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Abstract

An open economy macromodel, calibrated to typical institutions and shocks of a populous emerging market economy, shows that a monetary stimulus preceding a supply shock can abort inflation at minimum output cost, since of the appreciation of exchange rates, accompanying a fall in interest rates and rise in output. Analytic results obtained for two periods are generalized through simulations and validated through estimation. One instrument achieves both domestic output and exchange rate objectives, partly since it creates correct incentives for foreign exchange traders. Strategic interactions imply supporting institutions are required to coordinate monetary, fiscal policy, and markets to the optimal equilibrium.

Key words: Emerging Market Economy, Mundell-Fleming, Monetary Policy, FX Market, Supply Shocks

JEL Classification nos.: F31, F41

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1. Introduction

The paper examines the degrees of freedom for monetary policy in a small open emerging market economy (SOEME). It seeks to discover the conditions under which monetary policy delivers both domestic cyclical and exchange rate objectives, and foreign exchange (FX) markets support the policy since they profit by helping deliver the appropriate exchange rate. A monetary stimulus in anticipation of a temporary supply shock can abort inflation at minimum output cost, because of an appreciation of the exchange rate, and rise in output. The analysis is useful for Asian emerging market economies (EMEs) that are in the process of migrating to exchange rate regimes compatible with more openness.

The response of monetary policy to supply shocks, and its ability to deliver the required exchange rate, is examined in a small open economy model[1]. The latter has an aggregate demand function, a money demand function, a Phillips curve, and an interest arbitrage condition, but each component incorporates features of the EME. Structural features such as wage-price rigidities due to low per capita incomes and political interventions; high potential output due to high population density; but short-term bottlenecks due to frequent supply shocks[2] are built in. Forward-looking aspects come in through the exchange rate and consumer prices. Analytical results obtained in a simplified version with restrictions on parameters, are confirmed through simulations and sensitivity analysis with the full model. Estimation also justifies the chosen calibration.

The Central Bank's (CB's) optimization, given the constraints from the macromodel, affects the decisions and payoffs of market participants and vice versa. The outcome can be self-enforcing under certain parameter values, which we explore by solving for the outcome of interaction between the central bank and the market players[3].

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[1] New Keynesian Economics literature has developed a number of such models, where forward looking behavior is combined with price rigidities. Svensson (2000) was a seminal paper, even though his focus was on inflation targeting. The macromodel in this paper also draws on Oudiz and Sachs (1985) and Ghosh (2002).

[2] We are examining transient supply shocks such as a failure of rains of spike in oil prices. If supply shocks were persistent, such as a sustained rise in oil prices, exchange rate policy would not alone be adequate. A rise in productivity would be required.

[3] Forex traders are modeled following Bhattacharya and Weller (1997), Lyons (2001), and Jeanne and Rose (2002).

It turns out that monetary policy can impart limited volatility to the nominal exchange rate by using shocks yet reducing their amplification. This makes a smoother and more countercyclical interest rate feasible. Intervention may not be required at all since markets deliver the required exchange rate. The resulting exchange rate regime contributes to stimulating the real sector also through encouraging trade. If deviations from the competitive equilibrium real exchange rate are minimized, external balance is maintained over the long run. It contributes to the control of inflation by countering supply shocks, thus achieving a vital political goal. It encourages monetary policy to be forward looking rather than reactive. It also deepens and maintains stability in the FX market.

Full floating results in excessive volatility in immature markets with large foreign inflows, but some flexibility may moderate volatility. FX markets have a tendency towards excessive movement, as market participants tend to follow each other. Hedging removes the effect of currency movement in any one direction on profits by creating exposure in the opposite direction. Limited two-way movement improves incentives for hedging and therefore reduces currency risk. Since the number of agents whom a change in the nominal exchange rate affects falls, market stability rises. No hedge can cover a currency crisis, but random small movements reduce one-way bets that could otherwise magnify the movements, as happened during the East Asian crises when exchange rates were largely fixed. Currency risk aggravates systemic, liquidity and credit risk in thin EME financial markets. Global and regional measures are also required to reduce these risks, but this paper brings out the contribution of exchange rate regimes.

Under large capital inflows, facing fast growing EMEs today, accumulation of reserves and aggressive sterilization can prevent exchange rate appreciation, but interest rates rise. In the simple Mundell-Fleming (M-F) model this implies further inflows. Monetary policy looses its independence being tied to maintaining the fixed exchange rate. The cycle can end in a crisis with a reversal of inflows and a collapse of the exchange rate. A restrictive macroeconomic policy response may harm the real sector and lead to the

reversal it fears. But over appreciation of the exchange rate can harm trade, and intervention without full sterilization can cause a damaging over-expansion of the money supply, which again raises interest rates because of expected inflation. Monetary policy has to find a fine balance.

It turns out that some of the ways such an EME's structure differs from the prototype M-F model give degrees of freedom for monetary policy, despite large capital flows. The policy combination will be credible only if it improves real fundamentals in the economy. It will do this since the variation in the exchange rate allows interest rates to respond to the domestic cycle and reduces the impact of import price shocks on inflation. Since inflation is a very sensitive political issue, this will enhance the political feasibility of the policy. Inflation has been controlled in ways that have imposed large distortions and costs on society. So an exchange rate regime suited to structure and rigidities can reduce this waste and improve coordination, thus helping resolve a collective action problem to release potential surplus.

Section 2 presents the model, theoretical results, and empirical validation through regressions and simulations. Section 3 applies it to explain policy choices and prospects. Section 4 concludes.

2 The Model

A standard open economy IS-LM-UIP (uncovered interest parity) model is adapted by building in the dualistic labor market, specific wage-price rigidities, the typical structure of shocks, and a simple FX market.

2.1. A Macro Structural Model of a Small Open Economy

The building blocks of the model are first, an aggregate demand equation where output, y_t, responds positively to the real exchange rate and negatively to the real interest rate. All variables are expressed as log-linearized deviations from a mean.

$$y_t = \delta\left(e_t + p_t^* - p_t\right) - \sigma\left(i_t - \left(p_{t+1}^e - p_t\right)\right) \tag{1}$$

The nominal exchange rate e_t is measured in units of foreign currency so that a rise implies a depreciation of the home currency. Since p_t denotes home country prices and p_t^* foreign prices, the term in the first bracket gives the real exchange rate. Expected inflation $\left(p_{t+1}^e - p_t\right)$ subtracted from the nominal interest rate gives the real interest rate in the second bracket. Money market equilibrium gives:

$$m_t - p_t = \alpha y_t - \phi i_t - v_t \tag{2}$$

Since the money supply is assumed to target interest rates, v_t is the composite demand shock plus money supply response. A rise in v_t will reduce i_t.

Even without full capital account convertibility, mobile capital flows are assumed to be large enough to equate expected returns from deposits in domestic currency, to those from deposits in foreign currency plus country risk. Since capital account convertibility is limited[4], domestic residents cannot hold foreign bonds and sovereign bonds are not floated internationally. Therefore the share of foreign bonds in portfolios does not determine the risk premium, which depends on an exogenous country risk plus FX traders' risk[5], derived to be negatively related to the variance of exchange rates in section 3.4 below. With the foreign interest rate normalized to zero, arbitrage implies that expected depreciation of the exchange rate plus the risk premium ρ_t, must equal the interest differential:

$$i_t = e_{t+1}^e - e_t + \rho_t \tag{3}$$

On the supply side, producer prices are marked up on wages, so producer price inflation responds to nominal wage inflation, lagged output (through pro-cyclical mark-ups) and contemporaneous oil (η_{t+1}) or productivity (g_{t+1}) shocks to supply:

$$p_{t+1} - p_t = \left(w_{t+1} - w_t\right) + \psi y_t - g_{t+1} + \eta_{t+1} \tag{4}$$

The consumer price index, p_t^c, is a weighted average of home and foreign prices. Since p_t^* is normalized to zero, p_t^c responds directly to e_t:

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[4] This is true of both India and China.
[5] BIS forex market data shows that traders dominate forex transactions. Transactions due to trade or investment are a very small percentage of more than dollar trillion forex transactions. Goyal (2005) shows that the latter are much lower in EMEs compared to developed countries, but are growing rapidly.

$$p_t^c = \lambda p_t + (1-\lambda)e_t \tag{5}$$

Nominal wages respond to lagged inflation in consumer prices so, $w_t = p_{t-1}^c$. This feature follows from characteristics of a dualistic labor market where wages may not be indexed to inflation but the low wage level is highly sensitive to food price inflation[6]. Substituting out wages from equation (4) and assuming that productivity is not changing gives:

$$p_{t+1} - p_t = \left(p_t^c - p_{t-1}^c\right) + \psi y_t + \eta_{t+1} \tag{6}$$

With trade liberalization food prices become more closely linked to border prices and the weight of e_t in equation (5) rises; p_t^c responds to e_t; wages respond to p_t^c; and producer prices are marked up on wages. If w does not rise, neither will p_{t+1}, unless there is an adverse supply shock η_{t+1}. The effect of border prices in stabilizing food prices, allows a potential escape from the inflation cum subsidy trap.

The dualistic labor market structure implies that supply is elastic, if food prices are stable, since output is below the potential that absorbs the labor slack[7]. Mean output $\bar{y}$ lies below potential output $\bar{\bar{y}}$ and rises towards it over a horizon long enough for the capital stock to rise; there are constant returns to capital[8]. Capital availability, alleviation of specific bottlenecks, and institutional reforms reduce shocks to the supply curve[9].

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[6] Since there is no cost of living indexation in the large informal Indian labor market (accounting for 80 percent of the work force) nominal wage adjustment is lagged. There are political pressures to keep real wages fixed in terms of food; and pressures from well organized rural lobbies (the share of the rural population still exceeds 70 percent) for high and rising farm support prices. The compromise has been to subsidize both farmers and consumers; the latter through a low price public distribution system. Since the latter is not very effective, protection is not complete, and nominal wages rise with a lag in response to a rise in food prices.

[7] The Planning Commission (2006, pp.77), India, estimates that 35 million are unemployed and the labor force will increase by 52-65 million over the next five years because of population growth and more female labour force participation.

[8] Aghion et. al. (1999) derive this in a standard Cobb-Douglas production function $Y = AK^\beta L^{1-\beta}$ where Y is the output level, K the capital stock, L labor employed. Normalizing the constant consumption wage $W/P_t^c = 1$ (where W is the nominal wage and P the price level) and equating it to the marginal product of labor gives a value for L, which when substituted in the production function gives $Y = A\left((1-B)A\right)^{(1-\beta)/\beta} K = \tau K$ or the standard AK production function with CRS. Despite rapid growth in India since the late nineties, NSS earnings data show almost constant real wage rates over 1999-2000; only graduates and above saw a sizeable rise in earnings (Planning Commission, 2006, pp. 76-77).

[9] Reforms allow faster labor absorption and an upward trend in mean output. Capital accumulation and organizational change raise labor productivity; increasing competition through opening out reduces mark-ups. These factors all contribute to improving supply conditions.

Foreign inflows relieve constraints on imports of food stocks, fuel oils and capital goods. New technology helps bypass some deficiencies in infrastructure while easier finance funds its expansion[10]. Employers do not gain from lowering the subsistence real informal wage rate so wages rise in response to food prices. In our short run, therefore, if food prices are constant labor cost does not rise; if there is no cost shock, intermediate inputs prices also do not rise; if mark-ups are constant, deviations from mean output are demand-determined with constant costs.

The effect of money supply on prices comes in through the money market equation (2). Money expansion is inflationary, if short-run capacity constraints are reached but if cost shocks are dominant the output cost of a contraction can be high. To the extent money demand becomes unstable with development, money supply has to respond more frequently in order to prevent large fluctuations in interest rates, but the equilibrium condition (2) must continue to hold. Since the policy instrument may be a short interest rate, money supply m_t can be normalized to zero.

Simplifying assumptions, based on the structure of the EME and its typical shocks, allow analytical results to be derived. These are relaxed in simulations later. If dualism and rigidities lower the response to price variables in an EME, price elasticities such as δ, σ may be low[11]. Constant mark-ups and CRS imply that $\psi \sim 0$, and the large weight of food in P_t^c implies that λ is also low. Under a managed float with limited volatility of the real exchange rate that induces hedging we can assume $\delta = 0$, so the real exchange rate drops out of equation (1). All agents including the CB have a three period horizon (a simulation extends the results for n periods). No trade occurs in the FX market in period 3 since the

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[10] Inflows have been stable in labour surplus EMEs. Since portfolio inflows were allowed in the early nineties they have been negative only in 1998-99 and 2007-08. The Indian Government is seeking innovative ways for forex reserves to contribute to infrastructure spend.

[11] Ghosh (2002) estimates $\delta = 0.114$, $\sigma = 0.152$, $\alpha = 0.225$ and $\phi = 1.420$, for the US and OECD countries. Cavoli and Rajan (2004) estimate $\delta = -0.09$, $\sigma = 0.36$ for Thailand. Thus trade effects are small and of the wrong sign, and interest elasticity is large. Estimates of aggregate demand and supply functions for India, with monthly and quarterly data for the period after 1995, show δ to be insignificant, while σ is large and significant. Aggregate supply shows negative effects of excess capacity and positive impact of external prices on WPI inflation (see section 2.3). Estimation and structural VAR based tests (Goyal and Pujari, 2005) also support the critical assumption of long-run elastic supply.

exchange rate has stabilized. Predetermined variables are set to zero, so $p_o^c = p_1 = 0$. All exogenous foreign price variables are also taken to be zero. Since some supply shocks such as the effect of weather of agricultural output can be forecast, we consider the case of the period 1 monetary policy variable v_1 responding to an expected supply shock in period 2, η_2. As a result it is possible to set $v_2 = 0$ and $\eta_1 = 0$. We drop ρ from the arbitrage equation since the risk premium is assumed not to change.

In period 1 the CB learns that an adverse supply shock will impact the economy in period 2. It responds by lowering interest rates (raising v_1) in period 1. It announces both the expected shock and its action. Agents anticipate future prices and exchange rates and understand the CB's objective function. Expectations are model consistent and are realized in equilibrium. Therefore, starting with period 2 variables, equilibrium values are derived by the method of backward induction in Appendix 1. The signs of the response of variables to policy and cost shocks are collected in Table 1.

The results imply that an anticipatory policy response (v_1) to a supply shock η_2 that lowers period 1 interest rates would raise y_1, appreciate exchange rates in both periods, thus lowering p_1^c, p_2^c and moderating the rise p_2 and fall in y_2 due to this rise. The policy takes advantage of lags in pricing to neutralize the effect of the supply shock on consumer price inflation, thus lowering the output cost of inflation targeting. In period 2 interest rates rise to cover the expected depreciation required for mean reversion. The nominal appreciation in the exchange rate is what counters the effect of the supply shock on inflation. The exchange rate appreciates despite the rise in money supply because the rise in y raises money demand. The anticipated rise in p_2 together with the fall in i_1 lowers the real interest rate and stimulates y_1, but the rise in p_2 is itself moderated by the anticipated appreciation.

Table 1: Response of variables to shocks							
Variables \ Shocks	p_2	$e_1 = p_1^c$	y_1	$e_2 = p_2^c$	y_2	i_1	$i_2 = -e_2$
v_1	+	-	+	-	-	-	+
η_2	+	-	+	-	-	+	+

The output cost is low for this strategy of inflation reduction since appreciation will shift down the supply curve reducing inflation, and the rise in demand will maintain output, for the combination of shocks v_1 and η_2. Interest rates rise in period 2 to cover the expected depreciation of the exchange rate back to its equilibrium value, thus negatively impacting period 2 output. But this effect will be lowered to the extent the equilibrium exchange rate itself appreciates, and the CB tends to smooth interest rates, and attempt to bring down the large gap that exists between domestic and world interest rates, as part of the transition to maturity and reaching potential output. The interest gap can be factored as $i - \bar{i} + \bar{i} - i^*$, with average domestic interest rates exceeding international. This policy combination can contribute to shrinking the gaps.

Lowering the interest differential enters the CB's objective function, U, to capture its aim of reducing the deviation of output below potential, and smoothing interest rates. The weight on the loss due to inflation, w, is high. Optimal v^*_1 that maximizes U rises with η_2 and falls with w (Appendix II)[12]:

2.2. Simulations

Simulations allow us to get results for longer time periods, with the full optimization model[13], without imposing any zero restrictions. The results are similar to those from the analytical derivations documented in Table 1, but with more smoothing over time. Benchmark parameter values calibrated through sensitivity analysis ($\alpha = 1$; $\sigma = 0.4$; $\phi = 0.6$; $\lambda = 0.5$; $\psi = 0.1$; $\theta = 0.1$; $\delta = 0.1$) turn out to be close to estimated values for India (section 3.3) and for Asian EMEs (footnote 10). The simulations are run for 12 periods

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[12] Substituting $\eta^e_{2} = \theta \eta_2$ in the CB's loss function, where θ is the information disclosure, differentiating with respect to θ gives the solution for θ^* or the optimal degree of information disclosure. θ^* falls with η_2 and rises with v_1. Full disclosure benefits the CB since expected period 2 inflation lowers the real interest rate and stimulates output. Expected inflation rises because producer prices adjust only with a lag. Without full disclosure, period 2 inflation may not be fully expected.

[13] The simulations modified a GAUSS code for solving for optimal monetary policy under discretion, made available by Paul Soderlind on his website http://home.tiscalinet.ch/paulsoderlind. I thank Ramkishen Rajan and Tony Cavoli for suggesting this code.

with equal unit weights put on the variables in the loss function which are taken as p and y. Three of the simulations (g1 to g3) are reported in Chart 1.

Each column in the chart reports the optimal response of p, p^c, y, e and v respectively to a period one shock. Since the variables are measured in log deviations from steady state values, a shock leads to a diversion from zero with adjustment back towards equilibrium over time. For the first two simulations, the shock is a cost shock η_1, and for the last simulation, it is a positive demand shock to y. The variance of the period 1 shock is taken to be 0.1^2. Since v now adjusts gradually over the 12 periods the responses of the other variables are also smoothed over this period.

The basic pattern of a price shock leading to a rise in v, appreciation, fall in p^c, rise and then reversion in y and p, is established. After the initial jump away from zero, adjustments lead back to the steady state over the course of the 12 periods.

Compared to the analytical results with zero values, positive coefficients for the parameters ψ and δ moderate the rise in v, the resulting appreciation, rise in y and fall in p^c; p rises more in the first few periods and then rises less. But the basic pattern remains intact in the more general model. The pattern is robust to changes in most parameters.

The policy shock adjusts fully to compensate for changes in the money demand function. If ϕ is lower, v rises rise more. A higher effect of y on p, or a rise in ψ to 0.2 leads to a smaller rise in v, a smaller appreciation, a small fall in y, p^c now remains positive through out, while p is first higher and then lower. A fall in the interest elasticity of aggregate demand σ by 0.2 to 0.4 makes v rise slightly less initially and then slightly more, with appreciation echoing this pattern. The rise in y is less; p^c is less negative, and p higher. Since the value of 0.4 is closer to empirical estimations we take this as our benchmark.
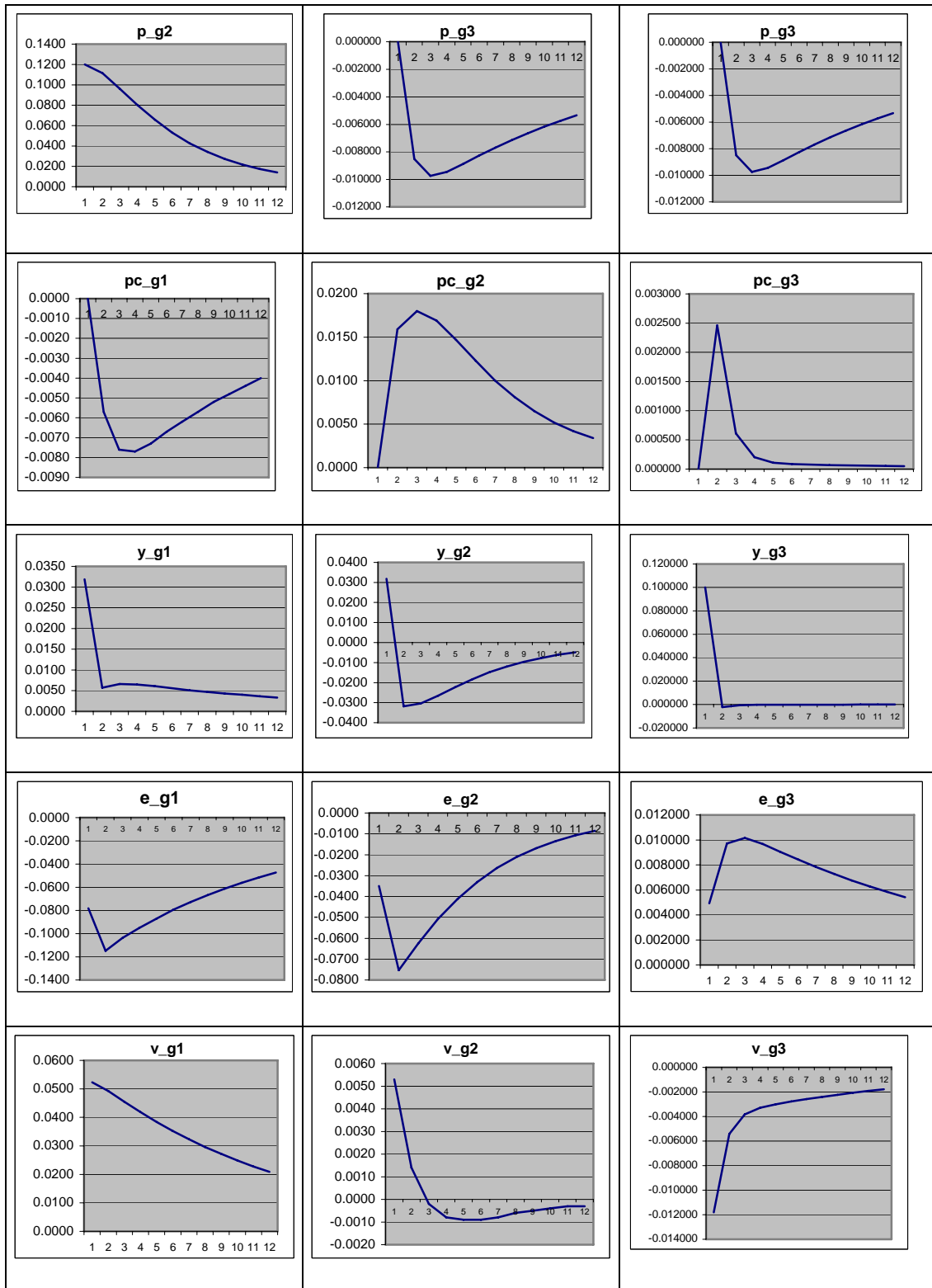
Chart 1: Impulse responses (simulations g1 to g4)
Each column except the last (g3) reports the effect of a period one cost shock of size 0.1^2 on p, p^c, y, e and v. In g1 (column 1) the parameter values are $\alpha = 1$; $\sigma = 0.6$; $\phi = 0.6$; $\lambda = 0.5$; $\psi = 0.1$; $\delta = 0.1$. In g2

(column 2) changes δ to 0.3, other parameters as in g1; g3 (column 3) has a positive output shock of variance 0.1^2, no cost shock, and other parameters as in the benchmark.

Results are sensitive to the elasticity of export demand. In g2 (column 2), as δ is raised to 0.2, the pattern changes. There is a fall in v, a smaller appreciation, fall in y, rise in both p and p^c in response to a cost shock. Appreciation is restrained since it hurts exports. But estimation rarely finds δ to exceed 0.1, and for δ = 0.1 the basic pattern continues to hold.

A positive demand shock (g3, column 3) leads to a fall in money supply. Output falls after the period 1 rise. The exchange rate depreciates; p^c is positive, and p negative. The pattern of response of variables is now different.

Therefore minimizing the *CB's loss function* leads to a *rise in money supply, in response to a supply shock. The resulting appreciation lowers prices, while output rises initially. Mean reversion occurs gradually.*

But shocks are also periods of excessive exchange rate volatility. Therefore we analyze the response of FX traders to such a policy package in section 2.4, after seeing, in the next section, how far Indian data supports assumed parameter values.

2.3 Estimation

Estimation of Indian aggregate demand and supply, for the period 1995-2004 with both monthly and quarterly data, is reported in Table 2. All variables are transformed as changes in log values, except interest rates[14].

To estimate aggregate supply, the log change in wholesale prices dwpi_t is regressed on log-lagged change in the consumer price index dcpi_t_2, US consumer price index duscpi, oil prices doil, a measure of potential output diippot, and a constant term, using monthly data. For quarterly data the potential output variable, dgdpq_pot, is based on gross domestic output, for which data is available on a quarterly basis, rather than the

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[14] All are stationary. Unit root tests done are not reported to save space. The data is sourced from the IFS (IMF) and RBI (www.rbi.org.in).

index of industrial production used with monthly data. Since there are only 36 observations with quarterly data, insignificant variables are dropped.

Table 2: Aggregate Demand and Supply in the Indian Economy

	AGGREGATE DEMAND		AGGREGATE SUPPLY	
	MONTHLY	QUARTERLY	MONTHLY	QUARTERLY
	diip_t	dip_t	dwpi_t	dwpi_t
diip_t_l	-0.496****(-5.88)	-0.362*** (-2.32)	--	--
cmr	1.464* (1.42)	-1.058*** (-2.26)	--	--
dz_t_l	-0.583 (-0.02)	-0.336 (-1.07)	--	--
dreallr	1.39**** (2.67)	--	--	--
dwpi_t	-0.963* (-1.36)	-1.396* (-1.48)	--	--
constant	-.744 (-0.73)	.025 (1.15)	0.161**(1.81)	-.004 (0.45)
realcmrqr	--	1.099***(2.33)	--	--
dcpi_t_2	--	--	0.403**(1.85)	-0.138** (-1.80)
diippot	--	--	-0.025***(2.24)	--
doil	--	--	-0.013**(-1.90)	--
duscpi	--	--	1.026****(4.34)	--
dgdpq_pot				-0.025** (-1.95)
No. of obs	115	37	115	36
F(5,109)	9.58	--	--	--
F(5,31)		5.94	--	--
F(4,110)	--	--	7.52	--
F(2,33)	--	--	--	4.49
Prob>F	0.00	0.0006	0.00	0.0189
R-squared	0.3053	0.4894	0.2147	0.2139
Adj.R-squared	0.2734	0.4070	0.1861	0.1662
Root MSE	4.0214	.03993	.55484	.00832

Note: t statistics in brackets; ****,***,**,* indicate 1%, 2.5 %, 5%, 10% significance levels respectively

To estimate aggregate demand log change in industrial production, diip_t, is regressed on its own lagged value, diip_t_1, the log change in wholesale prices, dwpi_t, the call money

rate, cmr, the real long-run loan interest rate, reallr, or the realcmr for quarterly data, one period lagged real depreciation dz_t_1, and a constant term.

Even though parsimonious specifications, as close as possible to the theoretical specifications, are estimated the R-squared, F and t statistics are good. Results are similar for both data sets. They validate the assumptions made in the theoretical section. Interest rate elasticity of output demand is high and real depreciation does not significantly affect output demand. Since India's prices and interest rates are still administered to some extent, the real long rate has a positive coefficient, while that on inflation is negative. This suggests that inflation is largely due to cost-push factors and has a negative effect on demand. Since long nominal rates do not adjust rapidly, real interest rates are low when inflation is high and demand is low, explaining the positive coefficient on real rates. The short nominal rate, cmr, has a positive coefficient in monthly aggregate demand and negative in quarterly, suggesting that monetary policy, which controls this, reacts and acts with a lag in response to shocks. The policy rate is procyclical at very short-horizons but countercyclical after a few months.

Table 3: GMM Estimation, Aggregate Supply (monthly) with Forward-Looking Variables		
	dcpi_t-1	**dwpi_t-1**
constant	-0.48 (-0.51)	0.46****(3.99)
dcpi_t	0.67****(5.57)	--
dcpi_t-2	0.36 ****(4.13)	--
dz_t-1	-16.83 ****(-2.87)	--
dwpi_t	--	-0.08 (-0.43)
dcpi_t-4	--	-0.12*(-1.50)
doil_t-2	--	0.02****(3.00)
dprod_t-1	--	-0.02***(-2.15)
No. of observations	113	111
$F_{(3,109)}$	36.21	--
$F_{(4,106)}$	--	4.43
Prob > F	0.00	0.00
Centered R^2	0.32	0.11
Uncentered R^2	0.48	0.38
Hansen J statistic	7.52	11.44

Note: t statistics in brackets; ****,***,**,* indicate 1%, 2.5 %, 5%, 10% significance levels respectively

Potential output has significant negative coefficient in both the estimated aggregate supply curves, suggesting that excess capacity made supply elastic in this period. Aggregate supply shows the effect of lagged consumer prices on wholesale price inflation, with some evidence of mean reversion in the quarterly estimate. Nominal exchange rates are not significant but may be affecting prices through the lagged CPI. Other external prices have a direct impact.

GMM estimates of monthly aggregate supply reported in Table 3, with forward-looking variables, instrumented with a large number of lagged variables, confirm the above picture. They clearly show that, as modeled in section 2, consumer prices are forward-looking, but producer or wholesale prices are not. Oil prices and improvements in productivity affect producer prices, and lagged exchange rates have a strong effect on consumer prices.

2.4. FX traders and strategic interaction with the Central Bank

FX traders arbitrage across currencies in response to expected profits. This can cause excess volatility. To understand their response to the proposed policy combination, we derive their net demand as a function of the equilibrium values obtained in Section 2.1, and examine their strategic interaction with the CB.

A trader's utility is a negative exponential of wealth W, with θ as the constant coefficient of absolute risk aversion. Their wealth is derived from trading profit and is normally distributed:

$$u(W) = -\exp(-\theta W) \tag{7}$$

It follows that the preferences, or the objective function, they maximize for period 1, can be represented as a simple function of the mean and variance of trading profit.

$$\max_{D^i} -\left[e_2^e - e_1\right]D^i - \frac{\theta}{2}\text{var}_1\left(e_2^e - e_1\right)D^i \tag{8}$$

Trading profits are given by the quantity transacted into the expected change in the exchange rate. The net demand function for period 1 obtained from maximizing (8) is:

$$D(e_1, i) = \frac{-\left(e_2^e - e_1\right)}{\theta \, \mathrm{var}_1 \, e_1} \tag{9}$$

Thus risk aversion implies that net demand is an inelastic function of the expected change in the exchange rate in that period. It rises with expected appreciation and falls with expected depreciation, and with the variance of the exchange rate. It is lower if θ is high. Summing over i traders of measure unity gives total market net demand $D(e_1)$ in period 1.

$$D(e_1) = \int_0^1 D(e_1, i) \, di \tag{10}$$

Markets must clear in equilibrium so that net demand equals net supply:

$$S(e_1) = D(e_1)$$

Substituting the values of e_2 and e_1 from equations (A7) and (A15) respectively for $v_1 = v^*_1$, net demand becomes:

$$D(e_1, i) = \frac{\left((v_1^* - \alpha y_1)/\phi\right)}{\theta \, \mathrm{var}_1 \, e_1}$$

Traders expect to profit from the appreciation in period 2, which will occur if optimal monetary policy is chosen in response to the expected supply shock. Net demand for the home currency rises in period 1 and causes the expected appreciation. Similarly expected appreciation in period 1 (equation A11) will raise net demand in period zero and cause the appreciation. Some traders who need to unwind their positions in order to rebalance portfolios will sell as the majority buys. Net sales in the next period will cause the expected reversion of the exchange rate to its mean value. If risk aversion is lower, the response will be more elastic.

Problems can arise if $v_1 \neq v_1^*$. Traders' response then depends on their expectations of the policy response. Since other periods can be analyzed similarly we focus on the expected period 1 payoffs. These are derived in Figure 1 by substituting solution values for v_1, i, e,

and p_2 in the CB and trader objective functions. From (10) the trader's optimal response to the CB's optimal policy v^*_1 in response to a supply shock η_2, is net buying (B). Since both the CB and FX traders are maximizing their objective functions, payoffs are highest in the strategy (v^*_1, B) shown as (10,10) in Figure 1. It is the unique sub-game perfect Nash equilibrium.
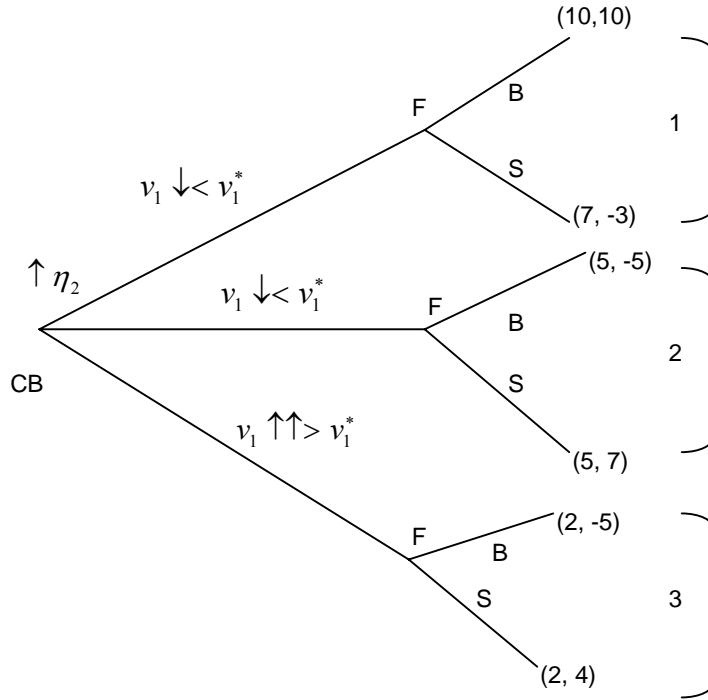
Figure 1: Payoffs to the CB and forex traders (F) under alternative strategy combinations

Figure 1 also shows the payoffs to all other strategy combinations. If traders sell when the CB plays v^*_1 they have negative returns as the currency appreciates. The CB also incurs some cost from intervention to attain its appreciation target so the payoffs to (v^*_1, S) are (7, -3). The other strategies available to the CB are to respond to η_2 by increasing v_1 above v^*_1 to v_H or decreasing it below v^*_1 to v_L. In each case FX traders decide whether to turn net buyers (B) or sellers (S) of the currency. From Table 10, if v_1 is decreased, output will fall, the interest rate will rise, and the exchange rate will depreciate. Dealers will gain more from a sell strategy compared to a buy strategy. The CB's payoffs will fall, since it has to intervene in order to appreciate the currency. This explains the payoffs in the central section (2) of Figure 1.

However, over expansion of the money supply is possible if v_1 is increased too much above v^*_1. If output is near full capacity, there is a large revenue deficit already boosting demand, the interest elasticities σ, ϕ are low, and the response of prices to output ψ is high even a small rise in v_1 may raise it much above v^*_1. An attempt to lower interest rates would then raise inflationary expectations and result in sharp exchange rate depreciation, making a defensive rise in interest rates necessary. The payoffs are lowest in this case (section 3 of Figure 1).

Traders are willing to support the policy combination 1, delivering the appreciation required to moderate the supply shock. Problems arise if v_1 differs from v^*_1. Traders act against policy in 2 and 3, enhancing volatility, and forcing intervention. Even so, the policy combination 2 of Figure 1 is most often found in practice. Conservative CBs prefer median low risk payoffs, especially when uncertainties are high, or there is fiscal fragility. If the EME is a democracy with low per capita income, even if the CB is not independent, the government will impose conservative inflation preferences. Or the Government may alternate between 1 and 3 or 1 and 2. Uncertainty in payoffs can lead to use of mixed strategies. But then the CBs experience will be that markets create volatility, and it is necessary to intervene and otherwise repress markets. FX players will follow a *maximin strategy* in response to the CB who is the first mover. That is, they will pick the strategy that gives them the highest possible payoff given that the CB's strategy makes traders' payoffs as low as possible.

The CB only has to implement optimal v^*_1 then it will be able to target the interest rate to the domestic cycle and counter supply shocks such as η. Operating one instrument v achieves desired movements in i, e, y and p. It may not need to intervene in FX markets at all, unless it is required to maintain the equilibrium level of the exchange rate under excessive temporary inflows. Intervention or signaling may also be required to dissipate the activity of noise traders who make systematic errors and try to derive information by observing market price and the activity of informed traders. Setting bounds on the exchange rate to limit variance, will lower returns to and attract fewer such noise traders (Jeanne and Rose, 2002). In thin markets and with high reserves, such CB actions can be

highly effective. If the CB does not want to announce its policy response or an explicit exchange rate target, it can allow traders to infer the direction of CB actions. This will take time, so that changes will be slower. The risk of over-shooting is reduced, but the CB has to put in more effort.

Indian policy choices and prospects are analyzed, using the basic model and the game, in the next section.

3. Policy choices

A benchmark real effective exchange rate (REER) was set after the devaluations of the early nineties, in order to maintain a competitive real exchange rate, encourage exports, and allow absorption of excess labour. But the nominal exchange rate showed bursts of high volatility[15] following periods when it was almost static. The response was a sharp rise in interest rates, which triggered an industrial recession and sustained it over 1997-2001. Pre-reform monetary policy followed a money supply targeting approach. But after the credit squeeze had a persistent effect on the level and term structure of interest rates the Reserve Bank of India (RBI) shifted to a multiple indicator approach. A new RBI Governor, Bimal Jalan, demonstrated, through staggered placement of government debt, that it was possible for interest rates to come down despite high fiscal deficits and committed to a soft interest rate regime but also to preventing excess volatility of the rupee (Jalan, 2003). So there were reversals during periods of exchange rate volatility, sometimes induced by fluctuations in foreign capital inflows, for example from mid-May to early August 2000. A number of short-term supply shocks also occurred and as our model implies, monetary tightening in the presence of supply shocks sustained the slowdown. Steady softening of nominal interest rates occurred only after February 2001, as world interest rates fell. The liquidity adjustment facility (LAF) implemented around that time helped fine-tune domestic liquidity and short-term interest rates drifted downwards. The absence of a reversal since 2000, contributed to an upswing in activity, as benign

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[15] Detailed means, volatilities, and correlations are available in a project report (Goyal, 2005). The analysis in this section is based on various bi-annual monetary policy statements issued in April and October every year by the RBI, speeches by RBI governors and data available on the RBI's website www.rbi.org.in and on Goyal (2002, 2005).

markets expectations strengthened. Bursts of high volatility in exchange rates were absent during this period.

Sharp defensive rise in interest rates after shocks amplified volatility. In our model, low interest elasticities imply v^*_1 is low, if there is a perception that interest elasticities are lower than they actually are, it would make $v_1 < v^*_1$. Interest rates were largely administered and had been only recently freed; interest elasticities were thought to be low. The impact of reforms on elasticities, in particular the impact of the interest rate on consumer spending, was not yet fully understood. In addition, political pressures made w, the weight given to inflation in the loss function, high. Although the RBI had greater autonomy after the reforms, it was still not fully independent of the ministry of finance, which conveys the political pressures. The fiscal deficit was thought to be large. There were doubts about the durability of capital inflows and fears of a possible reversal, which would have implied a shock to the risk premium, and a perception that markets create excess volatility. Finally, risk aversion or the fear of being caught in policy combination 3 pushed the RBI to adopt combination 2 (Figure 1). It followed combination 1 only after 2001, whereas over 1996-2000 it repeatedly reverted to combination 2. The chance, of falling world interest rates more than conscious design, led to combination 1.

Goyal (2005) shows that although post reform foreign financial inflows, measured by the surplus on the capital account rose, their volatility fell. The volatility of the current account deficit (CAD), however, rose, suggesting it was policy that was magnifying the volatility of the inflows, and hindering their absorption[16]. Although some agricultural liberalization and falling world food prices did reduce the political pressures that had raised food support prices and inflation, exchange rate policy was not systematically used to moderate the effect of the typical EME supply shocks: oil price shocks and failure of rains.   The results generalize to countries that share the crucial feature of high productivity growth releasing labor, thus allowing an elastic supply response[17].

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[16] FX reserves rose to over 200 billion US dollars in 2007, compared to a paltry 5 billion in 1990-91. 30 billion dollars were accumulated in just 18 months over January 2002 to August 2003. Arbitrage occurred at the short end since Indian short real rates were kept higher than US rates.

[17] See Goyal and Jha (2004) for a systematic comparison of macropolicy choices in China and India based on the similarities of their labor market structure and the differences in their political structure. Without

For the RBI to keep $v_1 = v^*_1$, restraint on revenue deficits and populist expenditure is necessary. Political and institutional features result in fiscal-monetary coordination such that the economy remains on an elastic stretch of the aggregate supply curve. Fiscal populism pushes monetary authorities towards conservatism in order to reduce inflationary expectations. But since the populism raises inefficiencies and therefore costs it shifts up the supply curve, while monetary tightening reduces demand, resulting in a large negative effect on output for little gain in reduced inflation. The Fiscal Responsibility and Budget Management (FRBM) Act 2003 put some restraint on fiscal laxity, but did not really address the need to change the composition of government expenditure away from consumption and towards investment in infrastructure and human capital, and reduce waste. However, more openness may aid monetary policy break out of past traps.

Since with high growth there is a continual inflow of foreign capital and the RBI keeps intervening to accumulate reserves, achieving v^*_1 is just a matter of finding the right balance between accumulation and sterilization. As long as fundamentals improve, markets help CBs achieve their objectives[18], while overreaction is moderated, and the risk premium lowered. There is evidence that while currency crises adversely affect trade, limited fluctuation in exchange rates do not have a large effect on trade (McKenzie 2004). If limited volatility helps prevent crises and lower interest rates, it may even benefit trade.

With forward looking agents a short-run tradeoff between inflation and output variability arises only if inflation is positive due to a cost shock, since excess demand can be removed without output cost. Forward-looking monetary policy can use its knowledge of structure to abort the inflationary process. During a catch-up period of rapid productivity growth potential output exceeds output. As supply shocks are the dominant source of inflation, optimal policy should aim to achieve an inflation target only over the medium-term by which time temporary supply shocks have petered out, or been countered by

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democratic pressure China was able to follow a stop-go policy with large swings in inflation. The suggested exchange rate regime would help it to moderate these and deepen its financial and FX markets.

[18] Ito and Park (2004) find an intermediate regime, such as a basket band regime, to be compatible with other monetary policy goals, such as inflation targeting, under a variety of shocks.

exchange rate policy, changes in tax rates, or improvement in efficiencies. Inflation targeting itself will prevent the inflationary wage-price expectations from setting in that can imply a permanent upward shift in the supply curve from a temporary supply shock. Monetary policy has to tighten only if there is excess demand.

The lag from the exchange rate to consumer prices is the shortest (Svensson, 2000), especially if commodities dominate imports. If two-way movement of the nominal exchange rate is synchronized with temporary supply shocks, and the exchange rate appreciates with a negative supply shock, food and intermediate goods prices fall. This pre-emption of the effect of temporary supply shocks on the domestic price-wage process, differs from fixing the exchange rate to bring down high levels of inflation, which often leads to real appreciation and ends in a crisis, as in Latin American exchange-based stabilization episodes. Building in a rule whereby there is an automatic announced response to an expected supply shock avoids the tendency to do nothing until it becomes necessary to over-react. Actions linked to exogenous shocks also avoid moral hazard.

4. Conclusion

We show in a simple open economy macromodel, calibrated to the typical institutions and shocks of an emerging market economy, that a monetary stimulus preceding a temporary supply shock can abort inflation at minimum output cost, since of exchange rate appreciation, accompanying a fall in interest rates and rise in output. The policy helps to maintain some exchange rate flexibility while permitting a counter-cyclical interest rate. It creates correct incentives for FX traders who support it. Model and parameter uncertainty, status-quoism, risk-aversion, and the lack of supporting fiscal policy is the reason the opposite policy combination is often chosen. With optimal policy CB intervention in FX markets may not be required at all.

The analysis is used to examine Indian macropolicy decisions. The policy is compatible with political constraints, but further institutional changes can make it self-enforcing, deepening markets and coordinating them with macroeconomic policy towards optimal outcomes. The economy did well when policy approached the optimal combination.

Limited volatility in exchange rates improves the structure of incentives making it possible to achieve four objectives. First, stimulate the real sector through a real exchange rate that follows its trend competitive value. Second, smooth nominal interest rates and suit them to the domestic cycle and towards achieving long-run external balance; so that eventual current account surpluses follow initial deficits. Third, an appreciation is an antidote to price shocks coming from food, oil and other intermediate inputs, which are the typical temporary supply shocks the economy faces. For example, when the underlying trend is that of nominal appreciation, a steeper short-term appreciation can reduce inflation, thus allowing interest rates to fall and contributing to control of inflation. The fourth benefit is stability in the external sector, and a fall in the likelihood of currency crises. Limited two-way movement of the exchange rate, creates incentives to hedge, reduces noise trader entry, and contributes to the deepening of FX markets.

Appendix I

The assumptions imply $i_2 = -e_2, p_2 = p_1^c$ since $e_3 = 0$ because of mean reversion in exchange rates and $p_1 = 0$. Also using equations (1) to (5) we can solve for y_2 and e_2 as functions of p_2, the inherited producer price:

$$e_2 = \frac{(\alpha\sigma - 1)p_2}{(\alpha\sigma + \phi)} \tag{A1}$$

$$y_2 = \frac{-\sigma(1+\phi)p_2}{\alpha\sigma + \phi} \tag{A2}$$

Reverting to period 1, the aggregate demand function reduces to:

$$y_1 = -\sigma\left[i_1 - p_2^e\right] \tag{A3}$$

The money market equilibrium gives:

$$i_1 = \frac{\alpha y_1 - v_1}{\phi} \tag{A4}$$

Arbitrage (3) gives, using (A4):

$$e_1 = e_2^e - \frac{(\alpha y_1 - v_1)}{\phi} \tag{A5}$$

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Price dynamics from the Phillips curve, remembering $p_o^c = p_1 = 0$ give:

$$p_2 = (1 - \lambda)e_1 + \psi y_1 + \eta_2 \tag{A6}$$

Since $\lambda \sim 0$ and $\psi \sim 0$, equation (A6) simplifies further to $p_2 = e_1 + \eta_1$. Substituting for e_1 and y_1 and imposing the condition that $e_2^e = e_2$ and $p_2^e = p_2$ so that expectations are realized gives:

$$p_2 = \frac{(\alpha\sigma + \phi)\phi(1 + \alpha\sigma)\eta_2 + (\alpha\sigma + \phi)v_1}{\phi(1 + \phi + \alpha\sigma(1 + 2\phi + \alpha\sigma))} \tag{A7}$$

Substituting (A7) in the equations for e_1 and y_1 allows us to solve for these variables as functions of the exogenous parameters and shocks. Calling the denominator of Equation (A7) ϕD, y_1 can be written as:

$$y_1 = \frac{\sigma\phi(\alpha\sigma + \phi)((1 + \alpha\sigma)\eta_2 + ((\alpha\sigma + \phi) + \sigma\phi D)v_1)}{(1 + \alpha\sigma)D} \tag{A8}$$

$$e_1 = \frac{-(1 - \alpha\sigma)p_2}{\alpha\sigma + \phi} - \frac{\alpha y_1}{\phi} + \frac{v_1}{\phi} \tag{A9}$$

Equation (A8) implies that

$$\frac{\delta y_1}{\delta \eta_2} > 0 \ \ and \ \ \frac{\delta y_1}{\delta v_1} > 0$$

Equation (A9) implies that

$$\underset{<0 \quad <0 \qquad >0}{\frac{\delta e_1}{\delta v_1} = \frac{\delta e_2}{\delta v_1} - \frac{\alpha\delta y_1}{\phi\delta v_1} + \frac{1}{\phi} < 0}$$

$$\underset{<0 \qquad <0}{\frac{\delta e_1}{\delta \eta_2} = \frac{\delta e_2}{\delta \eta_2} - \frac{\alpha\delta y_1}{\phi\delta \eta_2} < 0}$$

From equations (A9) a net fall in i_1 requires v_1 to exceed αy_1 and from equation (A5) this implies an expected appreciation of e_2. The condition for e_2 to actually appreciate $\alpha\sigma < 1$ is also required for v_1 to rise (Appendix II). The interest elasticity of output and income elasticity of money demand must not be too large. Estimated parameters satisfy these conditions. The response of p_2, e_2 and y_2 to the shocks can be readily derived from equations (A7), (A1) and (A2).

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Appendix II

Inserting equilibrium values of the variables in the CB's objective function and differentiating with reference to v_1, gives the optimal value v^*_1 of the policy variable v_1

$$U = Max_{V_1} - \frac{1}{2}\left\{\sum_t (i_t - i^*)^2 + wp_2^2\right\}$$

$$v_1^* = -\left(\frac{\Lambda\phi D + \Omega(\alpha\sigma + \phi)\phi(1+\alpha\sigma)\eta_2}{(\alpha\sigma + \phi)(\Gamma + \Omega)}\right)$$

$$\text{Where } \Lambda = \frac{(\alpha\sigma - 1)^2}{(\phi(1+\alpha\sigma))^2}$$

$$\Omega = \Gamma + X\left(\frac{\alpha\sigma + \phi}{\phi D}\right)$$

$$\Gamma = \frac{(\alpha\sigma - 1)\alpha\sigma\phi}{(\phi(1+\alpha\sigma))^2}$$

$$X = \frac{(\alpha\sigma\phi)^2}{(\phi(1+\alpha\sigma))^2} + \left(\frac{\alpha\sigma - 1}{\alpha\sigma + \phi}\right)^2 + w$$

The denominator of v^*_1 is positive since it reduces to $\frac{X(\alpha\sigma + \phi)}{\phi D} > 0$. Therefore $v_1^* > 0$ if

the numerator of v^*_1 is positive. This requires $\alpha\sigma < 1$ so that $\Gamma < 0$ and $|\Gamma| > X\frac{(\alpha\sigma + \phi)}{\phi D}$

so that $\Omega < 0$ and $|\Omega(\alpha\sigma + \phi)\phi(1+\alpha\sigma)\eta_2| > \Lambda\phi D$.

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