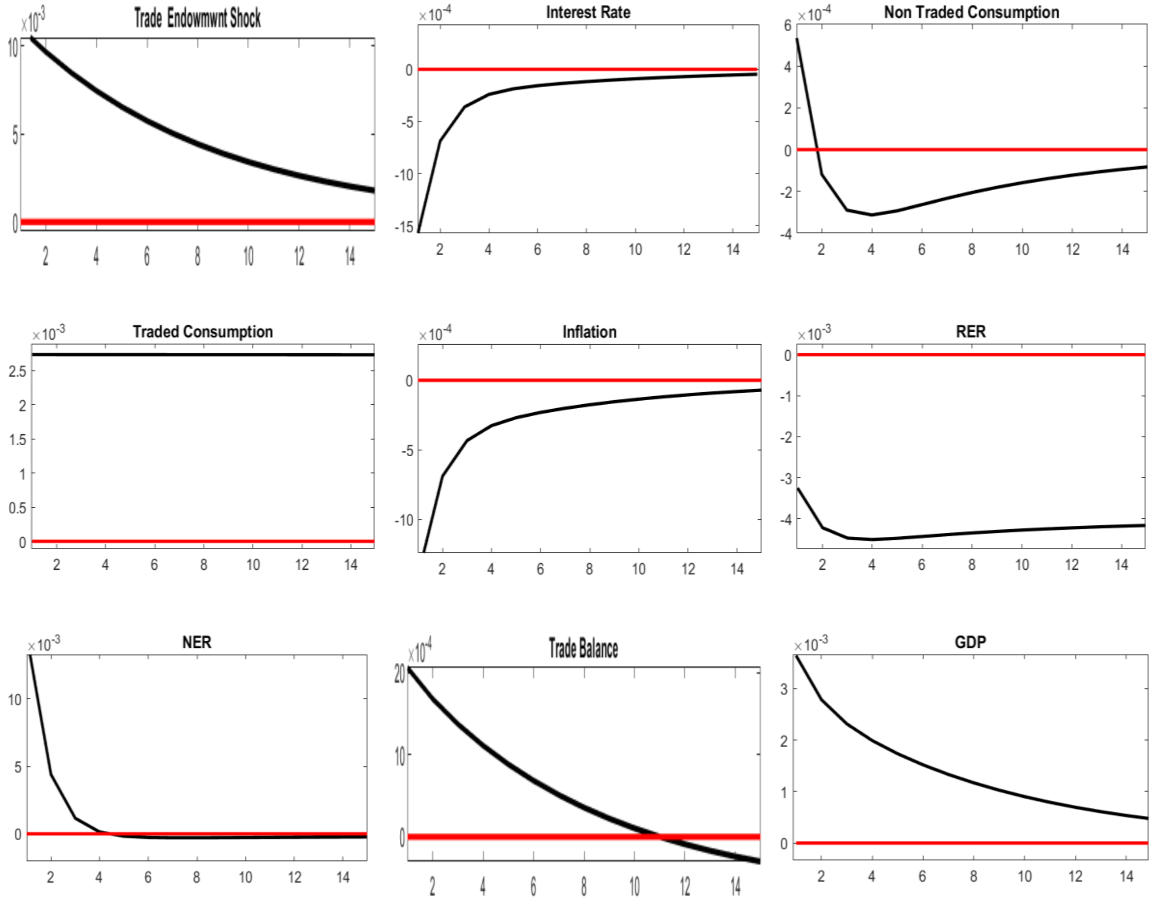
Fig 3C: IRF to World interest rate shocks



3.4 Impact of trade endowment shock:

A favorable shock to the trade endowment produces an adverse income effect. This effect works to decrease the aggregate demand, subsequently leading to a reduction in the present-period consumption of both tradable and non-tradable goods. Consequently, this brings about a decline in the absolute price of both traded and non-traded goods, thereby contributing to a further reduction in the relative price when assessed in real terms. As a result, the real exchange rate appreciates. Simultaneously, the nominal exchange rate experiences an appreciation, which results in making imports comparatively less expensive. However, this appreciation adversely affects the trade balance, leading to a deterioration in GDP and stimulating tendencies towards inflation.

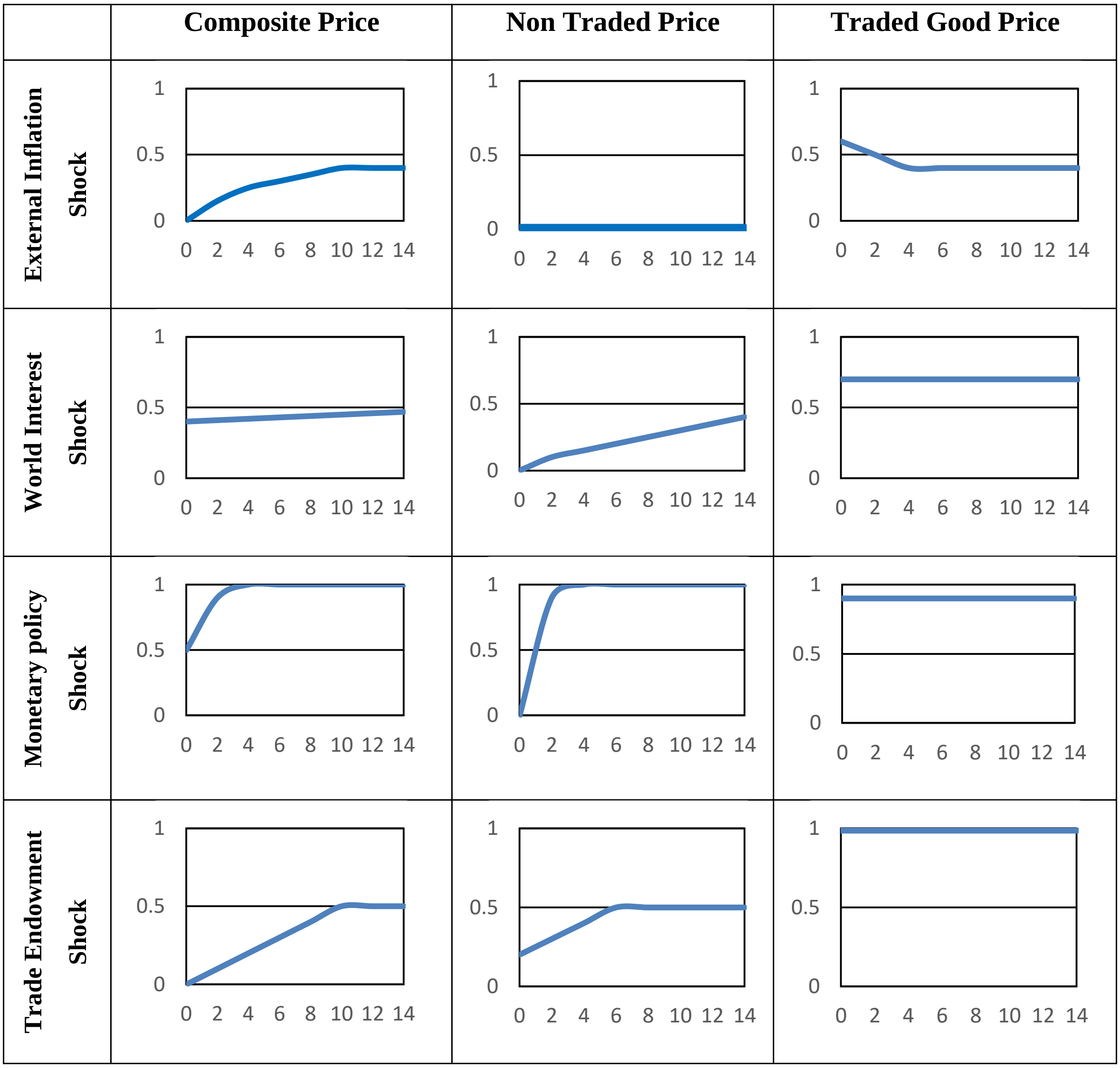
Fig 3D: IRF to trade endowment shock



3.2. Conditional Exchange Rate Pass-through(CERPT)

In this section, we delve into the calculation of Conditional Exchange Rate Pass-Through (CERPTs) based on the Impulse Response Functions (IRFs) derived from the previous subsection. Figure 3E illustrates how the CERPTs distinctly vary across the four shocks within the economy.

Fig 3E: Conditional ERPTs



To begin with, it is evident that the CERPTs for tradable goods consistently surpass those for non-tradable goods, primarily because the former are not restricted by price rigidities. Furthermore, the CERPTs for tradable prices exhibit a notably high level, with the responsiveness of tradable prices to Nominal Exchange Rate (NER) depreciation being nearly flawless, signifying a nearly complete Exchange Rate Pass-Through (ERPT). On the contrary, this isn't the case for the foreign-inflation shock, which doesn't necessitate a complete ERPT for any domestic price at any time horizon.

The CERPT for tradable goods following a foreign inflation shock begins around 0.55 in the initial period and gradually declines. This trajectory emerges due to the fact that external inflation experiences a more significant decrease compared to nominal depreciation, and tradable inflation stems from the interaction of these two factors.

The response of non-tradable goods is also more pronounced in the face of shocks to the world interest rate, tradable endowment, and monetary policy, compared to a foreign-inflation shock. While in the long run, these CERPTs should ultimately converge to unity, in the short term, near unity ERPT is achieved only in response to the monetary shock. In contrast, in reaction to changes in the external interest rate and tradable endowment, ERPT gradually escalates over time, whereas the response remains less dynamic for a foreign inflation shock. Nonetheless, the pass-through effect remains incomplete for non-tradable goods' prices.

As anticipated, the CERPT for the Consumer Price Index (CPI) falls between those for tradable and non-tradable goods. The most substantial CERPT is witnessed in response to the monetary shock, followed by the tradable endowment and foreign interest rate shocks. Conversely, the smallest CERPT is a result of a foreign inflation shock. Beyond differences in magnitude, the temporal evolution also varies. It's pertinent to comprehend the comparative significance of each shock in elucidating fluctuations in NER. As presented in Table A2 (see appendix), fluctuations in foreign inflation and the external interest rate take precedence as the primary drivers of NER fluctuations.

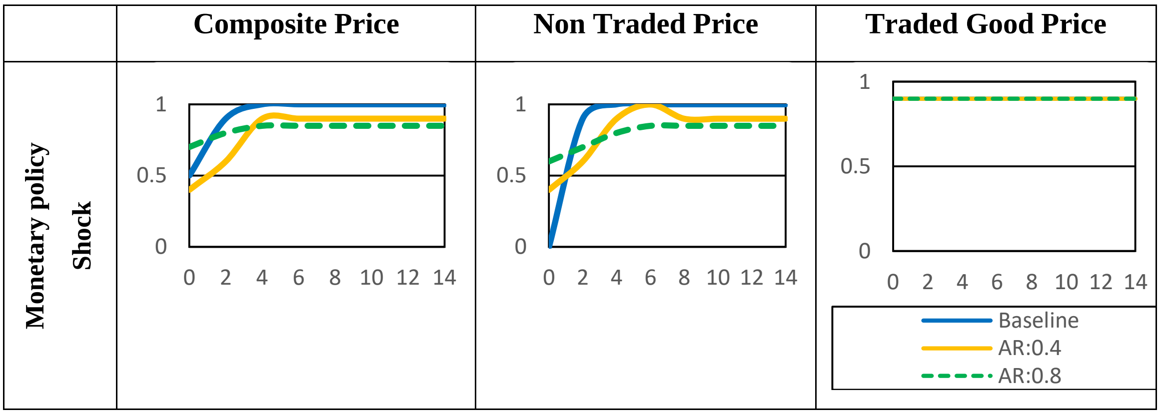
4. Monetary Policy.

The manner in which a central bank makes choices related to interest rates, targeting inflation, employing communication strategies, and implementing unconventional policies can collectively mould the process through which alterations in exchange rates affect domestic prices. The central bank's selection to elevate or diminish interest rates can wield a substantial influence on Exchange Rate Pass-Through (ERPT). An escalation in interest rates could draw foreign investment, prompting an increase in the value of the domestic currency (Grenville, 2023). In instances where a central bank effectively establishes stability in inflation and firmly anchors inflation expectations, it could potentially alleviate the transmission of exchange rate fluctuations into changes in domestic prices (Mendonca and Tiberto, 2017). Gali (2020) suggests that offering transparent information regarding forward shifts in interest rates and the economic landscape holds the potential to shape the anticipations of investors, consequently affecting exchange rates. Proficient forward guidance could potentially modify how exchange rate adjustments are conveyed into shifts in prices. Similarly, the central bank's involvement in quantitative easing, for example, has the potential to prompt a devaluation of the currency, potentially heightening the pass-through impact on domestic prices. Hence in this section the importance of monetary policy is explored in determining the extent of CERPT.

4.1 The Intensity of shocks

As an additional analytical exploration, Figure 4A illustrates the Conditional Exchange Rate Pass Through (CERPTs) in response to a monetary policy shock under different scenarios. In the baseline, it is assumed that the shocks are independent and identically distributed (i.i.d.), and then this subsection consider autocorrelated shocks with coefficients of 0.4 and 0.8. The impulse responses focus solely on the CERPTs following the monetary shock, as the other shocks remain unaffected by this shock.

Fig 4A: Conditional ERPTs under different intensity of monetary policy shocks



It's noticeable that the Exchange Rate Pass-Through (ERPT) for non-tradable goods and the overall Consumer Price Index (CPI) demonstrate significant changes when confronted with more persistent shocks. In contrast, the ERPT for tradable goods remains unchanged. Upon closer observation, as the autocorrelation coefficient increases, the CERPTs exhibit amplified fluctuations in the short term and exhibit a prolonged convergence toward one. This phenomenon can be explained by two primary factors. Firstly, a higher autocorrelation translates to more pronounced shifts in the entire impulse response curve, causing nontradable consumption and inflation to experience more substantial jumps. Although this also leads to a more considerable depreciation, the impact is comparatively smaller than the additional effect on inflation, which elucidates the initial magnified CERPT. Secondly, greater persistence in policy adjustments extends the time it takes for the depreciation rate to return to its steady-state value, thereby contributing to a prolonged and more enduring CERPT pattern.

4.2 Administration of Interest Rates:

This analysis involves a comparison of CERPTs under different policy scenarios. It juxtaposes the baseline approach, where the interest rate is consistently set according to the Taylor rule, with alternative strategies wherein the central bank, upon the shock's impact, opts to maintain a fixed interest rate for a specific number of periods before reverting to the Taylor rule. Specifically, two durations of fixed rates are examined: 2 and 4 periods. This simulation mirrors a plausible real-world situation wherein the central bank refrains from immediate response to an observed depreciation, potentially due to an assumption of low pass-through.

Initially, the ramifications of these alternative policy paths on Exchange Rate Pass-Through (ERPT) are not apparent, as the decision to fix the interest rate (which can be seen as a comparatively more accommodative policy than the baseline) leads to simultaneous increments in both inflation and the Nominal Exchange Rate (NER). As a result, the effect on the ratio that's computed in the ERPT remains uncertain.

Fig 4B: Conditional ERPTs after fixing interest rates

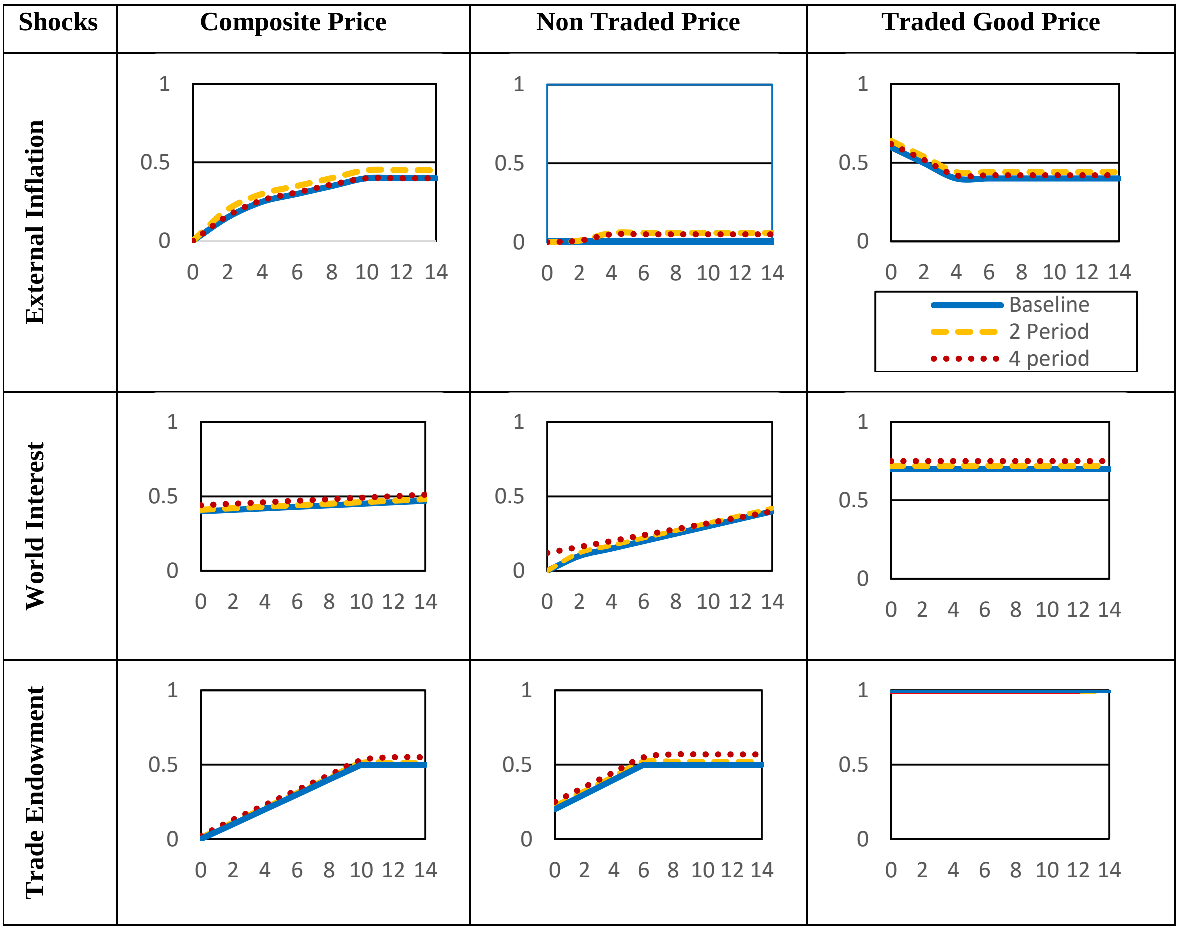


Figure 4B displays the diverse effects of these alternative policy paths, contingent on the nature of the shock. In the context of an alteration in external inflation, if the interest rate is held steady for 2 periods, CERPTs tend to be higher compared to scenarios where the interest rate adheres to the Taylor rule. Conversely, when the interest rate is maintained for 4 periods, CERPTs turn out to be lower in comparison to the other two cases. Conversely, when a global interest rate shock is considered, the impact of different policy paths appears more substantial and displays a consistent trend.

For instance, focusing on the composite price the outcome of a 10% depreciation triggered by changes in external inflation shifts from 1.4% to 1.6% and 1.2% when the rate is fixed for 2 and 4 periods, respectively. Similarly, if the depreciation stems from a global interest rate shock, the projected shift would alter from 3.4% to 3.8% and 4.2% under the same fixed-rate durations.

In essence, the analysis underscores the intricate interplay between policy choices, shocks, and their subsequent impacts on ERPTs. The outcomes demonstrate the nuanced dynamics that emerge in response to divergent policy paths within a complex economic context.

5. Currency specific Invoicing:

One of the explanations for the phenomenon of incomplete Exchange Rate Pass-Through (ERPT) is linked to the currency in which tradable goods are invoiced. When the currency of invoice matches the domestic currency (for instance, a US company invoicing its exports in US dollars), fluctuations in exchange rates have a direct impact on the prices of imported goods. If the domestic currency appreciates, the cost of imports in local currency terms decreases, leading to reduced prices for imported products. Conversely, when the domestic currency depreciates, the cost of imports in local currency terms rises, which could potentially result in higher prices for imported goods. In this scenario, ERPT tends to be higher because exchange rate changes directly translate into adjustments in import prices.

However, if the currency of invoice differs from the domestic currency (for example, a US company invoicing its exports in euros), changes in exchange rates might not be immediately passed on to import prices. Importers could absorb some of the exchange rate fluctuations in order to maintain stable local prices. This practice can lead to a lower degree of ERPT, as the complete impact of exchange rate fluctuations isn't immediately mirrored in import price changes.

Hence, the currency of invoice plays a pivotal role in determining the extent of ERPT. When the currency of invoice aligns with the domestic currency, ERPT is typically more pronounced. Conversely, when the currencies differ, ERPT might be weaker due to market dynamics and pricing strategies.

Given the existing evidence that suggests tradables are invoiced in a handful of major currencies (as indicated by Friberg, 1998; Coresetti et al., 2001;Devereux et al., 2004; Bacchetta & van Wincoop, 2005; Engel, 2006; Gopinath, Itskhoki & Rigobon, 2010; Amiti, Itskhoki & Konings, 2018; Gopinath et al., 2020; Bahaj & Reis, 2020; Egorov & Mukhin, 2023), this study also aims to investigate the Dominant Currency Paradigm (DCP) compared to Local Currency Pricing (LCP) and Producer Currency Pricing strategies

(PCP) in relation to Indian tradable goods.

In the original baseline model, there is no choice of currency for invoicing tradable goods. We have assumed perfect competition and also adhere to the presumption that the law of one price holds. Following the approach of Cicco and Schmidt (2020), we modify the baseline model as outlined below:

4.1 Model

Let the exportable bundle $C_t^{T,F}$, invoiced in foreign currency, demanded at time t be denoted by,

$$C_t^{T,F} = \left(\frac{P_t^{T,F,F}}{P_t^{T,*}}\right)^{-\varsigma *} C^{row} \tag{5.1}$$

where $P_t^{T,F,F}$ is price of the exported good, which is invoiced in foreign currency and is being purchased in the foreign country at time and C^{row} is the consumption level in rest of the world. $P_t^{T,*}$ denotes the international price of the good.

Equation 4.1 illustrates that the demand for exports is inversely correlated with the dollar-denominated price of the export relative to the global price of the standardized good. In a similar manner, the demand for total imports in domestic currency is formulated as a function of the price of the goods, which are invoiced in domestic currency and are sold in the home country.

$$C_t^{T,H} = (1-\gamma)\left(\frac{P_t^{T,H,H}}{P_t}\right)^{-\varsigma *} C_t \tag{5.2}$$

Every consumption combination $C_t^{T,d}$ for d = {H, F} is differentiated across varieties and then combined using Dixit-Stiglitz aggregation methods,

$$C_t^{T,d} = \left[\int_0^1 \left(C_t^{T,d}(j)\right)^{\frac{\epsilon_d - 1}{\varepsilon_d}} dj\right]^{\frac{\varepsilon_d}{\epsilon_d - 1}} \tag{5.3}$$

leading to,

$$C_t^{T,d}(j) = \left(\frac{P_t^{T,d,c}(j)}{P_t^{T,d,c}}\right)^{-\varepsilon_d} C_t^{T,d} \tag{5.4}$$

Moreover, it is posited that there exists a continuum of monopolists distributed in [0.1], who function under linear technology and acquire a uniform tradable commodity. These monopolists have the option to either utilize their trade endowment or resort to importing as a means of financing. Both groups of monopolists produce differentiated goods and implement Calvo-style pricing tactics in order to determine the pricing of their commodities. Subsequently, these goods are procured by two separate monopolistically competitive aggregators operating within the tradable sector. One of these aggregators caters to the domestic market, while the other engages in foreign sales. Various iterations of pricing strategies can emerge based on the advantageous selection of currency by these monopolists.

Let ${P_t^T}^{d,c}$ be the price of the tradable in time t be solid at a destination d in the currency of the country c (where both d and c can be Home, H or foreign, F.). Each of the monopolistically competitive firm chooses ${P_t^T}^{d,c}$ to maximize the following Lagrangian

$$E_t \sum_{\tau=0}^{\infty} (\beta s_d)^{\tau} \Lambda_{t,t+\tau}^{c} {P_t^T}^{d,c} C_{t+\tau}^{T,d} \left[\frac{\left({P_t^T}^{d,c}(i)\right)^{1-\varepsilon_d}}{\left({P_{t+\tau}^T}^{d,c}\right)^{1-\varepsilon_d}} \right] \left[\prod_{S=1}^{\tau} \left(\pi_{t+s}^{d,c}\right) \right]^{1-\varepsilon_d} - \left[\prod_{S=1}^{\tau} \left(\pi_{t+s}^{d,c}\right) \right]^{1-\varepsilon_d} \frac{MC_{t+\tau}^{c}}{{P_{t+\tau}^T}^{d,c}} \tag{5.5}$$

where $\Lambda_{t,t+\tau}^{c}$ is the stochastic discount factor for currency c such that $\Lambda_{t,t+\tau}^{H} \frac{e_{t+\tau}}{e_t} = \Lambda_{t,t+\tau}^{F}$ and $MC_t^H = e_t P_t^{T*}$ and $MC_t^F = P_t^{T*}$ being the marginal cost in the domestic and foreign currency respectively.

As can be seen from the Lagrangian, all the firms choose to set the price at $\bar{P}_t^{T,d,c}$ in time t. The optimality conditions can be recursively expressed as,

$$O_t^{T,d,c} = \left(\frac{\bar{P}_t^{T,d,c}}{P_t^{T,d,c}} \right)^{1-\varepsilon_d} \left(\frac{\varepsilon_d - 1}{\varepsilon_d} \right) C_t^{T,d} + \beta s E_t \left\{ \Lambda_{t,t+1}^{c} \left(\frac{\bar{P}_t^{T,d,c}}{\bar{P}_{t+1}^{T,d,c}} \right)^{1-\varepsilon_d} \left(\pi_{t+1}^{d,c}\right)^{1-\varepsilon_d} \pi_{t+1}^{T,d,c} O_{t+1}^{T,d,c} \right\} \tag{5.6}$$

$$O_t^{T,d,c} = \left(\frac{\bar{P}_t^{T,d,c}}{P_t^{T,d,c}}\right)^{-\varepsilon_d} \left(\frac{MC_t^c}{P_t^{T,d,c}}\right) C_t^{T,d} + \beta s_d E_t \left\{ \Lambda_{t,t+1}^c \left(\frac{\bar{P}_t^{T,d,c}}{\bar{P}_{t+1}^{T,d,c}}\right)^{-\varepsilon_d} \left(\pi_{t+1}^{d,c}\right)^{-\varepsilon_d} \pi_{t+1}^{T,d,c} O_{t+1}^{T,d,c} \right\} \tag{5.7}$$

In real terms

$$O_t^{T,d,c} = \left(\bar{p}_t^{T,d,c}\right)^{1-\varepsilon_d} \left(\frac{\varepsilon_d - 1}{\varepsilon_d}\right) C_t^{T,d} + \beta s_d E_t \left\{ \Lambda_{t,t+1}^c \left(\frac{\bar{p}_t^{T,d,c}}{\bar{p}_{t+1}^{T,d,c}} \cdot \frac{1}{\pi_{t+1}^{T,d,c}}\right)^{1-\varepsilon_d} \left(\pi_{t+1}^{d,c}\right)^{1-\varepsilon_d} \pi_{t+1}^{T,d,c} O_{t+1}^{T,d,c} \right\} \tag{5.8}$$

$$O_t^{T,d,c} = \left(\bar{p}_t^{T,d,c}\right)^{-\varepsilon_d} \left(\frac{MC_t^c}{P_t^{T,d,c}}\right) C_t^{T,d} + \beta s_d E_t \left\{ \Lambda_{t,t+1}^c \left(\frac{\bar{p}_t^{T,d,c}}{\bar{p}_{t+1}^{T,d,c}} \cdot \frac{1}{\pi_{t+1}^{T,d,c}}\right)^{-\varepsilon_d} \left(\pi_{t+1}^{d,c}\right)^{-\varepsilon_d} \pi_{t+1}^{T,d,c} O_{t+1}^{T,d,c} \right\} \tag{5.9}$$

The different alternatives of pricing in this context can be defined as

- Local Currency Pricing (LCP) holds when we choose the sticky prices ${P_t^T}^{F,F}$ and ${P_t^T}^{H,H}$ while ${P_t^T}^{F,H} = e_t {P_t^T}^{F,F}$ and ${P_t^T}^{H,F} = \frac{{P_t^T}^{H,H}}{e_t}$
- Producer Currency Pricing (PCP) holds when we choose the sticky prices ${P_t^T}^{F,H}$ and ${P_t^T}^{H,H}$ while ${P_t^T}^{F,F} = \frac{{P_t^T}^{F,H}}{e_t}$ and ${P_t^T}^{H,F} = \frac{{P_t^T}^{H,H}}{e_t}$
- Dominant Currency Pricing (Holds when we choose the sticky prices ${P_t^T}^{F,F}$ and ${P_t^T}^{H,F}$ while ${P_t^T}^{F,H} = e_t {P_t^T}^{F,F}$ and ${P_t^T}^{H,H} = e_t {P_t^T}^{H,F}$

The relationship between real price of the tradable good $\bar{p}_t^{T,d,c}$ and the inflation level $\pi_t^{T,d,c}$ can be summarized using

$$(1 - \theta_d)\left(\bar{p}_t^{T,d,c}\right)^{1-\varepsilon_d} + \theta_d \left(\frac{\pi_t^{d,c}}{\pi_t^{T,d,c}}\right) = 1 \tag{5.10}$$

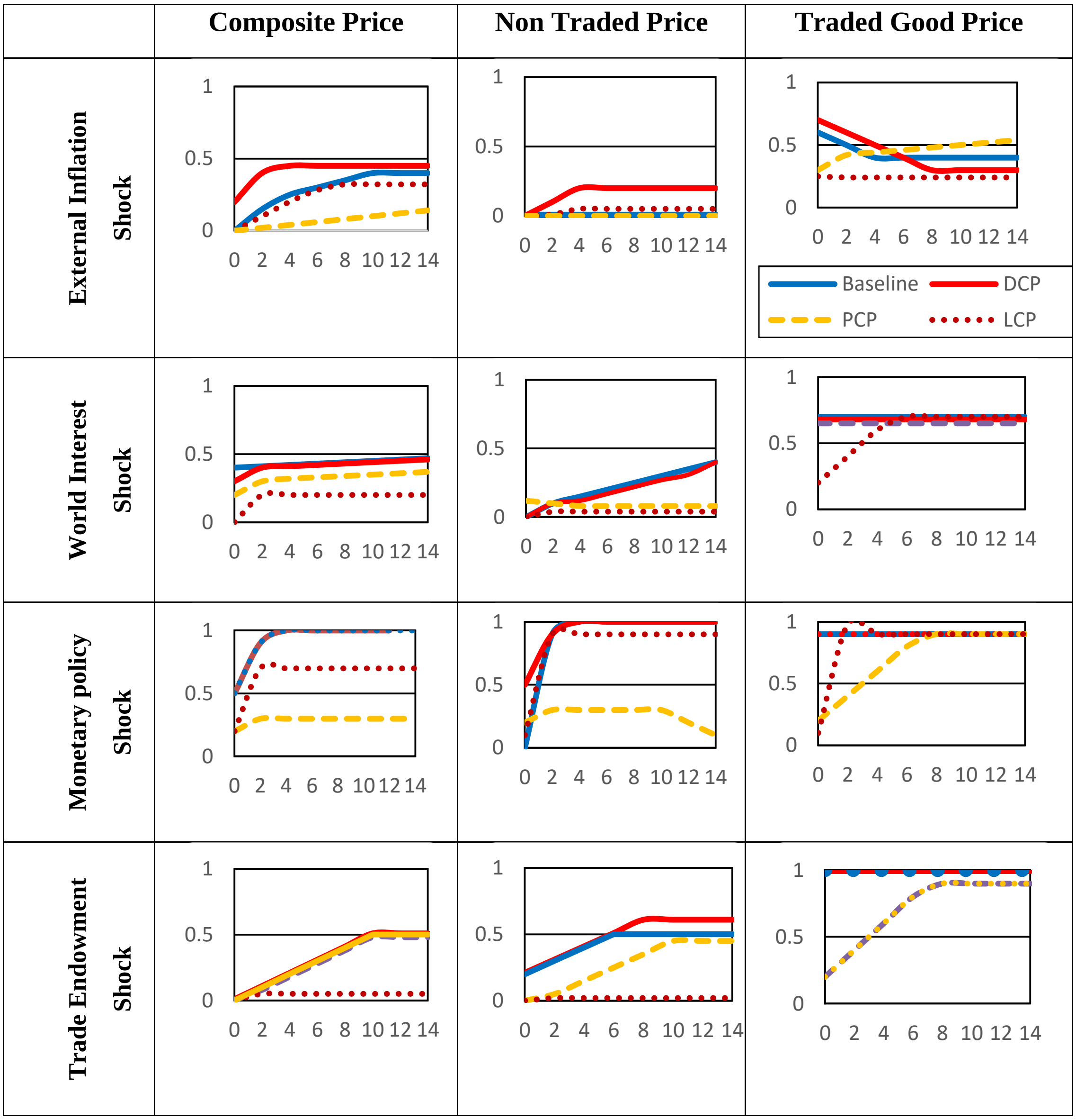
Given that sum of demand factors of production for all the monopolist should sum to the amount of tradable endowment and total imports

$$\int_0^1 \left[\left(\frac{P_t^{T,H,c}(j)}{P_t^{T,H,c}}\right)^{-\varepsilon_H} C_t^{T,H} + \left(\frac{P_t^{T,F,c}(j)}{P_t^{T,F,c}}\right)^{-\varepsilon_F} C_t^{T,F} \right] dj = Y_t^T + M_t \tag{5.11}$$

5.2 The Impulse Response Analysis

From the IRF’s generated for the modified model it can be said that when monopolists resort to PCP the ERPT is lower for the non tradables and higher for the tradables. This impact is similar under the influence of all the four shocks used in the model.

Fig 5A: Conditional ERPTs for different currency specific invoicing



The dynamics within these scenarios rely on how the domestic terms of trade develop over time. In the baseline and DCP (Scenario 1), the relationship between certain economic indicators remains unaffected by changes in the Nominal Exchange Rate (NER). In the case of LCP (Scenario 2), when there's a nominal depreciation of the currency, the terms of trade improve due to a relatively rigid denominator while the numerator is more responsive. Conversely, in the PCP scenario (Scenario 3), the opposite effect occurs.

Figure 5A illustrates the Conditional Exchange Rate Pass Through (CERPTs) for the four alternative models. Notably, the baseline and DCP models have nearly indistinguishable CERPTs when subjected to an external interest rate shock. Discrepancies arise post-shock in external inflation due to the DCP model's characteristic of elastic exports in response to changes in the Price Threshold (PT)*. The LCP alternative presents smaller CERPTs for tradable goods, primarily because their local currency prices remain inflexible. For nontradable goods, a nominal depreciation enhances the domestic terms of trade, leading to reduced demand contraction and a lesser impact on Domestic Price Level (PN).

Under PCP, CERPTs for tradables are also diminished compared to the baseline. However, the depreciation-induced decline in the domestic terms of trade leads to a decrease in consumption and inflation for non-tradable goods, resulting in lower CERPTs. Importantly, regardless of how tradable goods are priced, CERPTs exhibit substantial differences. Some of these differences are even more pronounced in certain scenarios.

To summarize, although the exchange rate pass-through is incomplete in most cases, it closely resembles the baseline in the DCP scenario, followed by the PCP scenario, and is least similar under the LCP scenario. Interestingly, the pass-through under the PCP scenario is lower than under the LCP scenario, particularly when influenced by a monetary policy shock.

6. Conclusion and Policy Recommendation

This paper integrates the concepts of Exchange Rate Pass-Through (ERPT), monetary policy, and considerations related to the currency of invoicing within the framework of a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model. When subjected to monetary policy or world interest shocks, inflation increases, leading to subsequent nominal and real depreciation that enhance trade balance and potential GDP growth. Conversely, positive external inflation or trade endowment shocks result in lowered GDP growth, deflation, and heightened unemployment. The CERPT consistently shows that ERPT for tradable goods exceeds that for non-tradable goods due to fewer constraints on prices in the former category. Specifically, CERPT for tradable goods indicates almost complete ERPT for monetary shocks, but incomplete ERPT for foreign inflation shocks.

The CERPT for the Consumer Price Index (CPI) falls between tradable and non-tradable goods, with monetary shocks having the highest impact and foreign inflation shocks having the lowest impact. In terms of the intensity of monetary policy shocks, persistent shocks induce significant changes in ERPT for non-tradable goods and the CPI, while ERPT for tradable goods remains constant. Increasing autocorrelation coefficients amplify short-term CERPT fluctuations and extend the convergence of ERPT to one. Regarding the administration of interest rates for specific periods, uncertain effects on ERPT are observed, with shorter fixed-rate periods increasing CERPT and longer periods reducing it.

Additionally, the study examines the influence of Currency-Specific Invoicing, highlighting how the currency choice for invoicing tradable goods affects ERPT. ERPT is generally incomplete, and it closely resembles the baseline in the Dominant Currency Paradigm (DCP) scenario, followed by the Producer Currency Pricing (PCP) scenario, and differs most from the Local Currency Pricing (LCP) scenario. Interestingly, the pass-through under the PCP scenario is lower than under the LCP scenario, particularly when influenced by a monetary policy shock.

Given the differential impacts of shocks on ERPT, policymakers should focus on enhancing the economy's resilience to various shocks. Implementing structural reforms that improve labor market flexibility, support domestic production, and enhance export diversification can reduce the vulnerability of the economy to external shocks, ultimately influencing ERPT positively. When possible, encouraging the alignment of the currency of invoice with the domestic currency can lead to more pronounced ERPT due to the direct transmission of exchange rate changes to import prices.

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Appendix

Table A1: The first order conditions for the endogenous variables of the baseline model:

$C_t^{-\sigma} = \lambda_t$	(EQ.1)
$\eta(L_t)^{\varphi} = \lambda_t w_t$	(EQ.2)
$\lambda_t = \beta E_t\left[\frac{\lambda_{t+1}R_t{}^{*}\pi_t^e}{\pi_{t+1}}\right]$	(EQ.3)
$\lambda_t = \beta E_t\left[\frac{\lambda_{t+1}R_t}{\pi_{t+1}}\right]$	(EQ.4)
$C_t^N = \gamma(p_t^N)^{-\theta}C_t$	(EQ.5)
$C_t^T = (1-\gamma)(rer_t)^{-\theta}C_t$	(EQ.6)
$(1-\gamma)(rer_t)^{1-\theta} + \gamma(p_t^N)^{-\theta} = 1$	(EQ.7)
$U_t^N = \frac{\epsilon-1}{\epsilon}(p_t^{N,*})^{1-\varepsilon}C_t^N + \beta s E_t\left(\frac{p_t^{N,*}}{p_{t+1}^{N,*}}.\frac{\pi_{t-1}^{\rho}\bar{\pi}^{(1-\rho)}}{\pi_{t+1}^N}\right)^{1-\varepsilon}\frac{\lambda_{t+1}}{\lambda_t}\frac{\pi_{t+1}^N}{\pi_{t+1}}U_{t+1}^N$	(EQ.8)
$U_t^N = \frac{1}{\alpha}(p_t^{N,*})^{\frac{-\varepsilon}{\alpha}}\frac{w_t}{p_t^{N,}}(C_t^N)^{\frac{1}{\alpha}} + \beta s E_t\left(\frac{p_t^{N,*}}{p_{t+1}^{N,*}}.\frac{\pi_{t-1}^{\rho}\bar{\pi}^{(1-\rho)}}{\pi_{t+1}^N}\right)^{\frac{1-\varepsilon}{\alpha}}\frac{\lambda_{t+1}}{\lambda_t}\frac{\pi_{t+1}^N}{\pi_{t+1}}U_{t+1}^N$	(EQ.9)
$\pi_t^N = \frac{p_t^N}{p_{t-1}^N}\pi_t$	(EQ.10)
$\pi_t^T = \frac{rer_t}{rer_{t-1}}\pi_t$	(EQ.11)
$(1-s)(p_t^{N,*})^{1-\varepsilon} + s[\pi_{t-1}^{\rho}\bar{\pi}^{(1-\rho)}]^{1-\varepsilon}\left(\frac{1}{\pi_t^N}\right) = 1$	(EQ.12)
$\left(\frac{R_t}{\bar{R}}\right) = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha\pi}\left(\frac{GDP_t}{\overline{GDP}}\right)^{\alpha_y}\exp(e_t^m)$	(EQ.13)

$$\frac{rer_t}{rer_{t-1}} = \frac{\pi_t^e \pi_t^*}{\pi_t}$$	(EQ.14)
$$R_t^* = R_t^w + \phi_B\left[e^{\hat{b}-b_t^*} - 1\right]$$	(EQ.15)
$$C_t^N = \Delta_t^{-\alpha} L_t^\alpha$$	(EQ.16)
$$(1-s)(p_t^{N,*})^{\frac{-\varepsilon}{\alpha}} + s\left[\frac{\pi_{t-1}^{\rho}\bar{\pi}^{(1-\rho)}}{\pi_t^N}\right]^{\frac{-\varepsilon}{\alpha}}\Delta_{t-1} = 1$$	(EQ.17)
$$TB_t = rer_t(Y^T - C_t^T)$$	(EQ.18)
$$rer_t.b_t^* = TB_t + \frac{rer_t}{\pi_t^*}R_{t-1}^* b_{t-1}^*$$	(EQ.19)
$$GDP_t = C_t + Y^T - C_t^T$$	(EQ.20)
$$p_t^Y.GDP_t = C_t + TB_t$$	(EQ.21)

Table A2: The Variance Decomposition

Variables	Foreign inflation shock	Monetary policy shock	World interest shock	Trade endowment shock
NER	87.33	0.21	11.26	1.19
Inflation	66.65	0.59	28.25	4.51
Interest Rate	68.21	0.88	28.39	2.52
Non traded Consumption	52.97	2.36	41.84	2.84
Non traded price	63.43	0	24.97	11.59
Traded consumption	63.43	0	24.98	11.59
Traded price	70.61	0.48	26.14	2.77
RER	63.43	0	24.97	11.59
GDP	13.87	0.62	10.96	74.55
Trade Balance	63.43	0	24.98	11.59
Shocks				
Trade endowment shock	0	0	0	100
Foreign inflation shock	100	0	0	0
Monetary policy shock	0	100	0	0
World interest shock	0	0	100	0

Table A3: Theoretical moments of select endogenous variables:

VARIABLE	MEAN	STD. DEV.	VARIANCE
NER	0.0074	0.0460	0.0021
Inflation	0.0074	0.0082	0.0001
Interest rate	0.0385	0.0119	0.0001
Non traded consumption	-0.5199	0.0056	0
Non traded price	0	0.2857	0.0816
Traded consumption	-1.5658	0.5495	0.3019
Traded good price	0.0074	0.0302	0.0009
RER	0	0.8132	0.6613
GDP	-0.1675	0.0076	0.0001
Trade Balance	0.0423	0.1492	0.0223
Foreign inflation shock	0	0.0199	0.0004
Monetary policy shock	0	0.0020	0
World interest shock	0.0311	0.0039	0
Trade endowment shock	-1.3815	0.0230	0.0005