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Abstract

This paper compares alternative monetary policy rules in a model of an emerging market economy that experiences external shocks to world interest rates and the terms of trade. The model is a two-sector dynamic open economy, with endogenous capital accumulation and slow price adjustment. Two key factors are highlighted in examining the response of the economy to shocks, and in the assessment of the effectiveness of monetary rules. These are: a) balance-sheet related financial frictions in capital formation; and b) delayed pass-through of changes in exchange rates to imported goods prices. We find that, while financial frictions cause a magnification of real and financial volatility, they have no effect on the comparison or ranking of alternative monetary policies. But the degree of exchange rate pass-through is very important for the assessment of monetary rules. With high pass-through, there is a trade-off between between real stability (in output or employment) and inflation stability. Moreover, the best monetary policy rule in this case is to stabilise non-traded goods prices. But, with delayed pass-through, the same trade off between real stability and inflation stability disappears, and the best monetary policy rule is CPI price stability.

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1 Introduction

Since the financial crises over the last decade, there has been great interest in the design of monetary policies for emerging market economies. Should these economies attempt to peg their exchange rates to the US dollar via currency boards or dollarisation, or should they allow the exchange rates to float and follow instead a domestically oriented monetary policy geared towards inflation targeting, following the recent example of many western economies? Moreover, how do the institutional features of each economy, in particular the structure of goods and financial markets, affect this comparison?

This paper develops a simple modelling framework that can be used to evaluate alternative monetary policy rules for emerging market economies. We ask in particular how important is exchange rate flexibility in implementing such rules. The model is specialised towards the emerging market environment in a number of ways. The economy is small and open, and is subject to external real interest rate and terms of trade shocks that are calibrated from the historical experience of Asian economies. In addition, we focus on the structural characteristics of emerging market economies that may make them more vulnerable to external shocks. Two such features are; constraints on the financing of investment through external borrowing, and the speed by which exchange rate shocks feed through to the domestic price level.

What is the appropriate monetary policy for an emerging market, given these structural characteristics and the pattern of external shocks? Much of the literature on emerging market crises has focused on inconsistencies in policy making, and problems of credibility in monetary and fiscal policy. By contrast, our paper does not investigate the credibility of monetary policies, or the interaction between political constraints and macroeconomic policies. Rather, we assume that all monetary policies are equally credible, and simply investigate the properties of alternative rules in terms of economic stabilisation and welfare.

The presence of financial market imperfections in capital inflows to emerging markets has received widespread attention in the last few years. An important theme in this literature is the moral hazard problem associated with investment financing in these countries, where contracts may be less enforceable than in Western economies. Accordingly, we explore the role of collateral constraints in investment financing for emerging markets, following the work of Bernanke, Gertler, and Gilchrist (1999) [hereafter BGG] and Carlstrom and Fuerst (1997). In particular, as emphasised by Krugman (1999), Aghion, Bacchetta and Banerjee (2001) and others, emerging market borrowers may find that interest rate and exchange rate fluctuations have large effects on their real net worth position, and so, through balance sheet constraints affecting investment spending, have much more serious macroeconomic consequences than for richer industrial economies. Our interest is in how these features affect the choice of monetary rules. For instance, it is suggested by Eichengreen and Hausmann (2003) and Calvo (1999) that emerging market economies may be much more reluctant to allow freely floating exchange rates due to the problem of 'liability dollarisation' in the presence of balance sheet constraints on external borrowing.[1]

A second important feature of emerging markets is the degree to which their price levels are sensitive to fluctuations in exchange rates. As emphasised by Calvo and Reinhart (2002), exchange rate shocks in emerging market economies tend to feed into aggregate inflation at a much faster rate than in industrial economies. Empirical evidence by Choudri and Hakura (2002) and Devereux and Yetman (2003) supports this view. This is likely to influence: a) what monetary policy rule should be used to adjust to external shocks; and b) how important is exchange rate adjustment as part of this rule.

While the difference in rates of pass-through may be partly due to historical features related to the conduct of monetary policy, we simply focus on whether and how this difference affects the choice of monetary policy. We compare three different types of monetary rules, a fixed exchange rate rule, and two types of inflation targeting rules. While a fixed exchange rate is a well-defined rule for a small economy, there is an infinite variety of different types of 'floating' exchange rates. We restrict our attention to two important rules: a policy of CPI inflation targeting (denoted the CPI rule hereafter), and a policy of targeting inflation in a subset of the CPI consisting of non-traded goods prices (denoted the NTP rule hereafter). The latter rule is a natural one in this context because it closely parallels the optimal rule of 'price stability' that falls out of many recent closed-economy sticky-price models (e.g. King and Wolman 1998, Woodford 2003).

Our approach is to first describe the response of the economy to the different external shocks under the various rules. Following this, we compute the overall volatility properties under alternative rules when the shock processes are calibrated to historical observations from Asian countries. Finally, we offer a welfare ranking of the alternative rules, computing an approximation to expected utility from a second-order accurate solution to the DSGE model.

[1] Calvo and Mishkin (2003) argue that the choice of exchange rate regime may be less relevant than institutional reform.

[2].

While we focus on two types of shocks that are especially important for emerging markets (disturbances to interest rates and the terms of trade), it turns out that our results regarding optimal monetary rules do not really depend on the source of shocks. In addition, echoing Cespedes, Chang and Velasco (2002a, 2002b) and Gertler, Gilchrist and Natalucci (2001) in quite different settings, we find that external financing constraints have essentially no implications for the ranking of monetary rules. While balance sheet constraints in the presence of liability dollarisation is an important propagation channel, it essentially generates a magnification effect in response to all shocks, leading both real and financial volatility to be greater than in an economy without these constraints. But balance sheet constraints do not alter the ranking of alternative monetary policy rules in welfare terms.[3]

On the other hand, the degree of exchange rate pass-through is an important factor in the welfare ranking of monetary policies. We find that the NTP rule is the best policy in an economy that exhibits high exchange rate pass-through. This is true whether or not there exist financial constraints on capital accumulation. With high pass-through, both fixed exchange rates and the CPI rule tends to stabilise inflation and exchange rates at the expense of substantial volatility in the real economy. In this case, there is a clear trade-off between real stability (of output and employment) and inflation stability (as well as nominal and real exchange rate stability). But in welfare terms, the NTP rule is the most desirable. It ensures that the economy responds in a manner equivalent to that of a fully flexible price economy.

In the environment of low exchange rate pass-through, however, our results are quite different. In this case, a policy of stabilising the CPI rather than stabilising the non-traded goods price is more desirable in welfare terms. With low pass-through, the prices of all goods in the consumption basket (both traded and non-traded) respond sluggishly to shocks, and it is more efficient for the monetary authority to target the overall CPI rather than just the non-traded component. In a low pass-through environment, the policy maker can simultaneously strictly target (CPI) inflation, but still allow high nominal exchange rate volatility in order to stabilise the real economy in face of external shocks. The low rate of pass-through ensures that

[2]To obtain this approximation, we employ the MATLAB codes of Schmitt-Grohe and Uribe (2004a)

[3]The result of Cespedes et al. contrast with those of Cook (2003) and Choi and Cook (2003). They show that the nature of the financial and banking system can alter the properties of exchange rate regimes when balance sheet constraints are binding, making fixed exchange rates look appealing. They do not derive a utility comparison across regimes however, as is done in this paper. We focus on the financial structure developed in BGG.

exchange rate shocks do not destabilise the price level.

When pass-through is very low, the exchange rate no longer acts as an 'expenditure-switching' device, altering the relative price of home and foreign goods. Thus we might imagine that exchange rate movement is no longer desirable. In fact, the exchange rate remains important in stabilising demand, by cushioning the effective real interest rate faced by consumers and firms.

An important feature of low pass-through is that it eliminates the trade-off between output volatility and inflation volatility in the comparison of fixed relative to floating exchange rates. By following a price stability rule (either CPI or NTP rule), the policy-maker can do better than a fixed exchange rate on both counts; both output volatility and inflation volatility may be lower than under a fixed exchange rate. Our results therefore suggest that the nature of the policy trade-off critically depends on the degree of exchange rate pass-through. On a welfare basis however, we find that the rate of pass-through does not affect the ranking of 'fixed versus flexible' exchange rate regimes. Given the structure of our model, we find that the policy maker would always want the exchange rate to be flexible.

Although our model does give a clear ranking of alternative monetary policies, we find (in line with much previous literature) that the welfare differences between policies are very small, when calibrated on Asian data and shock processes.[4]

The paper is organised as follows. Section 2 sets out the model. Section 3 discusses calibration and the solution of the model. Section 4 develops the main results. Some conclusions follow.

2 Monetary Policy in a Small Open Economy

2.1 Outline of the model

We construct a two-sector model of a small open economy. Two goods are produced: a non-traded good and an export good, which has a price fixed on world markets. Domestic agents consume the non-traded good and a foreign import good. The model exhibits the following three features: a) nominal rigidities, in the form of costs of price adjustment for non-traded goods firms; b) lending constraints on investment financing (in each sector), combined with the

[4] That said, we do not attempt to model the possible links between monetary policies and financial crises. Allowing for this could affect the welfare calculations. Moreover, our calibration is based on average condition over a long data interval. The differences between policies would be large during 'extreme' conditions.

requirement that investment borrowing is done in foreign currency; and c) slow pass-through of exchange rate changes into imported good prices.

Nominal rigidities are introduced in order to motivate a role for monetary policy. The presence of borrowing constraints on investment is motivated by the evidence on the importance of 'balance sheet constraints' in emerging market economies, in particular during the Mexican and Asian crises (e.g. Calvo 1999, Krugman 1999, and Eichengreen and Hausmann 2003). Finally, there is increasing evidence of delayed pass-through of exchange rates to consumer prices. It is well established from Engel (1999) that deviations from the law of one price are a major factor in determining real exchange rates. Nevertheless, there are significant differences across countries in the speed with which exchange rates pass-through to import and consumer prices (see Choudri and Hakura 2002, and Devereux and Yetman 2003). Accordingly, we consider alternative speeds of adjustment of import prices to exchange rate movements.

There are four sets of domestic actors in the model: consumers, firms, entrepreneurs, and the monetary authority. In addition, there is a 'rest of world' sector where foreign-currency prices of export and import goods are set, and where lending rates are determined. Figure A1 describes a flow chart of the structure of goods and assets markets in the economy. Foreign lenders write contracts with entrepreneurs for investment financing, and domestic households borrow or lend on international financial markets. Production firms in the two sectors hire labour from consumer-households and entrepreneurs, rent 'finished' capital from entrepreneurs, and sell goods to domestic residents and foreign importers. Competitive firms use capital as well as investment to produce 'unfinished capital goods' (incurring the adjustment costs of transforming investment into capital), which are then sold to entrepreneurs. In addition, importing firms buy foreign import goods and sell to the domestic market. The monetary authority sets nominal interest rates.

As a comparison, we will also examine a more standard economy, without financial frictions, where investment is done by domestic households.

2.2 Consumers

There is a continuum of consumer/households of measure one. The representative consumer has preferences given by

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \eta \frac{H_t^{1+\psi}}{1+\psi} \right) \tag{2.1}$$

where C_t is a composite consumption index, and H_t is labour supply . Composite consumption is a CES function of consumption of non-traded goods and an import good, where $C_t = (a^{\frac{1}{\rho}} C_{Nt}^{\frac{\rho-1}{\rho}} + (1-a)^{\frac{1}{\rho}} C_{Mt}^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}$, where $\rho > 0$. The implied consumer price index is then $P_t = (aP_{Nt}^{1-\rho} + (1-a)P_{Mt}^{1-\rho})^{\frac{1}{1-\rho}}$, with P_{Nt} (P_{Mt}) defined as the time t price of the non-traded (import) good. Since we wish to introduce nominal price setting in the non-traded goods sector, we must allow for imperfect competition in that sector. The consumption of both non-traded and import goods is differentiated, with elasticity of substitution across varieties equal to λ, so that for non-traded goods, $C_{Nt} = (\int_0^1 C_{Nt}(i)^{\frac{\lambda-1}{\lambda}} di)^{\frac{\lambda}{\lambda-1}}$, with $\lambda > 1$.

Households may borrow and lend in the form of non state-contingent bonds that are denominated in either domestic or foreign currency. Trade in foreign currency bonds is subject to small portfolio adjustment costs. If the household borrows an amount D_t, then these portfolio adjustment costs are $\frac{\psi_D}{2}(D_{t+1} - \bar{D})^2$ (denominated in the composite good), where $\bar{D}$ is an exogenous steady state level of net foreign debt.[5] The household can borrow directly in terms of foreign currency at a given interest rate i_t^* , or in domestic currency assets at an interest rate i_t. The consumer credit market is not subject to informational frictions. [6]

Households own all home production firms and therefore receive the profits on these firms. Since firms producing export goods and unfinished capital goods are perfectly competitive, profits in these sectors are zero. But profits are earned by monopoly firms in the non-traded sector. A consumer's revenue flow in any period then comes from the supply of hours of work to firms for wages W_t, profits from the non traded and importing good sector Π_t, less debt repayment from last period $(1 + i_t^*)S_t D_t + (1 + i_t)B_t$, as well as portfolio adjustment costs. Here S_t is the nominal exchange rate, D_t is the outstanding amount of foreign-currency debt, and B_t is the stock of domestic currency debt. The household then obtains new loans from the domestic and/or international capital market, and uses these to consume. Her budget constraint is thus

$$P_t C_t = W_t H_t + T_t + \Pi_t + S_t D_{t+1} + B_{t+1} - P_t \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 - (1 + i_t^*)S_t D_t - (1 + i_t)B_t \quad (2.2)$$

The household will choose non-traded and imported goods to minimise expenditure conditional

[5]As in Schmitt-Grohe and Uribe (2003), these portfolio adjustment costs eliminate the unit root in the economy's net foreign assets.

[6]We follow the majority of papers in this literature by assuming away any collateral constraints for consumer borrowing (e.g. BGG, Carlstrom and Fuerst (1997), Gertler, Gilchrist and Natalluci, Choi and Cook (2002), and Cook (2003)). Cespedes, Chang and Velasco (2002a,b) by contrast assume that households have to consume their current earnings, without any access to capital markets.

on total composite demand. Demand for non-traded and imported goods is then

$$C_{Nt} = a(\frac{P_{Nt}}{P_t})^{-\rho} C_t \tag{2.3}$$

$$C_{Mt} = (1-a)(\frac{P_{Mt}}{P_t})^{-\rho} C_t \tag{2.4}$$

The household optimum can be characterised by the following conditions.

$$\frac{1}{1+i^*_{t+1}}\left[1 - \frac{\psi_D P_t}{S_t}(D_{t+1} - \bar{D})\right] = \beta E_t \left\{ \frac{C_t^\sigma P_t}{C_{t+1}^\sigma P_{t+1}} \frac{S_{t+1}}{S_t} \right\} \tag{2.5}$$

$$\frac{1}{1+i_{t+1}} = \beta E_t \left(\frac{C_t^\sigma P_t}{C_{t+1}^\sigma P_{t+1}} \right) \tag{2.6}$$

$$W_t = \eta H_t^\psi P_t C_t^\sigma \tag{2.7}$$

Equation 2.5 and 2.6 represent the Euler equation for the purchase of foreign and domestic currency bonds. Equation 2.7 is the labour supply equation. The combination of equations 2.5 and 2.6 gives the representation of interest rate parity for this model.

2.3 Production Firms

The two final goods sectors differ in their production technologies. Both goods are produced by combining labour and capital. As in BGG, labour comes from both households and from entrepreneurs. Thus, in the non-traded sector, effective labour of firm i is defined as

$$L_{Nt}(i) = H_{Nt}(i)^\Omega H_{Nt}^e(i)^{1-\Omega} \tag{2.8}$$

where $H_{Nt}(i)$ is employment of household labour and $H_{Nt}^e(i)$ is employment of entrepreneur's labour. The overall production technology for a firm in the non-traded goods sector is then

$$Y_{Nt}(i) = A_N K_{Nt}(i)^\alpha L_{Nt}(i)^{1-\alpha} \tag{2.9}$$

where A_N is a productivity parameter. Exporters (all domestically-produced traded goods are exported) use the production function

$$Y_{Xt}(i) = A_X K_{Xt}(i)^\alpha L_{Xt}(i)^{1-\alpha} \tag{2.10}$$

Final goods firms in each sector hire labour and capital from consumers and entrepreneurs, and sell their output to consumers, entrepreneurs (for their consumption) and capital producing firms. Cost minimising behavior then implies the following equations

$$W_t = MC_{Nt}(1-\alpha)\Omega\frac{Y_{Nt}}{H_{Nt}} \tag{2.11}$$

$$W^e_{Nt} = MC_{Nt}(1-\alpha)(1-\Omega)\frac{Y_{Nt}}{H^e_{Nt}} \tag{2.12}$$

$$R_{Nt} = MC_{Nt}\alpha\frac{Y_{Nt}}{K_{Nt}} \tag{2.13}$$

$$W_t = P_{Xt}(1-\gamma)\Omega\frac{Y_{Xt}}{H_{Xt}} \tag{2.14}$$

$$W^e_{Xt} = P_{Xt}(1-\gamma)(1-\Omega)\frac{Y_{Xt}}{H^e_{Xt}} \tag{2.15}$$

$$R_{Xt} = P_{Xt}\gamma\frac{Y_{Xt}}{K_{Xt}} \tag{2.16}$$

Equations 2.11-2.13 describe the choice of employment of households and entrepreneurs and demand for capital which achieves cost minimisation in the non-traded goods sector, where MC_{Nt} denotes the marginal cost in that sector. Equations 2.14-2.16 characterise cost minimisation in the export good sector. Note that the price of the traded export good is P_{Xt}. Since the export sector is competitive, P_{Xt} represents the unit cost of production. Movements in this price, relative to the import price P_{Mt}, represent terms of trade fluctuations for the small economy.

There are adjustment costs of investment, so that the marginal return to investment in terms of capital goods is declining in the amount of investment undertaken, relative to the current capital stock. Capital stocks in the non-traded and export sectors evolve according to

$$K_{Nt+1} = [\frac{I_{Nt}}{K_{Nt}} - \frac{\psi_I}{2}(\frac{I_{Nt}}{K_{Nt}} - \delta)^2]K_{Nt} + (1-\delta)K_{Nt} \tag{2.17}$$

$$K_{Xt+1} = [\frac{I_{Xt}}{K_{Xt}} - \frac{\psi_I}{2}(\frac{I_{Xt}}{K_{Xt}} - \delta)^2)]K_{Xt} + (1-\delta)K_{Xt}. \tag{2.18}$$

Investment in new capital requires imports and non-traded goods in the same mix as the household's consumption basket. Thus, the nominal price of a unit of investment, in either sector, is P_t.

As described in Figure A1, competitive firms produce unfinished capital goods and sell them to entrepreneurs. We may think of these capital goods firms as combining investment (in the same composite as domestic consumption) and the existing capital stock to produce new unfinished capital goods using the production functions implicit in 2.17 and 2.18. For instance, in the non-traded sector, competitive capital producing firms will ensure that the price of capital sold to entrepreneurs is

$$Q_{Nt} = \frac{P_t}{1 - \psi_I(\frac{I_{Nt}}{K_{Nt}} - \delta)}. \tag{2.19}$$

This gives an implicit investment demand in each sector, depending on the sector specific 'Tobin's q'.[7].

2.4 Price setting

Firms in the non-traded sector set their prices as monopolistic competitors. We follow Rotemberg (1982) in assuming that each firm bears a small direct cost of price adjustment. As a result, firms will only adjust prices gradually in response to a shock to demand or marginal cost. Non-traded firms are owned by domestic households. Thus, a firm will maximise its expected profit stream, using the households discount factor. We define the discount factor as follows

$$\Gamma_{t+1} = \beta \frac{P_t C_t^{\sigma}}{P_{t+1} C_{t+1}^{\sigma}} \tag{2.20}$$

Using this, we may define the objective function of the non-tradable firm i as:

$$E_0 \sum_{t=0}^{\infty} \Gamma_t [P_{Nt}(i) Y_{Nt}(i) - MC_{Nt} Y_{Nt}(i) - P_t \frac{\psi_{P_N}}{2} (\frac{P_{Nt}(i) - P_{Nt-1}(i)}{P_{Nt}(i)})^2] \tag{2.21}$$

where $\Gamma_0 = 1$, $Y_{Nt}(i) = (\frac{P_{Nt}(i)}{P_{Nt}})^{-\lambda} Y_{Nt}$ represents total demand for firm i's non-traded product, and the third expression inside parentheses describes the cost of price change that is incurred by the firm.

Firm i chooses its price to maximise 2.21. Since all non-traded goods firms are alike, after imposing symmetry, we may write the optimal price setting equation as:

$$\begin{aligned} P_{Nt} \quad = \quad & \frac{\lambda}{\lambda - 1} MC_{Nt} - \frac{\psi_{P_N}}{\lambda - 1} \frac{P_t}{Y_{Nt}} \frac{P_{Nt}}{P_{Nt-1}} \left(\frac{P_{Nt}}{P_{Nt-1}} - 1 \right) + \\ & \frac{\psi_{P_N}}{\lambda - 1} E_t \left[\Gamma_{t+1} \frac{P_{t+1}}{Y_{Nt}} \frac{P_{Nt+1}}{P_{Nt}} \left(\frac{P_{Nt+1}}{P_{Nt}} - 1 \right) \right] \end{aligned} \tag{2.22}$$

[7] For example, in the non-traded sector, new capital is produced using the production function $G(I_N, K_N) = (\frac{I_N}{K_N} - \frac{\psi_I}{2}(\frac{I_N}{K_N} - \delta)^2)K_N$, and unfinished capital goods firms maximise profits, given by $Q_N(I_N, K_N) - PI_N - R_{KN}^G K_N$, where R_{KN}^G is the rental rate on non-tradeable capital in the unfinished goods capital sector - see the Appendix for details. Note that if there were no adjustment costs of accumulation, then capital producing firms would simply use final goods investment alone, and $Q = P$ would hold.

When the parameter ψ_{P_N} is zero, firms simply set price as a markup over marginal cost. In general, however, the non-traded goods price follows a dynamic adjustment process.

2.5 Local Currency Pricing

We assume that the law of one price must hold for export goods, so that

$$P_{Xt} = S_t P^*_{Xt}. \tag{2.23}$$

For import goods however, we allow for the possibility that there is some delay between movements in the exchange rate and the adjustment of imported goods prices. The assumption is that there is a set of monopolistic domestic importers (owned by home households) who purchase the foreign good at price $S_t P^*_{Mt}$, and then sell to the home market at price P_{Mt}. These importers face costs of price adjustment of the same form faced by the non-traded goods firms. Thus, the imported good price index for domestic consumers moves as

$$\begin{aligned} P_{Mt} &= \frac{\lambda}{\lambda-1} S_t P^*_{Mt} - \frac{\psi_{P_M}}{\lambda-1}\frac{P_t}{T_{Mt}}\frac{P_{Mt}}{P_{Mt-1}}\left(\frac{P_{Mt}}{P_{Mt-1}}-1\right) + \\ & \frac{\psi_{P_M}}{\lambda-1} E_t\left[\Gamma_{t+1}\frac{P_{t+1}}{T_{Mt}}\frac{P_{Mt+1}}{P_{Mt}}\left(\frac{P_{Mt+1}}{P_{Mt}}-1\right)\right] \end{aligned} \tag{2.24}$$

The interpretation of 2.24 is that monopolistic competitive importers wish to set the domestic price as a markup over the foreign price. But they incur quadratic price adjustment costs, and unless $\psi_{P_M} = 0$, they will move their price only gradually towards the desired price. We will use ψ_{P_M} as a parameter which governs the degree of exchange rate pass-through. The higher is ψ_{P_M}, the lower will be the rate of exchange rate pass-through into imported goods prices facing the domestic consumer.[8]

2.6 Entrepreneurs

Unfinished capital is transformed by entrepreneurs and sold to the final goods sector. But entrepreneurs must borrow in order to finance their investment. In modelling the actions of

[8] Note that the importing firm faces elasticity λ also, as we have assumed that the elasticity of substitution across types of imports is the same as that across types of non-traded goods. The problem of the importing firm may be described as maximising intertemporal profits, given by

$$E_0 \sum_{t=0}^{\infty} \Gamma_t \Big((P_{Mt}(i) - S_t P^*_{Mt}) T_{Mt}(i) - \frac{\psi_{P_M}}{2} P_t [\frac{P_{Mt}(i) - P_{Mt-1}(i)}{P_{Mt-1}(i)}]^2 \Big)$$

where $T_{Mt}(i) = (\frac{P_{Mt}(i)}{P_{Mt}})^{-\lambda} T_{Mt}$ is the demand for firm i's import good, and T_{Mt} is the total demand for imports of the domestic country.

entrepreneurs we follow the set-up of BGG, extending their closed- economy model of investment financing to the two-sector open economy. The details of the entrepreneurial sector and calibration of the external risk premium are set out fully in the Appendix. Here we give an intuitive account of the process.

Entrepreneurs borrow from foreign lenders, in order to finance their investment projects, which produce finished capital goods. But each project exhibits idiosyncratic productivity $\omega \in (0, \infty)$, drawn from a distribution $F(\omega)$, with pdf $f(\omega)$, and $E(\omega) = 1$. Productivity ω is observed by the entrepreneur, but can only be observed by the lender through costly monitoring. The borrowing arrangement between lenders and entrepreneurs is then constrained by the presence of private information. The optimal contract is a debt contract, which specifies a given amount of lending, and a state-dependent threshold level of entrepreneurial productivity $\bar{\omega}$. If the entrepreneur reports productivity exceeding the threshold, then a fixed payment $\bar{\omega}$ times the return on capital is made to the lender, and no monitoring takes place. But if reported productivity falls short of the threshold, then the lender monitors, incurring a monitoring cost μ times the value of the project, and receives the full residual amount of the project. The effect of this lending contract is to make borrowing more costly for entrepreneurs than financing investment out of internal resources. Moreover, the borrowing premium depends on the entrepreneur's net worth, relative to the total borrowing requirement.

There are two groups of entrepreneurs, one in each sector of the economy. Entrepreneurs borrow in foreign currency by assumption. [9] An entrepreneur j in the non-tradable sector wishing to invest K^j_{Nt+1} units of capital must pay nominal price $K^j_{Nt+1}Q_{Nt}$ to the unfinished capital good firm. Say that the entrepreneur begins with nominal net worth in domestic currency given by Z_{Nt+1} . Then she must borrow in foreign currency an amount given by

$$D^{e,j}_{t+1} = \frac{1}{S_t}(Q_{Nt}K^j_{Nt+1} - Z^j_{Nt+1}) \tag{2.25}$$

The total expected return on the investment is $E_t(R_{KNt+1}Q_{Nt}K_{Nt+1})$ (where R_{KNt+1} is defined below).

The optimal contract stipulates a cut-off value of the firm's productivity draw, $\bar{\omega}_{Nt+1}$, and an investment level, K_{Nt+1}. Under this contract structure, the entrepreneur receives an expected share $A(\bar{\omega}_{Nt+1})$, of the total return, and the lender receives share $B(\bar{\omega}_{Nt+1})$. In sum,

[9] Eichengreen and Hausmann (2003) provide ample evidence that borrowing in foreign currency is a constraint on most emerging economies. The reason for this constraint is a subject of ongoing research. See for instance Schneider and Tornell (2003).

$A(\bar{\omega}_{Nt+1}) + B(\bar{\omega}_{Nt+1}) = 1 - \phi_{N_{t+1}}$, where $\phi_{N_{t+1}}$ represents the expected cost of monitoring [10].

As shown in the Appendix, the first order conditions for the optimal contract can be arranged to obtain the following two equations:

$$\frac{E_t\left\{R_{KNt+1}\left[B(\bar{\omega}_{Nt+1})\frac{A'(\bar{\omega}_{Nt+1})}{B'(\bar{\omega}_{Nt+1})} - A(\bar{\omega}_{Nt+1})\right]\right\}}{E_t\left[\frac{A'(\bar{\omega}_{Nt+1})}{B'(\bar{\omega}_{Nt+1})}\frac{S_{t+1}}{S_t}\right]} = (1 + i^*_{t+1}) \tag{2.26}$$

$$\frac{R_{KNt+1}S_t}{S_{t+1}}B(\bar{\omega}_{Nt+1}) = (1 + i^*_{t+1})(1 - \frac{Z_{Nt+1}}{Q_{Nt}K_{Nt+1}}) \tag{2.27}$$

Equation 2.26 represents the relationship between the expected return on entrepreneurial investment in the non-traded sector, and the opportunity cost of investment. In the absence of private information (or with zero monitoring costs), the expected return would equal the opportunity cost of funds for the lender. But in general, the presence of moral hazard in the lending environment imposes an *external finance premium*, so that $E(R_{KNt+1}) \geq (1 + i^*_{t+1})E\frac{S_{t+1}}{S_t}$. The extent of this premium depends on the value of $\bar{\omega}_N$. The key feature of the BGG framework is that this premium is linked to the the amount borrowed. This relationship is seen in equation 2.27, which represents the participation constraint for the lender. The smaller is the entrepreneurs net worth Z_{Nt+1} relative to investment $Q_{Nt}K_{Nt+1}$, the more the entrepreneur must borrow. Equations 2.26 and 2.27 may then be used (see BGG, Appendix) to show that the external finance premium $\frac{E(R_{KNt+1})}{(1+i^*_{t+1})E\frac{S_{t+1}}{S_t}}$ is increasing in the *leverage ratio* $\frac{Q_{Nt}K_{Nt+1}}{Z_{Nt+1}}$. A fall in entrepreneurial net worth, (generated perhaps by a nominal exchange rate depreciation), will directly reduce investment, by raising the external finance premium, and increasing the cost of capital to the entrepreneur. This captures the 'financial accelerator' discussed by BGG.

How is entrepreneurial net worth determined? As in Carlstrom and Fuerst (1997) and BGG, the entrepreneurial sector must be designed so that entrepreneurs are always constrained by the need to borrow. The most simple way to allow for this is to assume that a new infusion of entrepreneurs arrives in every period, and a fraction of the existing stock of entrepreneurs randomly die, keeping the total population constant. In this way, entrepreneurs do not build up wealth to the extent that the borrowing constraint is non-binding.

At the beginning of each period, a non-defaulting entrepreneur j in the non-traded sector receives the return on investment $R_{Nt}Q_{Nt-1}K_{Nt}(j)(\omega_{Nt}(j) - \bar{\omega}_{Nt})$. Entrepreneurs die at any

[10] $A(\bar{\omega})$, $B(\bar{\omega})$ and ϕ_N may be written as follows; $A(\bar{\omega}) = \int_{\bar{\omega}}^{\infty} \omega f(\omega)d\omega - \bar{\omega}\int_{\bar{\omega}}^{\infty} f(\omega)d\omega$, $B(\bar{\omega}) = \bar{\omega}\int_{\bar{\omega}}^{\infty} f(\omega)d\omega + (1-\mu)\int_0^{\bar{\omega}} \omega f(\omega)d\omega$, $\phi_{Nt} = \mu\int_0^{\bar{\omega}} \omega f(\omega)d\omega$. It is straightforward to show that $A'(\bar{\omega}) \leq 0$, and $B'(\bar{\omega}) \geq 0$.

time period with probability $(1-\nu)$. They consume only in the period in which they die. Thus, at any given period, a fraction $(1-\nu)$ of the return on capital to entrepreneurs is consumed. Because entrepreneurial risk is i.i.d., the functional forms used here allow for aggregation, so that the mean return on capital in each sector is $R_{Nt}Q_{Nt-1}K_{Nt}A(\bar{\omega}_{Nt})$. Aggregate net worth is then determined by the unconsumed fraction of the return on capital, as well as wages earned by entrepreneurs working in the non-tradable sector. Thus,

$$Z_{Nt+1} = \nu R_{KNt}Q_{Nt-1}K_{Nt}A(\bar{\omega}_{Nt}) + W^e_{Nt} \tag{2.28}$$

Using the definition of $A(\bar{\omega})$ and the lender's participation constraint, we may rewrite this as

$$Z_{Nt+1} = \nu(1-\phi_{Nt})R_{KNt}Q_{Nt-1}K_{Nt} - \nu(1+i^*_t)\tfrac{S_t}{S_{t-1}}(Q_{Nt-1}K_{Nt} - Z_{Nt}) + W^e_{Nt} \tag{2.29}$$

Note that net worth depends negatively on the current exchange rate, since an unanticipated depreciation of the exchange rate raises the value of existing foreign currency liabilities for the firm. This adds a non-traditional mechanism for the evaluation of alternative exchange rate rules.

The details of the contract structure and net worth dynamics in the export sector are described in the identical way.

Finally, we may define the return to capital for entrepreneurs. Entrepreneurs rent their finished capital to both final goods firms, and also to firms who produce unfinished capital goods through investment and the use of existing capital (the production function for this is implicit in the adjustment cost technologies 2.17 and 2.18). The real return on capital is then written as the sum of the nominal rental rate on capital earned from final goods production firms, the rental rate earned from the unfinished capital goods firms, plus the value of the un-depreciated capital stock, divided by the original price of capital. Thus we write the rate of return as

$$R_{KNt+1} = \frac{1}{Q_{Nt}}\left(R_{Nt+1} + \left[1-\delta+\psi_I(\frac{I_{Nt+1}}{K_{Nt+1}}-\delta)\frac{I_{Nt+1}}{K_{Nt+1}} - \frac{\psi_I}{2}(\frac{I_{Nt+1}}{K_{Nt+1}}-\delta)^2\right]Q_{Nt+1}\right) \tag{2.30}$$

2.7 Monetary Policy Rules

The monetary authority uses a short-term interest rate as the monetary instrument. The general form of the interest rate rule used may be written as

$$1+i_{t+1}=\left(\frac{P_{Nt}}{P_{Nt-1}}\frac{1}{\bar{\pi}_n}\right)^{\mu_{\pi n}}\left(\frac{P_t}{[a(P_{Nt-1})^{1-\rho}+(1-a)(P_{Mt-1})^{1-\rho}]^{\frac{1}{1-\rho}}}\frac{1}{\bar{\pi}}\right)^{\mu_\pi}\left(\frac{S_t}{\bar{S}}\right)^{\mu_S}(1+\bar{i}) \tag{2.31}$$

The parameter μ_{π_n} allows the monetary authority to control the inflation rate in the non-traded goods sector around a target rate of $\bar{\pi}_n$. The parameter μ_π governs the degree to which the CPI inflation rate is targeted around the desired target of $\bar{\pi}$. Finally, μ_S controls the degree to which interest rates attempt to control variations in the exchange rate, around a target level of $\bar{S}$. We compare the properties of alternative exchange rate regimes under a variety of different assumptions regarding the values of these policy coefficients.[11]

2.8 Equilibrium

In each period, the non-traded goods market must clear. Thus, we have

$$\begin{aligned} Y_{Nt} &= a(\frac{P_{Nt}}{P_t})^{-\rho}[C_t+I_{Nt}+I_{Xt}+C_t^{Ne}+C_t^{Xe}+\frac{\psi_D}{2}(D_{t+1}-\bar{D})^2+ \\ &\quad \frac{\psi_{P_N}}{2}(\frac{P_{Nt}}{P_{Nt-1}}-1)^2+\frac{G_{Nt}K_{Nt}}{P_t}\phi_{Nt}+\frac{G_{Xt}K_{Xt}}{P_t}\phi_{Xt}+\frac{\phi_{P_M}}{2}[\frac{P_{Mt}-P_{Mt-1}}{P_{Mt-1}}]^2] \end{aligned} \tag{2.32}$$

Equation 2.32 indicates that demand for non-traded goods comes from household consumption, investment and the consumption of entrepreneurs. In addition, because portfolio adjustment costs, costs of price adjustment, and the costs of monitoring loans in each sector are represented in terms of the composite final good, part of these costs must be incurred in terms of non-traded goods. The demand for the import good T_{Mt} can be derived analogously (see Appendix).

The aggregate balance of payments condition for the economy may be derived by adding the budget constraint of the household and the entrepreneurs in each sector. We may write it as

$$\begin{aligned} &P_tC_t+P_tC_{Nt}^e+P_tC_{Xt}^e+P_t\frac{\psi_D}{2}(D_{t+1}-\bar{D})^2+S_t(1+i_t^*)(D_t+D_t^e) \\ &+P_t\frac{\psi_{P_N}}{2}\frac{(P_{Nt}-P_{Nt-1})^2}{P_{Nt-1}^2}+(\phi_{Nt}R_{Nt}K_{Nt}Q_{Nt-1}+\phi_{Xt}R_{Xt}K_{Xt}Q_{Xt-1}) \\ &+P_t(I_{Nt}+I_{Xt})=P_{Nt}Y_{Nt}+P_{Xt}Y_{Xt}+S_t(D_{t+1}+D_{t+1}^e)+\Pi_{Mt} \end{aligned} \tag{2.33}$$

This just says that total expenditures, which comprise of consumption of households, entrepreneurs in each sector, investment in each sector, bond adjustment costs, price adjustment costs, monitoring costs, and total foreign debt repayment (the sum of private and

[11] In each case, we set policy so that the equilibrium is determinate.

entrepreneurial debt), must equal total receipts, which are output of each sector, plus new net foreign borrowing, plus profits from the import sector, where we define the latter as $T_{Mt}(P_{Mt} - S_t P^*_{Mt}) - P_t \frac{\psi_{P_M}}{2}[\frac{(P_{Mt}-P_{Mt-1})}{P_{Mt-1}}]^2$ [12]

In addition, both the households and the entrepreneur labour market conditions must be satisfied:

$$H_{Xt} + H_{Nt} = H_t \tag{2.34}$$

$$H^e_{Xt} = 1 \tag{2.35}$$

$$H^e_{Nt} = 1 \tag{2.36}$$

2.9 Comparison economy without entrepreneurs

In order to explore the importance of financing constraints, we also solve the model under the more conventional assumptions about the financing of capital accumulation. In this economy, investment is done directly by households, and there are no entrepreneurs or external finance premium on investment.[13] This alters only the equations governing the household budget constraint and the Euler equation for the determination of sectoral capital. The Appendix outlines this economy in detail.

3 Calibration and Solution

We now derive a numerical solution for the model, by first calibrating and then simulating. The calibration of the model is somewhat more complicated than the usual dynamic general equilibrium framework, since the model has two production sectors and it involves parameters describing the entrepreneurial sector. The benchmark parameter choices for the model are described in Table 1. Some standard parameter values are those governing preferences. It is assumed that the inter-temporal elasticity of substitution in consumption is 0.5. This is within the range of the literature. Following Stockman and Tesar (1995), we set the elasticity of substitution between non-traded and imported goods in consumption to unity.[14] The elasticity

[12] We can further decompose 2.33 to show that expenditure at *world prices* must equal receipts at world prices, but to save on notation, we refrain from this.

[13] The dynamics of this economy are effectively identical to one where there exist entrepreneurs that finance investment, but information on their returns is public. Focusing on a model without entrepreneurs makes our results more comparable with previous literature, however.

[14] Mendoza (1994) uses a smaller value of 0.67. Using the lower value would not affect our results.

of labour supply is also set to unity, following Christiano, Eichenbaum, and Evans (1997). In addition, the elasticity of substitution between varieties of non-tradable goods determines the average price-cost mark-up in the non-tradable sector. We follow standard estimates from the literature in setting a 10 percent mark-up, so that $\lambda = 11$ (an identical value is assumed for the elasticity of substitution between varieties of imports).

Assuming that the small economy starts out in a steady state with zero consumption growth, the world interest rate must equal the rate of time preference. We set the world interest rate equal to 6 percent annually, an approximate number used in the macro-RBC literature, so that at the quarterly level, this implies a value of 0.985 for the discount factor. We set $\bar{D}$ so that steady state debt is 40 percent of GDP, approximately that for East Asian economies in the late 1990's.

The factor-intensity parameters are quite important in determining the dynamics of the model. In the short run, only labour is mobile between sectors, so the impact of interest rate and terms of trade shocks on output will depend on the labour intensity of the different sectors. For two Asian economies, Malaysia and Thailand, Cook and Devereux (2001) find that the non-traded sector is more labour intensive than the traded sector. Both country's estimates of sectoral wage shares are quite similar. Following these estimates, we set total share of labour in GDP to 52 percent, the labour share of traded goods (i.e. export) output to 30 percent, and the share of wages in non-traded output to 70 percent. In combination with the other parameters of the model, the parameter a, governing the share of non-traded goods in the CPI, determines the share of non-traded goods in GDP. Following the classification followed by De Gregorio et al. (1994), we found that the average share of non-traded goods in total GDP in Thailand was 54 percent over the period 1980-1998. Cook and Devereux (2001) find a similar figure for Malaysia. Given the other parameters, this implies a value of a equal to 0.55.

We follow BGG in setting ϕ_I so that the elasticity of Tobin's q with respect to the investment capital ratio is 0.3. With respect to the costs of portfolio adjustment, we follow the estimate of Schmitt-Grohe and Uribe (2003) to set $\psi_D = .0007$.

To determine the degree of nominal rigidity in the model, we set the parameter governing the cost of price adjustment, ψ_{P_N} so that, if the model were interpreted as being governed by the dynamics of the standard Calvo price adjustment process, all prices would adjust on average after 4 quarters. This follows the standard estimate used in the literature (e.g. Chari, Kehoe and McGratten 2000). To match this degree of price adjustment requires a value of $\psi_{P_N} = 120$. We consider two values for the import price pass-through variable, setting $\psi_{P_M} = 0$

and $\psi_{P_M} = 120$. The former represents the complete pass-through case; the latter implies the same degree of price stickiness in the import sector as governs the non-tradable good sector.

We follow BGG in choosing a steady state risk spread of 200 basis points. We set a leverage ratio of 3, higher than BGG (who use 2), but more consistent with the higher leverage observed in emerging market countries. In addition, we assume a bankruptcy cost parameter μ equal to 0.2, roughly mid-way between that of Carlstrom and Fuerst (1997) and BGG. Finally, given the other parameters chosen, the implied savings rate of entrepreneurs is 0.94.

We consider two types of external shock: a) shocks to the world interest rate, and b) terms of trade shocks. In the model, a) is represented by shocks to i_t^*, and b) is represented by shocks to $\frac{P_X^*}{P_M^*}$.

The general form of the interest rule in equation 2.31 allows for a variety of different types of monetary policy stances. We focus the investigation by limiting our analysis to three types of rules. The first rule is one whereby the monetary authorities target the inflation rate of non-traded goods prices (NTP rule), so that $\mu_{\pi_n} \rightarrow \infty$. This is analogous to the targeting of domestically-generated inflation that is analyzed in a number of recent papers (e.g. Benigno 2001). The general rationale for such a rule is that by adjusting the monetary instrument to prevent inflation in non-traded goods, it eliminates the need for non-traded goods producers to adjust their prices, so that their inability to quickly change prices becomes irrelevant. In the absence of other nominal rigidities or distortions, this policy would replicate the real response of the flexible price economy. We also analyze a CPI targeting rule (CPI rule), whereby the monetary authority targets the domestic consumer price index $\mu_\pi \rightarrow \infty$. This is motivated by the fact that the CPI is the most common index used in practice by those countries that follow a policy of explicit inflation targeting. With high exchange rate pass-through, the price stability rule is very similar to an exchange rate peg, while with delayed pass-through, it is closer to the non-traded goods price targeting. Finally, we analyze a simple fixed exchange rate $\mu_S \rightarrow \infty$, whereby the monetary authorities adjust interest rates so as to keep the nominal exchange rate from changing.

The model is solved numerically using a second order approximation to the true dynamic stochastic system, where the approximation is done around the non-stochastic steady state. It is necessary to use a second order approximation because we wish to compare alternative monetary rules in terms of welfare, where welfare is represented by the expected utility of households and entrepreneurs. As discussed by Woodford (2003) and Schmitt-Grohe and Uribe (2004), a second order accurate representation of expected utility can be obtained only through a second order representation of the underlying dynamic system, except in special cases. Hence, to evaluate expected utility, we use the method of Schmitt-Grohe and Uribe (2003) in computing a second order representation of the model. [15]

4 External shocks under alternative monetary rules

Here we explore the impact of shocks under the three alternative monetary rules. In order to illustrate the workings of the model, we assume that both shocks may be described as AR(1) processes with persistence 0.46 and 0.77, for the interest rate and terms of trade shock respectively. This corresponds quite closely to our empirical estimates for Asia, discussed below.

The Figures show alternatively how the collateral constraints and the speed of exchange rate pass-through determines the transmission of shocks to the economy. The illustrations are divided into categories of real variables (total output, employment, the trade balance, absorption, the real exchange rate, the real interest rate, and sectoral outputs), and those of nominal or financial variables (overall inflation, the nominal exchange rate, the nominal interest rate, and imported goods price inflation).

4.1 Interest Rate Shocks

Figures 1-3 illustrates the effect of a persistent shock to the world interest rate. Figures 1 and 2 show the impact of the shock without and with the presence of financing constraints respectively, under complete pass-through in import prices (i.e. assuming that $\phi_{P_M} = 0$). We subsequently allow for incomplete pass-through in Figure 3.

The unanticipated rise in the cost of external borrowing leads first to a fall in total absorption, so that both private consumption and investment fall. The fall in absorption causes a fall in demand for non-traded goods, leading to a real exchange rate depreciation. Non-traded output falls, while output in the export sector will rise, and the economy experiences an increase in the trade surplus. In principle, the impact of the interest rate spike on output is ambiguous, since total output is a combination of non-traded and export sector output. As Figure 1 shows, the output impact of the interest rate shock depends critically on the monetary rule. The NTP rule involves an expansionary monetary policy, since the fall in demand tends

[15] Our solution is obtained using Schmitt-Grohe and Uribe's MATLAB code, available at $http://www.econ.duke.edu/\%7Euribe/2nd_order.htm$.

to generate a deflation in the non-traded goods sector, and in order to prevent the pressure for non-traded goods prices to fall, monetary policy must be expansionary. The NTP rule in this case in fact sustains the flexible-price response of the economy. Aggregate output and employment expand slightly under this rule. Note also however that the NTP rule requires a very large nominal exchange rate depreciation, followed by an appreciation. Due to high exchange rate pass-through, this means a large initial burst of inflation.

The mechanism by which this stabilises GDP is seen in Figure 1. The immediate but temporary rise in the nominal exchange rate leads to a cushioning of the nominal and real interest rate from the full effects of the rise in foreign borrowing. The domestic real interest rate rises by less than half of the rise in the foreign interest rate. This is because at the date of the shock, the real exchange rate is expected to appreciate, following the initial large depreciation. By reducing the net increase in the real interest rate, the expected real appreciation cushions the impact of the shock on absorption, demand, and GDP.

Under the other two policy rules, however, the interest rate shock tends to be highly contractionary. Moreover, the exchange rate peg and the inflation target have almost the same implications. Both rules must act so as to prevent a nominal exchange rate depreciation; the fixed exchange rate rule does this by design, while the CPI rule does so because in order to stabilise the CPI in face of sticky non-traded goods prices, the policy must essentially stabilise the exchange rate. By preventing an immediate real exchange rate depreciation, these policies prevent the cushioning of the shock on the real interest rate, and ensure that the full impact of the foreign real interest rate shock is passed through to the domestic economy. There is a much larger fall in absorption, output in the non-traded sector, and overall GDP. Now we see that total employment falls. On the other hand, the trade surplus is larger, because total absorption is less.

How does the presence of a collateral constraint in investment financing affect this conclusion? Figure 2 illustrates the impact of the same foreign interest rate shock in the model with entrepreneurs and investment financing constraints. The key effect of the financing constraints is to increase the downward shift of investment, and so overall absorption. This occurs because the higher borrowing costs reduce the value of existing capital for entrepreneurs in each sector, and also because the unanticipated real exchange rate depreciation raises the debt burden for entrepreneurs. Both channels reduce net worth, raising the effective cost of borrowing, and reducing investment by more than we see in the model without financing constraints. In the aggregate, the impact of the financing constraints is therefore to magnify the impact of the interest rate shock. Output and employment fall by more, and the trade balance increases by more, since the greater fall in absorption causes a sharper collapse in non-traded output, and traded goods output rises by more than the economy without financing constraints.

It follows that the role of financing constraints is to significantly increase the 'multiplier' effect of external shocks. But, from the figures, it is clear that the financing constraints have qualitatively no impact on the rankings of the alternative policy rules in terms of their impacts on the economy. The NTP rule still acts so as to cushion output from the interest shock. But the fixed exchange rate and CPI rule lead to a much greater response in real variables than the NTP rule. Hence, the ranking of alternative policies remains the same as in the economy without financing constraints.

Just as the impact of financing constraints is to increase the response of real aggregates, it also implies a magnified response of exchange rates and prices. The NTP rule requires a much higher response of the nominal and real exchange in the presence of financing constraints. As a result, the inflationary consequences of the NTP rule are significantly greater in the presence of financing constraints; the initial jump in both the exchange rate and the consumer price level after an interest rate shock is almost twice that of the economy without financing constraints.

The results so far are based on the assumption that exchange rate pass-through to imported goods prices is immediate. How does the presence of delayed pass-through affect the results? We now let $\psi_{P_M} = 120$, so that price adjustment of the imported good follows the same process as that of the non-tradable good. Figure 3 illustrates the response of the economy to an interest rate shock under delayed pass-through. Note that the response under the fixed exchange rate does not change, since with a fixed exchange rate the speed of import price response to exchange rate shocks is irrelevant. From a qualitative point of view, the slower exchange rate pass-through does not change the way in which the economy responds to interest rate shocks. It is still the case that absorption falls, the trade balance improves as resources are shifted into the export good sector, aggregate output falls, and there is a real exchange rate depreciation. This indicates that closing off the 'expenditure-switching' effect, by which exchange rate changes immediately affect the relative price of home to foreign goods, does not alter the qualitative dynamics of the economy.

Quantitatively, however, the presence of delayed pass-through has a big effect on the response to an interest rate shock. Moreover, it has important implications for the comparison of alternative monetary policy rules. The most significant feature of Figure 3, when compared with Figure 1, is that there is now a distinct difference between the performance of the CPI rule and a fixed exchange rate. When pass-through is instantaneous, a policy maker cannot stabilise CPI inflation without largely stabilising the exchange rate. But with delayed pass-through, this becomes possible. Under the CPI rule, there is a big initial depreciation in the nominal exchange rate, far larger than the exchange rate response when the same rule is applied under full pass-through. The result is that there is a substantial real depreciation, which allows the policy-maker to cushion the impact of the shock on the real interest rate. As a result, under a CPI rule, the fall in total absorption and GDP, and the rise in the trade balance is much less than in the case of immediate pass-through. The absence of pass-through therefore rationalises the use of strict inflation targeting in an emerging market, at least for dealing with shocks to the foreign interest rate. CPI targeting becomes much closer to the NTP policy rule.

The NTP rule, as before, acts so as to stabilise output, by generating substantial movements in the real exchange rate. Both policy rules (NTP and CPI) operate by actively employing the nominal exchange rate in order to stabilise the effective real interest rate. It is interesting to note here that, while the strict 'expenditure-switching' mechanism for the exchange rate is greatly diminished when there is delayed exchange rate pass-through (since nominal exchange rate changes no longer alter relative prices facing consumers and firms), there is still a critical role played by the exchange rate in controlling effective real interest rates. By altering the rate of expected real exchange rate depreciation, monetary policy stabilises the economy, even in the absence of pass-through.[16]

A corollary of these results is that the inflation output volatility trade-off is altered by the presence of delayed pass-through. With full pass-through, the policy of stabilising non-traded goods inflation cushions the impact of an interest rate shock on GDP. But this can only be done by allowing a large initial burst of inflation, following up the exchange rate depreciation. A fixed exchange rate, on the other hand, stabilises inflation, but de-stabilises GDP. Hence, the trade-off between fixed and flexible exchange rates (under an NTP rule) can be described as a trade-off between output volatility and inflation volatility. But Figure 3 now shows us that both GDP and inflation can be substantially stabilised simultaneously, using either CPI rule or an NTP rule. Indeed, we see from Figure 3 that the response of inflation under a fixed exchange rate is now in absolute terms as great as that under the non-traded inflation target rule. Thus, under delayed pass-through, fixing the exchange rate no longer ensures lower inflation volatility.

[16]An alternative perspective is to note that while the law of one price relationship no longer holds instantaneously, the interest rate parity relationship is still an important macroeconomic linkage.

4.2 Terms of Trade Shocks

Figures 4-6 illustrate the effect of a persistent negative shock to the terms of trade. In this model, a terms of trade shock is equivalent to a negative income shock coming from the export sector. This negative wealth effect leads to a decline in consumption and a rise in labour supply. Since it also equivalent to a negative productivity shock in the export sector, output and employment falls in that sector. Because the shock is transitory, the trade balance deteriorates. The implications for other aggregates depends on the policy being followed. Under the NTP policy, there is a fall in the nominal interest rate, which stimulates output in the non-traded goods sector. Under the other rules, interest rates rise, and output in non-traded goods either falls or rises much less than under the NTP rule.

As was the case for the interest rate shock, we see that the introduction of financing constraints (Figure 5) does not alter the qualitative pattern of responses to a terms of trade shock but just acts as an amplification device. But, as before also, incomplete pass-through in import prices significantly alters the relative performance of the alternative monetary rules: in particular, the CPI rule performs much better in terms of stabilising output. In addition, with incomplete pass-through, we observe much larger real exchange rate movements for the activist monetary regimes, but much smaller inflation volatility.

5 Overall Regime Evaluation

We now turn to an evaluation of the overall performance of alternative policy regimes in responding to external shocks. To obtain empirical variances, covariances and autocorrelations for the shock processes, we ran a quarterly VAR system over 1982.1 to 2000.3 for the US real interest rate and the terms of trade for the Asia region in the IMF's International Financial Statistics. The results are shown in Table 2 and indicate that there is a low correlation between shocks to the real interest rate and terms of trade. Both types of disturbance have similar variances but terms of trade shocks tend to be more persistent than interest rate shocks (autoregressive coefficients of 0.77 and 0.46 respectively).

Table 3 shows, for each of our three scenarios, the standard deviations of key macroeconomic variables when the model is driven by the shock processes estimated in the VAR exercise.

In case I (no finance constraints and full pass-through), the NTP rule delivers lower output volatility than the other rules. It is apparent that the big difference between the rules lies in the differences in the variability of investment. Since the NTP rule tends to stabilise real interest rates, the volatility of investment is reduced considerably under this policy. However, at the same time, this policy generates a higher volatility of inflation, the nominal exchange rate, and the real exchange rate than either the CPI rule or the fixed exchange rate. Moreover, the CPI rule is only slightly different in terms of volatility of output, consumption investment etc, from the fixed exchange rate. This is not surprising given the high rate of exchange rate pass-through in this case. Roughly speaking, we may summarise the results for this case by saying that the NTP rule delivers a higher volatility of financial variables (inflation and nominal exchange rates) relative to the other two policies, but a lower volatility of real variables (except for the real exchange rate). It may be shown that there is a negative trade-off between the standard deviation of GDP and the standard deviation of CPI inflation as the monetary policy moves from a rule of targeting inflation in the non-traded sector inflation to one of an exchange rate peg.

Comparing cases I and II (introducing financing constraints), the main difference is that output, employment, and investment are significantly more volatile in the economy with finance constraints. In addition, as suggested by the impulse response figures above, inflation and nominal/real exchange rate volatility is significantly higher in the finance-constrained economy. But the rankings of the rules are left unchanged; output, consumption and investment are all more stable with the NTP than under the CPI rule or the fixed exchange rate rule.

Case III illustrates the impact of incomplete pass-through. This has a dramatic effect on the workings of the monetary policy rules. Output volatility is lowered for the two types of inflation targeting rules. In addition, the CPI rule is much more stabilising from an overall perspective when pass-through is incomplete. Under this rule, output, consumption, and investment volatility are significantly lower than in the case of full pass-through. Real and nominal exchange rate volatility increases quite substantially when pass-through is delayed, for both types of inflation targeting. But the striking feature of this case is that the increase in exchange rate volatility occurs without a concomitant increase in inflation volatility. In fact, inflation volatility is now lower for the NTP rule than for the fixed exchange rate. In contrast to the case of full pass-through, it is possible to show that the presence of delayed pass-through may produce a *positive* relationship between output volatility and inflation volatility, as monetary policy moves from a policy of stabilising non-traded goods prices towards stabilising the nominal exchange rate.

5.1 Welfare Evaluation of Alternative Monetary Policy Rules

Table 3 also reports a welfare calculation of the costs of each monetary policy. The solution method produces a second order accurate measure of expected utility in each of the separate cases for monetary policy, pass-through, and financing constraints examined in the last subsection. Table 3 reports expected utility measures directly. In the model without entrepreneurs, expected utility is measured as

$$E_0 \sum_{t}^{\infty} \beta^t U(C_t, H_t) \tag{5.37}$$

In the model with entrepreneurs, the expected utility measure is amended to take account of the utility of entrepreneurs directly. Since entrepreneurs are risk neutral, derive utility only from consumption, and consume at any time period with probability $1 - \nu$, we can write the utility of entrepreneurs (given measure 1 of entrepreneurs in total) as

$$E_0 \sum_{t}^{\infty} \beta^t C_t^e \tag{5.38}$$

where we have assumed that the monetary authority discounts the utility of future entrepreneurs at the same rate that private households discount future utility.

The welfare results are consistent with the discussion above. In the economy without entrepreneurs and full pass-through, the NTP rule delivers highest utility. This is intuitive, since we know that the NTP rule implements the flexible price equilibrium in the model without entrepreneurs financing distortions. Next best is the CPI rule, while the fixed exchange rate rule is worst in welfare terms.

Introducing entrepreneurs and financing constraints, but maintaining full exchange rate pass-through does not alter the welfare rankings of the policies - again the NTP rule is best, the fixed exchange rate rule is worst, and the CPI rule is in between the two.

The presence of delayed pass-through does however alter the utility rankings of monetary policies. As suggested by the previous discussion, we find that with delayed pass-through (in the model without entrepreneurs) the CPI rule achieves higher expected utility than does the NTP rule. But the fixed exchange rate rule still has lower utility than the other two. Intuitively, when the import price responds slowly to exchange rates, it becomes more desirable to follow a monetary policy that tends to stabilise the CPI, which is an average of import and non-traded goods prices.

For completeness, Table 3 also documents that the welfare benefits of CPI targeting in an environment of delayed pass-through also hold in the economy subject to finance constraints.

5.2 Consumption equivalent comparisons

How important are the differences between policies? Our model, calibrated to the shocks inferred from Table 2, implies that the utility differences across regimes are very small. The last column of Table 3 gives a measure of the relative benefits of each policy. Following the method of Schmitt-Grohe and Uribe (2004b), we use the following welfare metric. Take first the model without entrepreneurs. Then for a given monetary policy r, expected utility is written as

$$V^r = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{r(1-\sigma)}}{1-\sigma} - \eta \frac{H_t^{r(1+\psi)}}{1+\psi} \right)$$

where we define C^r and H^r as the permanent(annuity) consumption and labour supply associate with regime r. That is,

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{r(1-\sigma)}}{1-\sigma} - \eta \frac{H_t^{r(1+\psi)}}{1+\psi} \right) = \sum_{t=0}^{\infty} \beta^t \left(\frac{C^{r(1-\sigma)}}{1-\sigma} - \eta \frac{H^{r(1+\psi)}}{1+\psi} \right) \quad (5.39)$$

We define ϵ as the fraction of permanent consumption that a consumer in an economy governed by monetary policy r would be willing to give up in order to make her indifferent between this and an economy governed by monetary policy s. Thus, ϵ is defined as

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{1-\sigma} - \eta \frac{H^{r(1+\psi)}}{1+\psi} \right) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C^{s(1-\sigma)}}{1-\sigma} - \eta \frac{H^{s(1+\psi)}}{1+\psi} \right) \quad (5.40)$$

In the economy with entrepreneurs and financing constraints, expected utility is the sum of the utility of households and the utility of entrepreneurs. We then characterise ϵ as the fraction of permanent consumption that must be offered *both* to households and entrepreneurs so as to make them indifferent between the two regimes. That is, regime ϵ is defined implicitly by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{1-\sigma} - \eta \frac{H^{r(1+\psi)}}{1+\psi} + (1-\epsilon) C_t^{re} \right)$$
$$= E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C^{s(1-\sigma)}}{1-\sigma} - \eta \frac{H^{s(1+\psi)}}{1+\psi} + C_t^{se} \right) \quad (5.41)$$

In the last column of Table 3, the values of ϵ are reported for each case. In the economy without entrepreneurs and full pass-through, the NTP rule dominates. Hence the value ϵ is positive for the comparison of the NTP rule with the CPI rule and with the fixed exchange rate rule. A value of $\epsilon = 1$ represents one percentage point of permanent consumption. Here we find that the the absolute size of ϵ is very small, even for a comparison with the fixed exchange rate regime. This is in line with previous literature that compares monetary rules in sticky price general equilibrium models (Bergin and Tchakarov 2003, Devereux Engel and Tille 2002)

For the economy with entrepreneurs and financing constraints, with full pass-through, again the NTP rule dominates. Now however the cost of moving to a CPI rule or a fixed exchange rate rule is substantially higher, although still less than a percentage point of permanent consumption at most (for the fixed exchange rate rule).

In the case of delayed pass-through, the CPI rule dominates, and the values of ϵ measure the consumption costs of moving from a CPI rule to either the NTP rule or to the fixed exchange rate. Again, as before, the cost is very small for the economy without entrepreneurs, and substantially larger for the economy with entrepreneurs and financing constraints.

6 Conclusions

This paper has conducted an investigation of exchange rate regimes and alternative monetary policy rules for an emerging market economy that is subject to a volatile external environment in the form of shocks to world interest rates and the terms of trade, and when the economy is constrained by external financing risk-premia associated with domestic net worth. One key finding is that degree of pass-through in import prices is central in determining the stabilisation properties of an inflation targeting regime. Accordingly, a high priority for (theoretical and empirical) research is to understand the determinants of the degree of pass-through. Here, candidate variables include the level of trend inflation, policy credibility, policy uncertainty and the competitive structure of goods markets. A second key finding is that financial distortions amplify external shocks but have little impact on the ranking of alternative policy regimes.

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Figure A1: Flow chart for the Economy

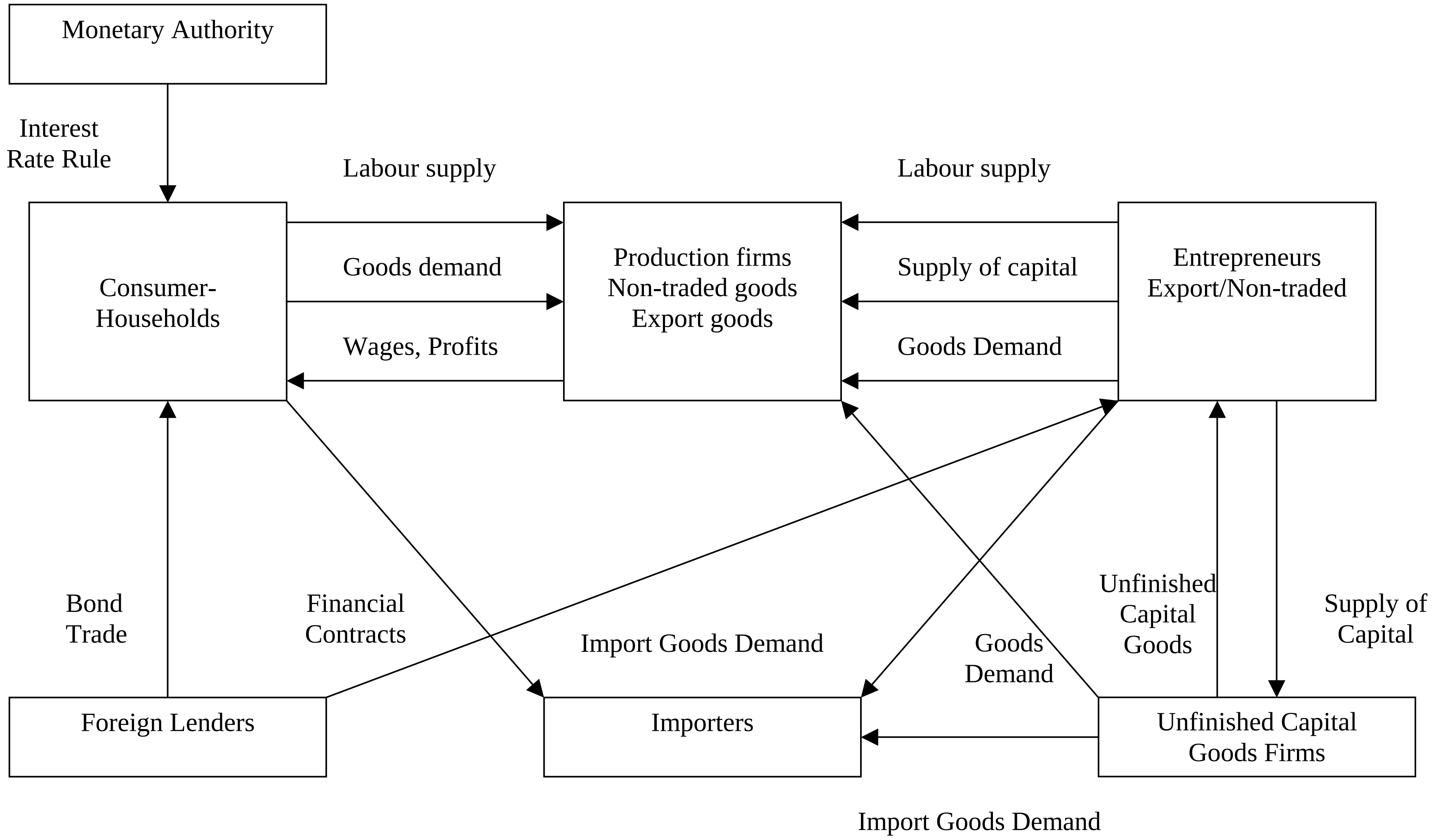


Table 1: **Calibration of the Model**

Parameter	Value	Description
σ	2	Inverse of elasticity of substitution in consumption
β	0.985	Discount factor (quarterly real interest rate is $\frac{1-\beta}{\beta}$)
ρ	1	Elasticity of substitution between non-traded goods and import goods in consumption
λ	11	Elasticity of substitution between varieties (same across sectors)
η	1.0	Coefficient on labour in utility
ψ	1.0	Elasticity of labour supply
γ	0.7	Share of capital in export sector
α	0.3	Share of capital in non-traded sector
δ	0.025	Quarterly rate of capital depreciation (same across sectors)
a	0.55	Share on non-traded goods in CPI
ψ_{P_N}	120	Price adjustment cost in the non-traded sector
ψ_I	12	Investment adjustment cost (same across sectors)
ψ_D	0.0007	Bond adjustment cost
σ_ω	0.5	Standard error of the technology shock of entrepreneurs
μ	0.2	Coefficient of monitoring cost for lenders
ν	0.94	Aggregate saving rate of entrepreneurs
Ω	0.95	Share of households' labour in the effective labor

Table 2: **VAR Results (Asia 1983.2-2000.3)**[a]

	Interest Rate	**Terms of Trade**
Interest Rate (−1)	0.46	−0.02
	(4.7)	(−0.26)
Terms of Trade (−1)	0.06	0.77
	(0.07)	(11.2)
Constant	−0.0007	−0.0006
	(−0.4)	(−0.5)
Adjusted R2	0.22	0.61
Variance (residual)	0.00015	0.00017
Correlation (residual)	0.042	

[a]Note: Quadratic-detrened quarterly data. Real interest rate is US prime lending rate minus US inflation. Terms of trade is Asian aggregate terms of trade. Source: IMF's *International Financial Statistics* CD-ROM.

Table 3: **Standard Deviations** [b]

	Output	**Cons**	**Inves**	**Labor**	**Real ER**	**Real IR**	**Inflation**	**Nom. ER**	**Nom. IR**	**Exp. Utility**	**Cons. Cost**
No Credit Constraint Case, Full Pass-through											
NTP	0.853	0.7573	2.6302	0.6698	0.9648	0.2956	0.5692	1.7442	0.082	−26.4423	0
CPI	0.9575	0.8437	3.153	0.7199	0.7777	0.5485	0	1.0266	0.5486	−26.4445	0.011
FER	1.0261	0.8888	3.3752	0.7966	0.7001	0.5678	0.249	0	0.6383	−26.448	0.0286
With Credit Constraint Case, Full Pass-through											
NTP	1.1024	1.336	5.6322	0.9731	1.9068	0.3129	1.0021	3.4468	0.2002	−28.8610	0
CPI	1.3377	1.4733	7.3475	1.2686	1.5359	0.6516	0	1.7964	0.6516	−28.8917	0.0763
FER	1.5012	1.5489	8.2006	1.5226	1.3588	0.6092	0.4622	0	0.6584	−28.9260	0.1614
No Credit Constraint Case, Delayed Pass-through											
NTP	0.8263	0.7422	2.8467	0.817	1.4343	0.1687	0.1302	1.8755	0.1146	−26.4467	0.0105
CPI	0.7947	0.7702	2.5967	0.7013	1.1835	0.2269	0	1.2503	0.2269	−26.4446	0
FER	1.026	0.8888	3.3746	0.7965	0.7002	0.5678	0.2491	0	0.6383	−26.448	0.0171
With Credit Constraint Case, Delayed Pass-through											
NTP	1.182	1.2974	3.1412	1.1493	2.7811	0.2091	0.242	3.6211	0.1755	−28.8848	0.0093
CPI	1.032	1.3422	4.567	1.0818	2.299	0.1487	0	2.3274	0.1488	−28.8811	0
FER	1.5011	1.5488	8.2	1.5226	1.3589	0.6091	0.4624	0	0.6584	−28.9260	0.1114

[b] Note: NTP refers to a monetary rule which keeps the non-traded goods inflation rate fixed. CPI refers to a monetary rule which keeps the CPI inflation rate fixed, and FER refers to a monetary rule which keeps the nominal exchange rate fixed. Variables are Output, Consumption, Investment, Hours, Real Exchange Rate, Real Interest Rate, CPI inflation, Nominal Exchange Rate, Nominal Interest Rate, Expected Utility and the Consumption Equivalent Welfare Measure.

Figure 1: **Impulse Response to i^*: No Financial Constraint, Full Pass-through**

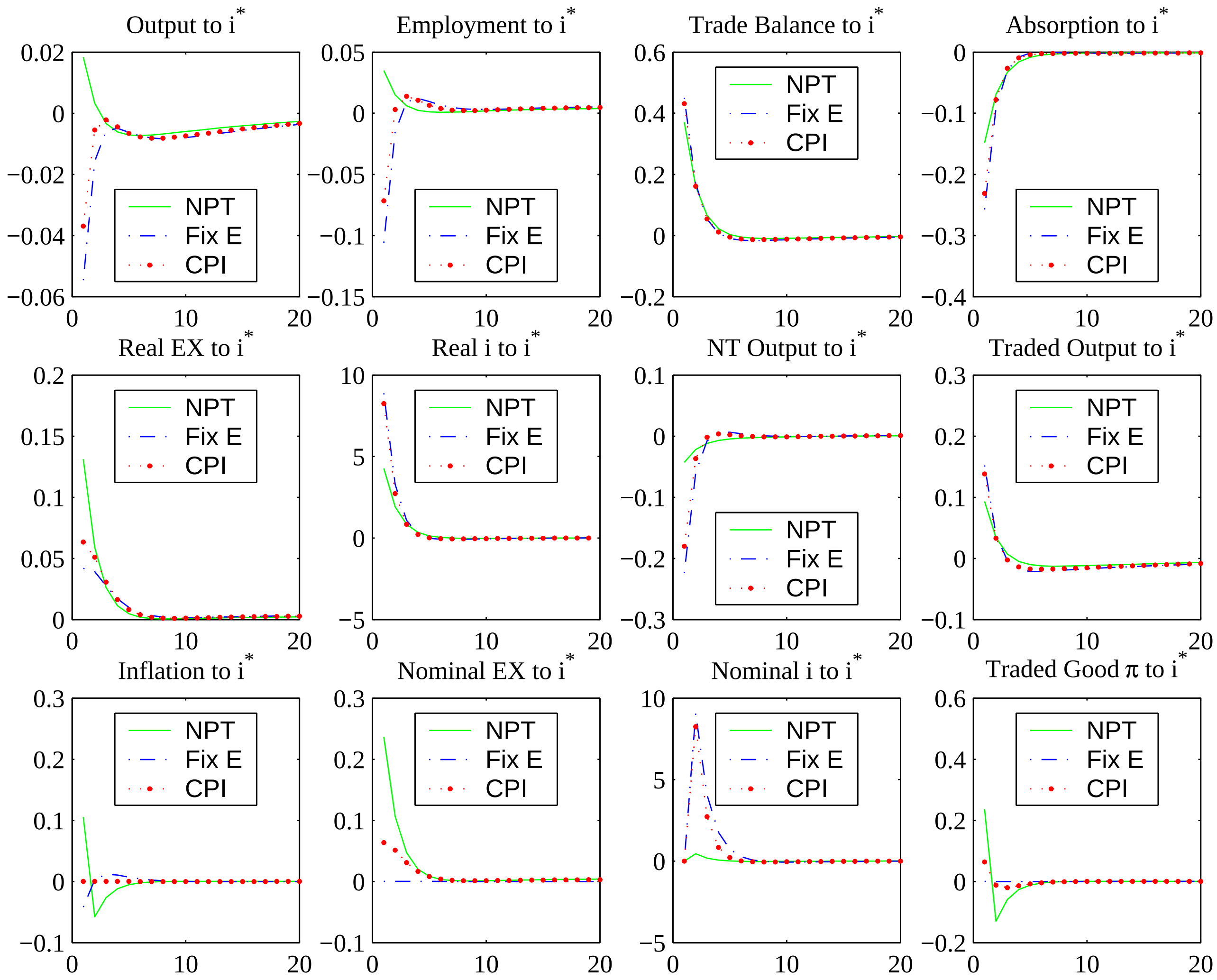


Figure 2: **Impulse Response to i^*: With Financial Constraint, Full Pass-through**

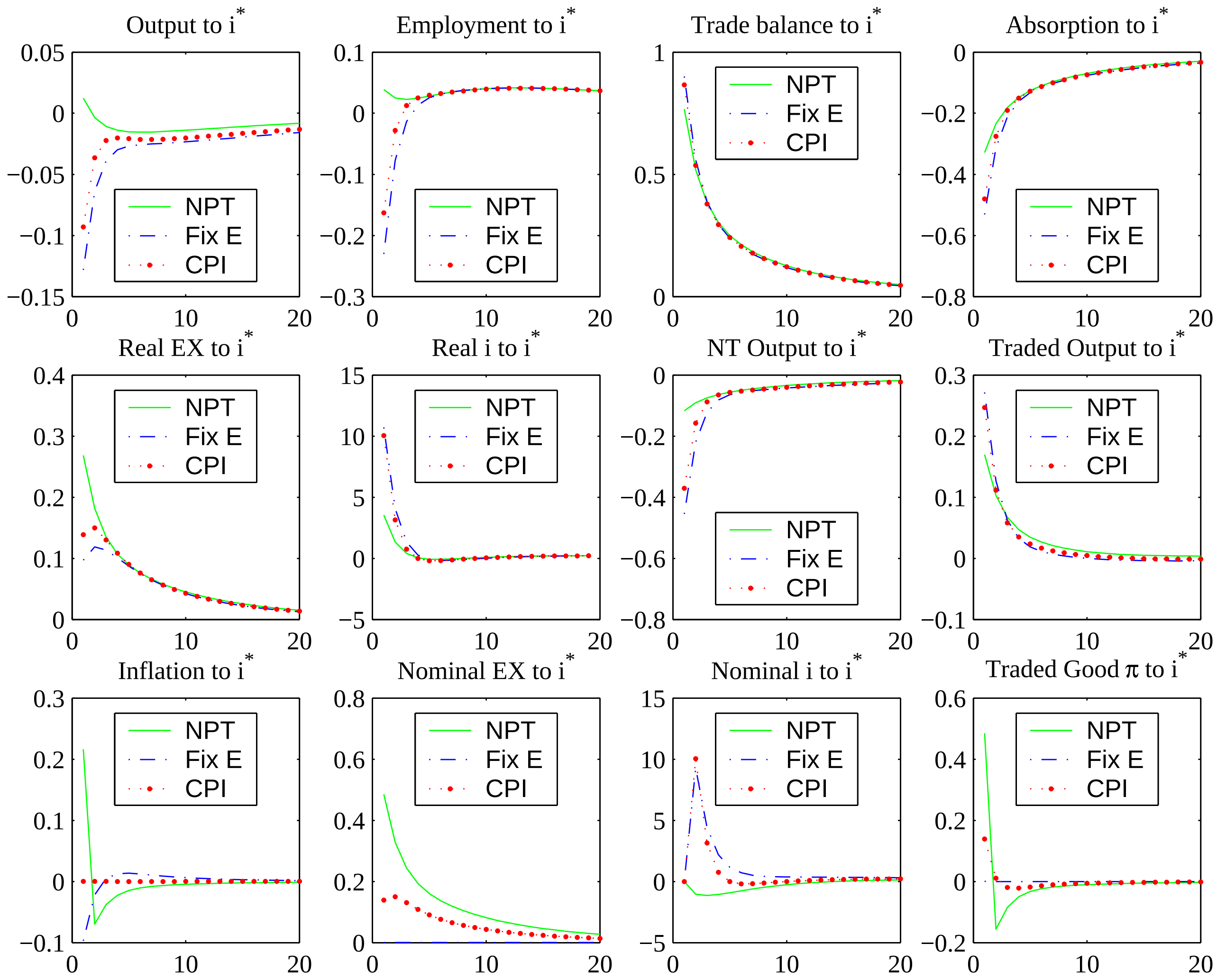


Figure 3: **Impulse Response to i^*: No Financial Constraint, Delayed Pass-through**

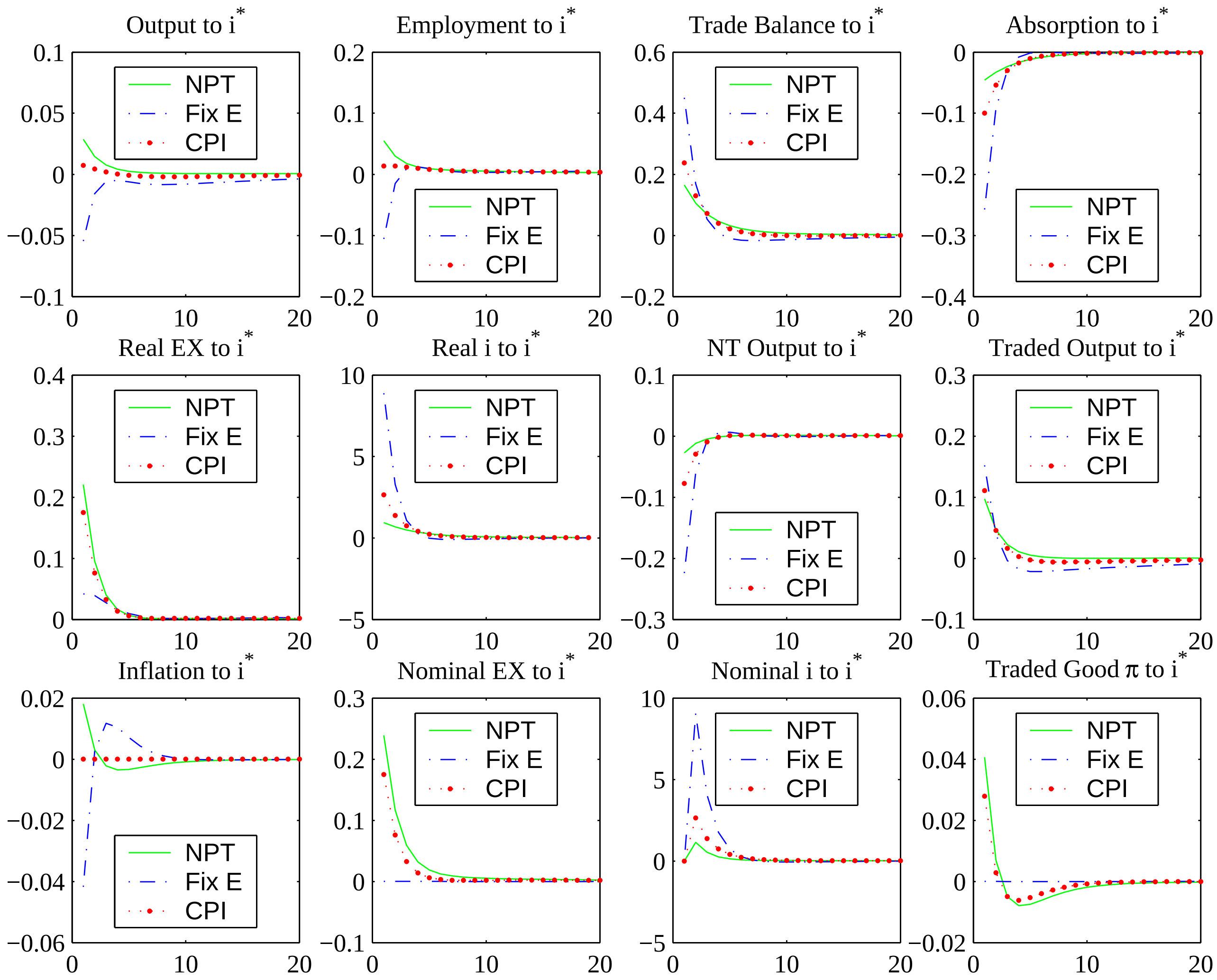


Figure 4: **Impulse Response to -TOT: No Financial Constraint, Full Pass-through**

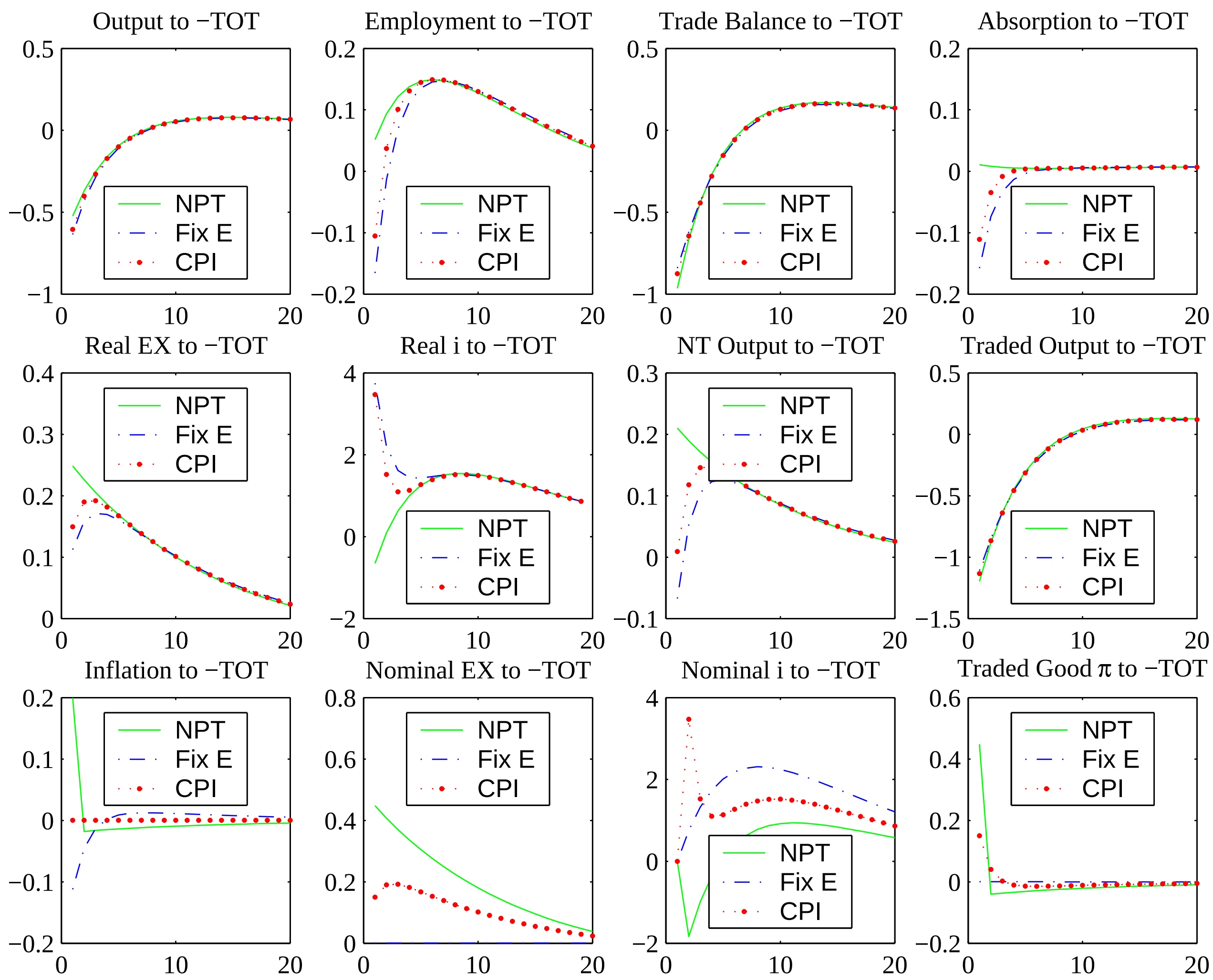


Figure 5: **Impulse Response to -TOT: With Financial Constraint, Full Pass-through**

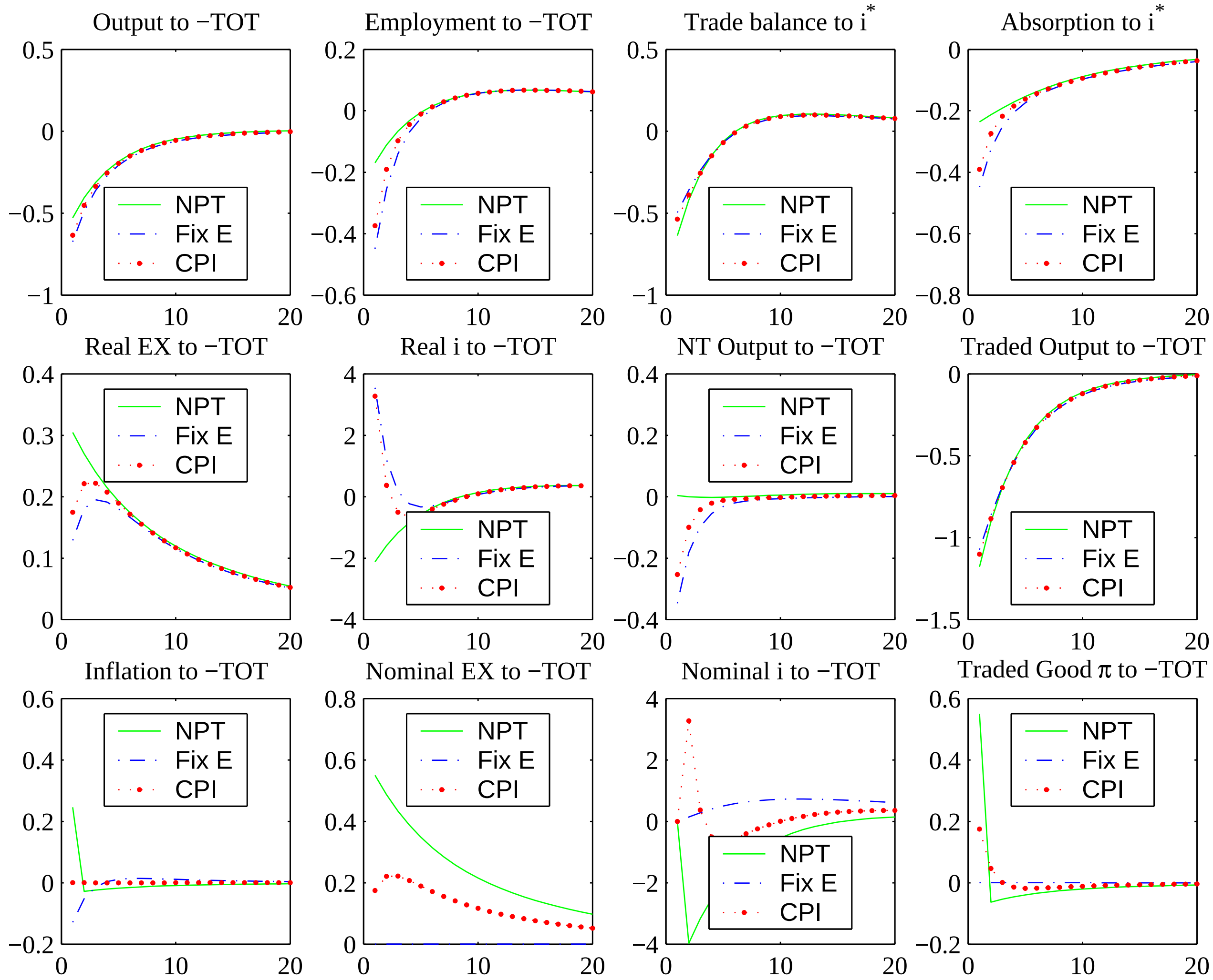
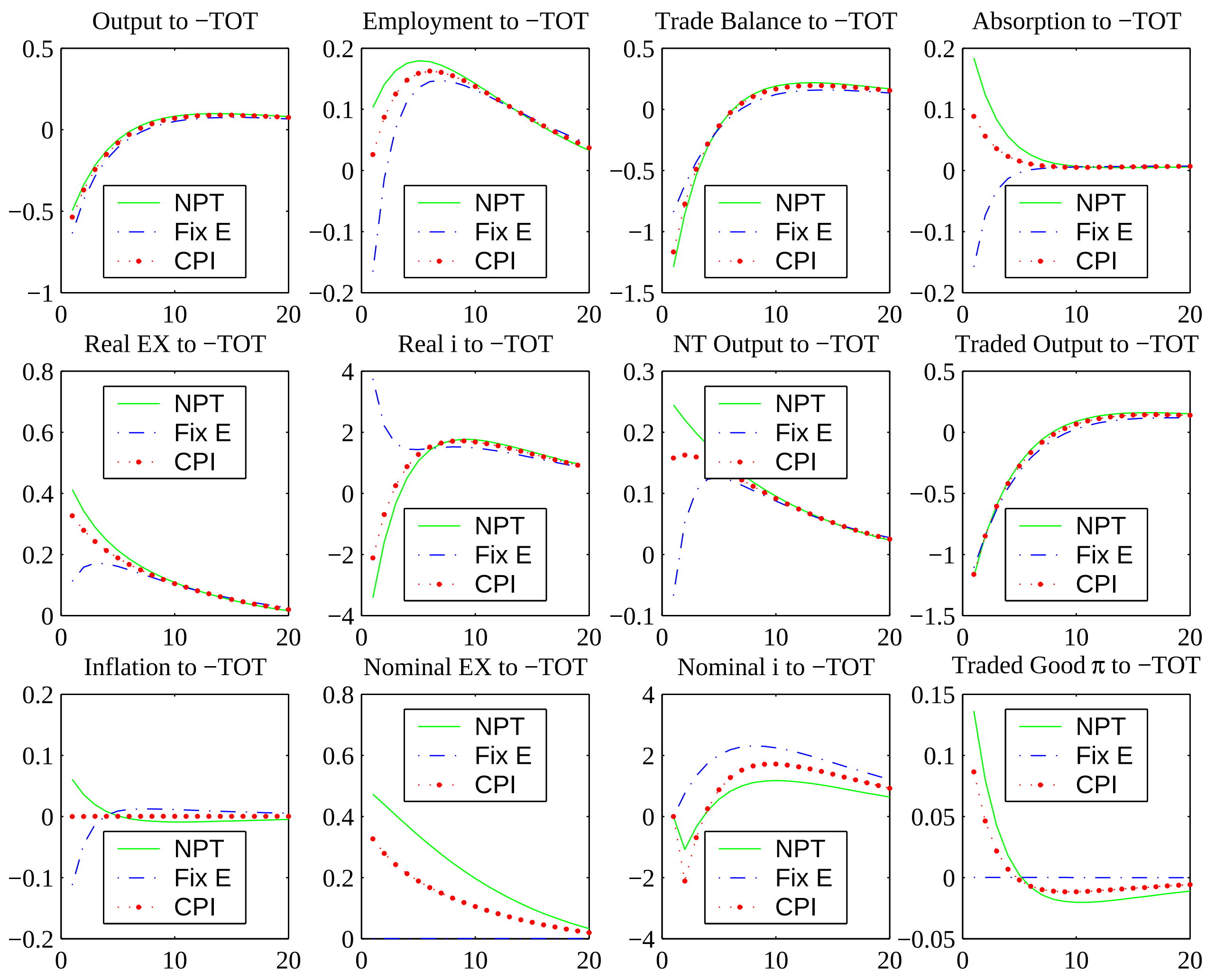


Figure 6: **Impulse Response to -TOT: No Financial Constraint, Delayed Pass-through**



Technical Appendix of
"Exchange Rates and Monetary Policy in Emerging Market Economies "

Not to be Published

1 Equilibrium

In this appendix, we provide a detailed outline of how the model of the paper is constructed.

1.1 Households

The household's budget constraint is described in 2.2 of the text.

The household optimality conditions for labor, domestic bonds, and foreign bonds are:

$$W_t = \eta H_t^{\psi} P_t C_t^{\sigma} \tag{1.1}$$

$$\frac{1}{1+i_{t+1}} = \beta E_t \left(\frac{C_t^{\sigma} P_t}{C_{t+1}^{\sigma} P_{t+1}} \right) \tag{1.2}$$

$$\frac{1}{1+i_{t+1}^{*}} \left[1 - \frac{\psi_D P_t}{S_t}(D_{t+1} - \bar{D}) \right] = \beta E_t \left\{ \frac{C_t^{\sigma} P_t}{C_{t+1}^{\sigma} P_{t+1}} \frac{S_{t+1}}{S_t} \right\} \tag{1.3}$$

where the price index is defined as :

$$P_t = (a P_{Nt}^{1-\rho} + (1-a) P_{Mt}^{1-\rho})^{\frac{1}{1-\rho}} \tag{1.4}$$

The household's non-tradable goods and tradable goods demand are:

$$C_{Nt} = a\left(\frac{P_{Nt}}{P_t}\right)^{-\rho} C_t \tag{1.5}$$

$$C_{Mt} = (1-a)\left(\frac{P_{Mt}}{P_t}\right)^{-\rho} C_t \tag{1.6}$$

1.2 Production Firms

Non-tradable goods firms have production functions given by

$$Y_{Nt} = A_N K_{Nt}^{\alpha} H_{Nt}^{\Omega(1-\alpha)} (H_{Nt}^{e})^{(1-\Omega)(1-\alpha)} \tag{1.7}$$

Cost minimisation leads to the following implicit demand for both types of labor, and capital:

$$W_t = MC_{Nt}(1-\alpha)\Omega\frac{Y_{Nt}}{H_{Nt}} \tag{1.8}$$

$$W^e_{Nt} = MC_{Nt}(1-\alpha)(1-\Omega)\frac{Y_{Nt}}{H^e_{Nt}} \tag{1.9}$$

$$R_{Nt} = MC_{Nt}\alpha\frac{Y_{Nt}}{K_{Nt}} \tag{1.10}$$

Export sector firms have production function:

$$Y_{Xt} = A_X K^{\gamma}_{Xt} H^{\Omega(1-\gamma)}_{Xt} (H^e_{Xt})^{(1-\Omega)(1-\gamma)} \tag{1.11}$$

And

Cost minimisation in the export sector leads to demand for labor and capital:

$$W_t = P_{Xt}(1-\gamma)\Omega\frac{Y_{Xt}}{H_{Xt}} \tag{1.12}$$

$$W^e_{Xt} = P_{Xt}(1-\gamma)(1-\Omega)\frac{Y_{Xt}}{H^e_{Xt}} \tag{1.13}$$

$$R_{Xt} = P_{Xt}\gamma\frac{Y_{Xt}}{K_{Xt}} \tag{1.14}$$

1.3 Unfinished Capital Goods firms

These firms invest (where one unit of investment costs P_t, since the investment composite is of the same form as the consumption good) and rent capital to produce new unfinished capital goods for sale to entrepreneurs. Capital in each sector therefore receives a rental payment from unfinished capital goods firm as well as from final goods firms. Capital accumulation in each sector may be described as:

$$K_{Nt+1} = \phi(\frac{I_{Nt}}{K_{Nt}})K_{Nt} + (1-\delta)K_{Nt} \tag{1.15}$$

$$K_{Xt+1} = \phi(\frac{I_{Xt}}{K_{Xt}})K_{Xt} + (1-\delta)K_{Xt} \tag{1.16}$$

where $\phi(\frac{I^j_t}{K^j_t}) = \frac{I^j_t}{K^j_t} - \frac{\psi_I}{2}\left(\frac{I^j_t}{K^j_t} - \delta\right)^2$, and $j = X, N$.

Unfinished capital goods firms then have the CRS production functions given by $\phi(\frac{I_{Nt}}{K_{Nt}})K_{Nt}$ and $\phi(\frac{I_{Xt}}{K_{Xt}})K_{Xt}$. If the price of an unfinished capital good in the non-traded sector is Q_{Nt}, then the firm's profit maximisation implies that

$$Q_{Nt}\phi'(\frac{I_{Nt}}{K_{Nt}}) = P_t \tag{1.17}$$

$$Q_{Nt}\phi(\frac{I_{Nt}}{K_{Nt}}) - Q_{Nt}\phi'(\frac{I_{Nt}}{K_{Nt}})\frac{I_{Nt}}{K_{Nt}} = R^G_{KNt} \tag{1.18}$$

where R^G_{KNt} is defined as the rental rate that entrepreneurs receive for renting their current capital to unfinished capital goods firms.

The unfinished capital goods firms in the export sector have analogous decisions.

1.4 Price Setting

Profit maximising firms in the non-traded goods sector lead to the condition for price setting:

$$\begin{aligned} P_{Nt} &= \frac{\lambda}{\lambda-1}MC_{Nt} - \frac{\psi_{P_N}}{\lambda-1}\frac{P_t}{Y_{Nt}}\frac{P_{Nt}}{P_{Nt-1}}\left(\frac{P_{Nt}}{P_{Nt-1}} - 1\right) + \\ &\quad \frac{\psi_{P_N}}{\lambda-1}E_t\left[\Gamma_{t+1}\frac{P_{t+1}}{Y_{Nt}}\frac{P_{Nt+1}}{P_{Nt}}\left(\frac{P_{Nt+1}}{P_{Nt}} - 1\right)\right] \end{aligned} \tag{1.19}$$

where Γ_t is the home nominal discount factor, defined by 2.20 in the text.

Assuming that importing goods firms face similar costs of price change, we get:

$$\begin{aligned} P_{Mt} &= \frac{\lambda}{\lambda-1}S_tP^*_{Mt} - \frac{\psi_{P_M}}{\lambda-1}\frac{P_t}{T_{Mt}}\frac{P_{Mt}}{P_{Mt-1}}\left(\frac{P_{Mt}}{P_{Mt-1}} - 1\right) + \\ &\quad \frac{\psi_{P_M}}{\lambda-1}E_t\left[\Gamma_{t+1}\frac{P_{t+1}}{T_{Mt}}\frac{P_{Mt+1}}{P_{Mt}}\left(\frac{P_{Mt+1}}{P_{Mt}} - 1\right)\right] \end{aligned} \tag{1.20}$$

where T_{Mt} is the demand for imports, $S_tP^*_{Mt}$ is the marginal cost for importers.

The export good price is determined on world markets as:

$$P_{Xt} = S_tP^*_{Xt} \tag{1.21}$$

1.5 The entrepreneur's problem:

The details of the optimal contract are derived in section 2 of the appendix below. Here we outline the specification of the entrepreneur's behavior that are important in the solution of the model.

The finance premium rp_{Nt+1} in the non-tradable sector (adjusted for exchange rate changes) is determined in the following equation:

$$E_t\left[R_{KNt+1}\frac{1}{rp_{Nt+1}}\right] = (1 + i^*_{t+1}) \tag{1.22}$$

where

$$rp_{Nt+1} = \frac{E_t\left(\frac{A'(\bar{\omega_{Nt+1}})}{B'(\bar{\omega_{Nt+1}})}\frac{S_{t+1}}{S_t}\right)}{\left[B(\bar{\omega_{Nt+1}})\frac{A'(\bar{\omega_{Nt+1}})}{B'(\bar{\omega_{Nt+1}})} - A(\bar{\omega_{Nt+1}})\right]} \tag{1.23}$$

Here $A(\bar{\omega})$ is defined as the fraction of the return on capital that is obtained by entrepreneurial sector in the aggregate, and $B(\bar{\omega})$ is the fraction of the return that is obtained international lenders, net of the costs of monitoring. These functions are further defined below.

The participation constraint for international lenders is given by:

$$\frac{R_{KNt}S_{t-1}}{S_t}B(\bar{\omega_{Nt}}) = (1+i_t^*)(1-\frac{Z_{Nt}}{Q_{Nt-1}K_{Nt}}) \tag{1.24}$$

where Z_{Nt} is the net worth of entrepreneurs in the non-tradable sector.

Entrepreneurs die at rate $(1-\nu)$ and consume their return on capital if they die. The aggregate consumption of entrepreneurs in the non-tradable good sector is:

$$P_tC_t^{Ne} = (1-\nu)R_{KNt}Q_{Nt-1}K_{Nt}A(\bar{\omega_{Nt}}) \tag{1.25}$$

The evolution of net worth may be written as

$$\begin{aligned} Z_{Nt+1} &= \nu R_{KNt}Q_{Nt-1}K_{Nt}A(\bar{\omega_{Nt}}) + W_{Nt}^e \\ &= \nu R_{KNt}Q_{Nt-1}K_{Nt}\left(1-B(\bar{\omega_{Nt}})-\mu\int_0^{\bar{\omega_{Nt}}}\omega f(\omega)d\omega\right) + W_{Nt}^e \\ &= \nu(1-\phi_{Nt})R_{KNt}Q_{Nt-1}K_{Nt} - \nu(1+i_t^*)\frac{S_t}{S_{t-1}}(Q_{Nt-1}K_{Nt}-Z_{Nt}) + W_{Nt}^e \end{aligned} \tag{1.26}$$

where ϕ_{Nt} is the fraction of the payoff representing monitoring costs, and by 2.25 in the text $\frac{1}{S_{t-1}}(Q_{Nt-1}K_{Nt}-Z_{Nt}) = D_{Nt}^e$ represent foreign currency debt of the non-traded goods entrepreneurial sector. Then note that we may combine 1.25 and 1.26 to get the flow (aggregate) budget constraint of entrepreneurs in the non-traded goods sector as:

$$P_tC_t^{Ne} + Q_{Nt+1}K_{Nt+1} = S_tD_{Nt+1}^e + (1-\phi_{Nt})R_{KNt}Q_{Nt-1}K_{Nt} - (1+i_t^*)S_tD_{Nt}^e + W_{Nt}^e \tag{1.27}$$

which just says that total consumption, plus the purchase of capital goods, is equal to new foreign borrowing, plus the return on existing capital (net of monitoring costs) less the interest rate on existing foreign debt, plus wage income.

The rate of return for entrepreneurs in the non-traded sector consists of the rental return on capital received from the final goods sector as well as the unfinished capital goods sector, plus the value of undepreciated capital, divided by the original price of capital. This is

$$R_{KNt+1} = \frac{R_{Nt+1} + \left[1-\delta-\phi'(\frac{I_{Nt+1}}{K_{Nt+1}})\frac{I_{Nt+1}}{K_{Nt+1}} + \phi(\frac{I_{Nt+1}}{K_{Nt+1}})\right]Q_{Nt+1}}{Q_{Nt}} \tag{1.28}$$

1.6 Definition of $A(\bar{\omega})$, $B(\bar{\omega})$, and ϕ_{Nt}

$A(\cdot)$ is defined as the expected fraction of the return on capital accruing to the entrepreneur as part of the optimal contract. We may write is as:

$$A(\bar{\omega}) = \int_{\bar{\omega}}^{\infty} \omega f(\omega) d\omega - \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega$$

Likewise the return to the lender, net of monitoring costs, is

$$B(\cdot) = \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega + (1-\mu) \int_{0}^{\bar{\omega}} \omega f(\omega) d\omega$$

We define ϕ_{Nt} as the fraction of the return on capital (in the non-tradeable sector) that is wasted in monitoring:

$$\phi_{Nt} = \mu \int_{0}^{\omega \bar{N}t} \omega f(\omega) d\omega$$

The case when ω_t^i is log-normally distributed with $E(ln\omega) = -\frac{\sigma_\omega^2}{2}$ and $Var(ln\omega) = \sigma_\omega^2$ is described in detail below.

The details of the entrepreneurial environment in the export sector are exactly analogous.

1.7 Interest Rate Rule

The monetary authority follows the interest rule given by:

$$1 + i_{t+1} = \left(\frac{P_{Nt}}{P_{Nt-1}} \frac{1}{\bar{\pi}_n} \right)^{\mu_{\pi n}} \left(\frac{P_t}{P_{t-1}} \frac{1}{\bar{\pi}} \right)^{\mu_\pi} \left(\frac{S_t}{\bar{S}} \right)^{\mu_S} (1 + \bar{i}) \tag{1.29}$$

1.8 Market Clearing and Balance of Payments

The non-tradable goods market clearing condition is written as total demand coming from consumers, firms, and entrepreneurs, including demand which is required to pay the costs of price adjustment (of both non-traded firms and foreign exporters), monitoring, and foreign bond adjustment[17]. Thus:

$$Y_{Nt} = a(\frac{P_{Nt}}{P_t})^{-\rho}[C_t + I_{Nt} + I_{Xt} + C_t^{Ne} + C_t^{Xe} + \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 + \frac{\psi_{P_N}}{2} \frac{(P_{Nt} - P_{Nt-1})^2}{P_{Nt-1}^2} +$$
$$\frac{R_{KNt} Q_{Nt-1} K_{Nt}}{P_t} \phi_{Nt} + \frac{R_{KXt} Q_{Xt-1} K_{Xt}}{P_t} \phi_{Xt} + \frac{\psi_{P_M}}{2} [\frac{(P_{Mt} - P_{Mt-1})}{P_{Mt}}]^2 \tag{1.30}$$

[17]Implicitly we are assuming that the foreign exporter does not use imports or home non-traded goods in order to pay the costs of price adjustment, but uses foreign goods (either non-traded or goods not consumed by the home country). This is to keep the notation more simple. We found that the results are identical if we assume foreign price adjustment costs must be paid in domestic imports and domestic non-traded goods

Total demand for import goods (necessary to compute the foreign price adjustment equation 2.24) is:

$$T_{Mt} = (1-a)(\frac{P_{Mt}}{P_t})^{-\rho}[C_t + I_{Nt} + I_{Xt} + C_t^{Ne} + C_t^{Xe} + \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 + \frac{\psi_{P_N}}{2}\frac{(P_{Nt} - P_{Nt-1})^2}{P_{Nt-1}^2} + \frac{R_{KNt}Q_{Nt-1}K_{Nt}}{P_t}\phi_{Nt} + \frac{R_{KXt}Q_{Xt-1}K_{Xt}}{P_t}\phi_{Xt} + \frac{\psi_{P_M}}{2}[\frac{(P_{Mt} - P_{Mt-1})}{P_{Mt}}]^2] \quad (1.31)$$

The households labor supply must be divided between the two sectors:

$$H_{Xt} + H_{Nt} = H_t \quad (1.32)$$

Entrepreneur's labor supply is fixed at one for each entrepreneur:

$$H_{Xt}^e = 1 \quad (1.33)$$

$$H_{Nt}^e = 1 \quad (1.34)$$

The economy's aggregate balance of payment condition may be obtained by summing the budget constraint of households and of entrepreneurs in each sector[18] :

$$\begin{aligned} P_tC_t + P_tC_{Nt}^e + P_tC_{Xt}^e + P_t\frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 + S_t(1+i_t^*)(D_t + D_t^e) \\ +P_t\frac{\psi_{P_N}}{2}\frac{(P_{Nt} - P_{Nt-1})^2}{P_{Nt-1}^2} + P_t(\phi_{Nt}R_{Nt}K_{Nt}Q_{Nt-1} + \phi_{Xt}R_{Xt}K_{Xt}Q_{Xt-1}) \\ +P_t(I_{Nt} + I_{Xt}) = P_{Nt}Y_Nt + P_{Xt}Y_{Xt} + S_t(D_{t+1} + D_{t+1}^e) + \Pi_{Mt} \end{aligned} \quad (1.35)$$

The equilibrium of this economy is a collection of 39 sequences of allocation $(W_t, H_t, P_t, i_t, C_t, C_t^{Ne}, C_t^{Xe}, D_t, D_t^e, S_t, \Gamma_t, M_t, C_{Nt}, C_{Mt}, P_{Nt}, P_{Xt}, P_{Mt}, H_{Nt}, H_{Xt}, H_{Nt}^e, H_{Xt}^e, W_{Nt}^e, W_{Xt}^e, K_{Nt}, K_{Xt}, I_{Nt}, I_{Xt}, R_{Nt}, R_{Xt}, Q_{Nt}, Q_{Xt}, Y_{Nt}, Y_{Xt}, T_{Mt}, MC_{Nt}, R_{KNt}, R_{KXt}, \bar{\omega_{Nt}}, \bar{\omega_{Xt}}, Z_{Nt+1}, Z_{Xt+1})$, satisfying the equilibrium conditions 2.2 of the text, 1.1-1.17, the counterpart of 1.17 for the export sector, 1.19-1.21, 1.22, 1.24 - 1.26, and the counterpart of the four last conditions for the export sector, 1.28 and its counterpart for the export sector, and 1.29-1.35, where we define $D_t^e = D_{Nt} + D_{Xt}$ as the entrepreneurial sector net foreign debt.

[18]Note to obtain 2.33 we must use the definition of capital accumulation 1.15 and 1.16, as well as the optimality conditions of the unfinished capital goods firms in each sector

2 The derivation of the external finance premium

Here we derive the details underlying the external finance premium used in the text. We closely follow the model of BGG in this regard, so our description is kept brief. We focus on the entrepreneur supplying capital to the non-traded sector(the traded sector is exactly analogous).

At the end of period t a continuum of entrepreneurs (indexed by i) need to finance the purchase of new capital K_{Nt+1}^{i} that will be used in period $t+1$. Assume that each entrepreneur has access to a technology for converting borrowed funds into capital for use in the non-traded firms. Entrepreneurs are subject to idiosyncratic risk however, so that if one unit of funds(in terms of domestic currency) is invested by entrepreneur i, then the return is given by $\omega^{i}R_{KNt+1}$, where R_{KNt+1} is the gross return of entrepreneurs' capital investment in the non-traded sector, and ω^{i} follows a log-normal distribution with with mean $-\frac{\sigma_{\omega}^{2}}{2}$ and variance σ_{ω}^{2}(so that the expected value of ω^{i} is unity), and is distributed i.i.d. across entrepreneurs and time.

The realization of ω^{i} can be observed by the entrepreneur but not by the lender. But lenders can discover the true realization at a cost ϕ times the payoff of the investment. Both lenders and entrepreneurs are risk neutral. Standard results then establish that the optimal contract between entrepreneur and lender is a debt contract, whereby the entrepreneur pays a fixed amount $\bar{\omega}^{i}R_{KNt+1}Q_{t}K_{Nt+1}^{i}$ to the lender if $\omega^{i} > \bar{\omega}^{i}$. If $\omega^{i} < \bar{\omega}^{i}$, the lender monitors the project, the entrepreneur gets nothing, and the lender receives the full proceeds of investment net of monitoring costs. So the expected return to the entrepreneur is

$$R_{KNt+1}Q_{Nt}K_{Nt+1}^{i}\left[\int_{\bar{\omega}_{Nt+1}^{i}}^{\infty}\omega^{i}f(\omega)d\omega - \bar{\omega}_{Nt+1}^{i}\int_{\bar{\omega}_{Nt+1}^{i}}^{\infty}f(\omega)d\omega\right] \equiv R_{KNt+1}Q_{Nt}K_{Nt+1}^{i}A(\bar{\omega}_{Nt+1}^{i}) \tag{2.36}$$

The expected return to the lender is then

$$R_{KNt+1}Q_{Nt}K_{Nt+1}^{i}\left[\bar{\omega}_{Nt+1}^{i}\int_{\bar{\omega}_{Nt+1}^{i}}^{\infty}f(\omega)d\omega + (1-\mu)\int_{0}^{\bar{\omega}_{Nt}^{i}}\omega_{Nt+1}^{i}f(\omega)d\omega\right] \equiv R_{KNt+1}Q_{Nt}K_{Nt+1}^{i}B(\bar{\omega}_{Nt+1}^{i}) \tag{2.37}$$

Then lender must receive a return at least equal to the world opportunity cost, given by $R_{t+1}^{*} = 1 + i_{t+1}^{*}$. Thus, the participation constraint of the lender (in terms of the foreign currency) is:

$$\frac{R_{KNt+1}Q_{Nt}K_{Nt+1}^{i}B(\bar{\omega}_{Nt+1}^{i})}{S_{t+1}} = \frac{R_{t+1}^{*}(Q_{Nt}K_{Nt+1}^{i} - Z_{Nt+1}^{i})}{S_{t}} \tag{2.38}$$

An optimal contract chooses the threshold value $\bar{\omega}^i_{Nt+1}$ and K^i_{Nt+1} to solve the following problem:

$$\max E_t \left(R_{KNt+1} Q_{Nt} K^i_{Nt+1} A(\bar{\omega}^i_{Nt+1}) \right) \tag{2.39}$$

subject to the participation constraint 2.38.

Note that the only aggregate uncertainty faced by the entrepreneur and lender is the exchange rate that will prevail when the foreign currency loans must be repaid. And it is assumed that the risk-neutral entrepreneurs bear all the aggregate risk. So the return of the investment R_{KNt+1} and thus the optimal threshold level $\bar{\omega}^i_{Nt+1}$ will be state contingent on the realizations of the exchange rate and the participation constraint will hold with equality, at every possible state ex post.

The two first order condition implied by the contract is then:

$$E_t \left[R_{KNt+1} Q_{Nt} A(\bar{\omega}^i_{Nt+1}) \right] + E_t \left[\lambda_{t+1} \frac{R_{KNt+1} Q_{Nt} A(\bar{\omega}^i_{Nt+1})}{S_{t+1}} - \frac{R^*_{t+1} Q_{Nt}}{S_t} \right] = 0 \tag{2.40}$$

$$\lambda_{t+1}(\theta) = -\frac{\pi(\theta) A'(\bar{\omega}^i_{Nt+1}(\theta)) S_{t+1}(\theta)}{B'(\bar{\omega}^i_{Nt+1}(\theta))} \tag{2.41}$$

where $\theta \in \Theta$ is a state of the world, $\pi(\theta)$ is the probability of state θ and λ_{t+1} is the Lagrange multiplier associated with the participation constraint. Substitute 2.41 into 2.40, we get:

$$E_t \left\{ R_{KNt+1} \left[\frac{A'(\bar{\omega}^i_{Nt+1})}{B'(\bar{\omega}^i_{Nt+1})} B(\bar{\omega}^i_{Nt+1}) - A(\bar{\omega}^i_{Nt+1}) \right] \right\} = E_t \left[\frac{A'(\bar{\omega}^i_{Nt+1})}{B'(\bar{\omega}^i_{Nt+1})} \frac{S_{t+1}}{S_t} R^*_{t+1} \right] \tag{2.42}$$

Since ω^i is i.i.d across entrepreneurs, every entrepreneur actually faces the same financial contract, so we could drop the superscript i. Rearranging 2.42, we could get 1.22.

The entrepreneurs are assumed to die at any time period with probability $(1-\nu)$. Thus, at any given period, a fraction $(1-\nu)$ of entrepreneurial wealth is consumed. So the consumption of entrepreneurs in the non-traded sector is given by 1.25. And the net wealth Z_{Nt+1} is given by:

$$Z_{Nt+1} = \nu R_{KNt} Q_{Nt-1} K_{Nt} A(\bar{\omega}_{Nt}) + W^e_{Xt} \tag{2.43}$$

Use the fact that $B(\bar{\omega}) = 1 - A(\bar{\omega}) - \mu \int_0^{\bar{\omega}} \omega f(\omega) d\omega$ and imposing the participation constraint, we get 1.26.

3 Derivation of $A(\cdot)$, $A'(\cdot)$, $B(\cdot)$ and $B'(\cdot)$

We know that:

$$A(\bar{\omega}) = \int_{\bar{\omega}}^{\infty} \omega f(\omega) d\omega - \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega \tag{3.44}$$

$$B(\bar{\omega}) = \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega + (1-\mu) \int_{0}^{\bar{\omega}} \omega f(\omega) d\omega \tag{3.45}$$

If ω_t^i is log-normally distributed with mean $-\frac{\sigma_\omega^2}{2}$ and variance σ_ω^2, we know that

$$E(\omega) = \int_{-\infty}^{\infty} \omega f(\omega) d\omega = 1 \tag{3.46}$$

where the density function $f(\omega)$ is given by:

$$f(\omega) = \frac{1}{\sigma_\omega \omega \sqrt{2\pi}} \exp\left\{ -\frac{(\ln\omega + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} \tag{3.47}$$

Then we may write

$$\begin{aligned}
\int_{\bar{\omega}}^{\infty} \omega f(\omega) d\omega &= \int_{\ln\bar{\omega}}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{ -\frac{(y + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} \exp(y) dy \\
&= \int_{\ln\bar{\omega}}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{ -\frac{(y - \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} dy \\
&= \frac{1}{\sqrt{\pi}} \int_{\ln\bar{\omega}}^{\infty} \exp\left\{ -\frac{(y - \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} d(\frac{y - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}) \\
&= \frac{1}{2} erfc\left(\frac{\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega} \right) \qquad (3.48)
\end{aligned}$$

where $erfc(z) = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-t^2} dt$ is the "complementary error function".

And similarly,

$$\begin{aligned}
\bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega &= \bar{\omega} \int_{\bar{\omega}}^{\infty} \frac{1}{\sigma_\omega \omega \sqrt{2\pi}} \exp\left\{ -\frac{(\ln\omega + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} d\omega \\
&= \bar{\omega} \int_{\bar{\omega}}^{\infty} \frac{1}{\sigma_\omega \sqrt{2\pi}} \exp\left\{ -\frac{(\ln\omega + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} d\ln\omega \\
&= \bar{\omega} \int_{\ln\bar{\omega}}^{\infty} \frac{1}{\sqrt{\pi}} \exp\left\{ -\frac{(\ln\omega + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2} \right\} d(\frac{\ln\omega + \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}) \\
&= \frac{\bar{\omega}}{2} erfc\left(\frac{\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega} \right) \qquad (3.49)
\end{aligned}$$

So we get:

$$A(\bar{\omega}) = \frac{1}{2} erfc\left(\frac{\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right) - \frac{\bar{\omega}}{2} erfc\left(\frac{\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right) \tag{3.50}$$

Then we may write

$$\begin{aligned} \int_0^{\bar{\omega}} \omega f(\omega) d\omega &= \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\ln\bar{\omega}} \exp\left\{-\frac{(y - \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right\} d(\frac{y - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}) \\ &= \frac{1}{2}\left[1 + erf\left(\frac{\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right)\right] \end{aligned} \tag{3.51}$$

$$B(\bar{\omega}) = \frac{\bar{\omega}}{2} erfc\left(\frac{\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right) + (1-\mu)\frac{1}{2}\left[1 + erf\left(\frac{\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right)\right] \tag{3.52}$$

where $erf(z) = \frac{2}{\sqrt{\pi}} \int_0^z e^{-t^2} dt$ is the "error function".

Therefore, it can be easily derived that:

$$A'(\bar{\omega}) = -\frac{1}{\sqrt{2\pi}\sigma_\omega}\left[\frac{1}{\bar{\omega}} \exp\left(-\frac{(\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right) - \exp\left(-\frac{(\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right)\right] - \frac{1}{2} erfc\left(\frac{\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right) \tag{3.53}$$

But we can prove that

$$\begin{aligned} \frac{1}{\bar{\omega}} \exp\left(-\frac{(\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right) &= \exp[-\ln(\bar{\omega})] \exp\left(-\frac{(\ln(\bar{\omega}) - \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right) \\ &= \exp\left(-\frac{(\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right) \end{aligned} \tag{3.54}$$

Therefore,

$$A'(\bar{\omega}) = -\frac{1}{2} erfc\left(\frac{\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2}}{\sqrt{2}\sigma_\omega}\right) \tag{3.55}$$

Note that $E(\omega) = 1$, so $B(\bar{\omega}) = 1 - A(\bar{\omega}) - \mu \int_0^{\bar{\omega}} \omega f(\omega) d\omega$, thus

$$B'(\bar{\omega}) = -A'(\bar{\omega}) - \frac{\mu}{\sqrt{2\pi}\sigma_\omega} \exp\left(-\frac{(\ln(\bar{\omega}) + \frac{\sigma_\omega^2}{2})^2}{2\sigma_\omega^2}\right) \tag{3.56}$$

4 Computing the Consumption Equivalent Welfare Measures

This section gives the details of the derivation of the consumption equivalent comparisons ϵ. First take the model without entrepreneurs. For monetary policy regime r, the expected utility can be written as:

$$V^r = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{r(1-\sigma)}}{1-\sigma} - \eta \frac{H_t^{r(1+\psi)}}{1+\psi} \right) \tag{4.57}$$

where $\{C_t^r\}$ and $\{H_t^r\}$ are the stream of the consumption and labour supply under policy regime r. To compare across different regimes, we may define C^τ and H^τ as the permanent(annuity) consumption and labor supply associate with regime τ such that

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{r(1-\sigma)}}{1-\sigma} - \eta \frac{H_t^{r(1+\psi)}}{1+\psi} \right) = \sum_{t=0}^{\infty} \beta^t \left(\frac{C^{r(1-\sigma)}}{1-\sigma} - \eta \frac{H^{r(1+\psi)}}{1+\psi} \right) \tag{4.58}$$

Thus, the expected utility under regime r is given by

$$V^r = \frac{C^{r(1-\sigma)}}{(1-\sigma)(1-\beta)} - \eta \frac{H^{r(1+\psi)}}{(1+\psi)(1-\beta)} \tag{4.59}$$

Similarly, the expected utility under monetary policy regime s can be written as:

$$V^s = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{s(1-\sigma)}}{1-\sigma} - \eta \frac{H_t^{s(1+\psi)}}{1+\psi} \right) = \frac{C^{s(1-\sigma)}}{(1-\sigma)(1-\beta)} - \eta \frac{H^{s(1+\psi)}}{(1+\psi)(1-\beta)} \tag{4.60}$$

ϵ is defined as the fraction of permanent consumption that a consumer in an economy governed by monetary policy r would be willing to give up in order to make her indifferent between this and an economy governed by monetary policy s, Thus, ϵ can be derived from the following equality

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{1-\sigma} - \eta \frac{H^{r(1+\psi)}}{1+\psi} \right) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C^{s(1-\sigma)}}{1-\sigma} - \eta \frac{H^{s(1+\psi)}}{1+\psi} \right) \tag{4.61}$$

Or

$$\frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{(1-\sigma)(1-\beta)} - \eta \frac{H^{r(1+\psi)}}{(1+\psi)(1-\beta)} = \frac{C^{s(1-\sigma)}}{(1-\sigma)(1-\beta)} - \eta \frac{H^{s(1+\psi)}}{(1+\psi)(1-\beta)} \tag{4.62}$$

Define $\eta \frac{H^{\tau(1+\psi)}}{(1+\psi)(1-\beta)}$ as V_h^τ, the disutility of labor under regime τ, we may get:

$$\begin{aligned} \frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{(1-\sigma)(1-\beta)} &= V^s + V_h^r \\ \Rightarrow \epsilon &= 1 - \frac{[(V^s + V_h^r)(1-\sigma)(1-\beta)]^{\frac{1}{1-\sigma}}}{C^r} \end{aligned} \tag{4.63}$$

From Equation 4.59, we may get

$$C^r = [(V^r + V_h^r)(1-\sigma)(1-\beta)]^{\frac{1}{1-\sigma}} \tag{4.64}$$

Thus

$$\epsilon = 1 - \left(\frac{V^s + V_h^r}{V^r + V_h^r}\right)^{\frac{1}{1-\sigma}} \tag{4.65}$$

For the economy with entrepreneurs, ϵ is defined as the fraction of permanent consumption that must be offered both to households and entrepreneurs so as to make them indifferent between the two regimes

$$\frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{(1-\sigma)(1-\beta)} - \eta\frac{H^{r(1+\psi)}}{(1+\psi)(1-\beta)} + \frac{(1-\epsilon)C^{re}}{1-\beta} = \frac{C^{s(1-\sigma)}}{(1-\sigma)(1-\beta)} - \eta\frac{H^{s(1+\psi)}}{(1+\psi)(1-\beta)} + \frac{C^{se}}{1-\beta} \equiv V^s \tag{4.66}$$

where $C^{\tau e}$ is the permanent consumption of entrepreneurs under regime τ.

If we define $V_e^\tau = \frac{C^{\tau e}}{1-\beta}$ as the expected utility for entrepreneurs under regime τ, we may derive ϵ analogously:

$$\frac{[(1-\epsilon)C^r]^{(1-\sigma)}}{(1-\sigma)(1-\beta)} + (1-\epsilon)V_e^r = V^s + V_h^r \tag{4.67}$$

Since $\frac{C^{r(1-\sigma)}}{(1-\sigma)(1-\beta)} = V^r + V_h^r - V_e^r$, we may derive ϵ implicitly from the following equation:

$$(1-\epsilon)^{1-\sigma}(V^r + V_h^r - V_e^r) + (1-\epsilon)V_e^r = V^s + V_h^r \tag{4.68}$$

5 The model without entrepreneurs

The comparison economy without private information or an entrepreneurial sector is identical to the set-up we have described, except that capital is accumulated directly by households without any external finance constraint. Here we simply list the equations used to solve this economy. They are exactly analogous to those of the previous model, except in the details of the determination of aggregate capital, and the absence of entrepreneurial consumption and wealth dynamics. They are:

$$W_t = \eta H_t^\psi P_t C_t^\sigma \tag{5.1}$$

$$\frac{1}{1+i_{t+1}} = \beta E_t\left(\frac{C_t^\sigma P_t}{C_{t+1}^\sigma P_{t+1}}\right) \tag{5.2}$$

$$\frac{1}{1+i^*_{t+1}}\left[1-\frac{\psi_D P_t}{S_t}(D_{t+1}-\bar{D})\right]=\beta E_t\left\{\frac{C_t^\sigma P_t}{C_{t+1}^\sigma P_{t+1}}\frac{S_{t+1}}{S_t}\right\} \tag{5.3}$$

$$\frac{M_t}{P_t}=\frac{\chi^{\frac{1}{\varepsilon}}C_t^{\frac{\sigma}{\varepsilon}}}{\left(1-\frac{1}{1+i_{t+1}}\right)^{\frac{1}{\varepsilon}}} \tag{5.4}$$

$$P_t=(aP_{Nt}^{1-\rho}+(1-a)P_{Mt}^{1-\rho})^{\frac{1}{1-\rho}} \tag{5.5}$$

$$W_t=MC_{Nt}(1-\alpha)\frac{Y_{Nt}}{H_{Nt}} \tag{5.6}$$

$$R_{Nt}=MC_{Nt}\alpha\frac{Y_{Nt}}{K_{Nt}} \tag{5.7}$$

$$Y_{Nt}=A_N K_{Nt}^\alpha H_{Nt}^{(1-\alpha)} \tag{5.8}$$

$$W_t=P_{Xt}(1-\gamma)\frac{Y_{Xt}}{H_{Xt}} \tag{5.9}$$

$$R_{Xt}=P_{Xt}\gamma\frac{Y_{Xt}}{K_{Xt}} \tag{5.10}$$

$$Y_{Xt}=A_X K_{Xt}^\gamma H_{Xt}^{(1-\gamma)} \tag{5.11}$$

$$P_{Nt}=\frac{\lambda}{\lambda-1}MC_{Nt}-\frac{\psi_{P_N}}{\lambda-1}\frac{P_t}{Y_{Nt}}\frac{P_{Nt}}{P_{Nt-1}}\left(\frac{P_{Nt}}{P_{Nt-1}}-1\right)+\frac{\psi_{P_N}}{\lambda-1}E_t\left[\Gamma_{t+1}\frac{P_{t+1}}{Y_{Nt}}\frac{P_{Nt+1}}{P_{Nt}}\left(\frac{P_{Nt+1}}{P_{Nt}}-1\right)\right] \tag{5.12}$$

$$P_{Mt}=\frac{\lambda}{\lambda-1}SP_{Mt}^*-\frac{\psi_{P_M}}{\lambda-1}\frac{P_t}{T_{Mt}}\frac{P_{Mt}}{P_{Mt-1}}\left(\frac{P_{Mt}}{P_{Mt-1}}-1\right)+\frac{\psi_{P_M}}{\lambda-1}E_t\left[\Gamma_{t+1}\frac{P_{t+1}}{T_{Mt}}\frac{P_{Mt+1}}{P_{Mt}}\left(\frac{P_{Mt+1}}{P_{Nt}}-1\right)\right] \tag{5.13}$$

$$P_{Xt}=S_tP_{Xt}^* \tag{5.14}$$

$$Q_{Xt}=\frac{P_t}{1-\psi_I(\frac{I_{Xt}}{K_{Xt}}-\delta)} \tag{5.15}$$

$$Q_{Nt}=\frac{P_t}{1-\psi_I(\frac{I_{Nt}}{K_{Nt}}-\delta)} \tag{5.16}$$

$$K_{Xt+1}=\left[\frac{I_{Xt}}{K_{Xt}}-\frac{\psi_I}{2}\left(\frac{I_{Xt}}{K_{Xt}}-\delta\right)^2\right]K_{Xt}+(1-\delta)K_{Xt} \tag{5.17}$$

$$K_{Nt+1}=\left[\frac{I_{Nt}}{K_{Nt}}-\frac{\psi_I}{2}\left(\frac{I_{Nt}}{K_{Nt}}-\delta\right)^2\right]K_{Nt}+(1-\delta)K_{Nt} \tag{5.18}$$

$$E_t\left[\frac{R_{KNt+1}}{C_{t+1}^\sigma P_{t+1}}\right]=\frac{1}{C_t^\sigma P_t} \tag{5.19}$$

$$R_{KNt+1} = \frac{R_{Nt+1} + \left[1 - \delta + \psi_I(\frac{I_{Nt+1}}{K_{Nt+1}} - \delta)\frac{I_{Nt+1}}{K_{Nt+1}} - \frac{\psi_I}{2}(\frac{I_{Nt+1}}{K_{Nt+1}} - \delta)^2\right] Q_{Nt+1}}{Q_{Nt}} \tag{5.20}$$

$$E_t\left[\frac{R_{KXt+1}}{C^{\sigma}_{t+1}P_{t+1}}\right] = \frac{1}{C^{\sigma}_t P_t} \tag{5.21}$$

$$R_{KXt+1} = \frac{R_{Xt+1} + \left[1 - \delta + \psi_I(\frac{I_{Xt+1}}{K_{Xt+1}} - \delta)\frac{I_{Xt+1}}{K_{Xt+1}} - \frac{\psi_I}{2}(\frac{I_{Xt+1}}{K_{Xt+1}} - \delta)^2\right] Q_{Xt+1}}{Q_{Xt}} \tag{5.22}$$

$$Y_{Nt} = a(\frac{P_{Nt}}{P_t})^{-\rho}[C_t + I_{Nt} + I_{Xt} + \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 + \frac{\psi_{P_M}}{2}(\frac{P_{Mt}}{P_{Mt-1}} - 1)^2 + \frac{\psi_{P_N}}{2}(\frac{P_{Nt}}{P_{Nt-1}} - 1)^2] \tag{5.23}$$

$$T_{Mt} = (1-a)(\frac{P_{Mt}}{P_t})^{-\rho}[C_t + I_{Nt} + I_{Xt} + \frac{\psi_D}{2}(D_{t+1} - \bar{D})^2 + \frac{\psi_{P_M}}{2}(\frac{P_{Mt}}{P_{Mt-1}} - 1)^2 + \frac{\psi_{P_N}}{2}(\frac{P_{Nt}}{P_{Nt-1}} - 1)^2] \tag{5.24}$$

$$H_{Xt} + H_{Nt} = H_t \tag{5.25}$$

$$S_t(1 + i^*_t)D_t - S_t D_{t+1} = P_{Xt}Y_{Xt} - S_t P^*_{Mt}T_{Mt} \tag{5.26}$$

$$1 + i_{t+1} = \left(\frac{P_{Nt}}{P_{Nt-1}}\frac{1}{\bar{\pi_n}}\right)^{\mu_{\pi_n}} \left(\frac{P_t}{[a(P_{Nt-1})^{1-\rho} + (1-a)(P_{Lt-1})^{1-\rho}]^{\frac{1}{1-\rho}}}\frac{1}{\bar{\pi}}\right)^{\mu_\pi} \left(\frac{S_t}{\bar{S}}\right)^{\mu_S} (1 + \bar{i}) \tag{5.27}$$

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