Dollarization of Liabilities, Net Worth Effects, and Optimal Monetary Policy*

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Abstract

We consider optimal interest rate policies in an open economy model with balance sheet effects à la Bernanke-Gertler (1989) and overlapping wage contracts à la Calvo (1983). The optimal "flexible inflation targeting" policy under discretion involves a floating exchange rate and partial reaction of home interest rates to external shocks. This policy yields higher welfare than a policy of strictly fixed nominal exchange rates. Other optimal inflation targeting policies under discretion also dominate fixing. These results hold in spite of the credibility advantage of fixing and the presence of dollar liabilities and balance sheet effects.

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1. Introduction

Recent crises in emerging markets have caused the profession to reevaluate received wisdom about exchange rate regimes. In particular, analysis of the connection between imperfections in the financial sector and exchange rate policy has risen to the top of the research agenda.[1] There are strong reasons for this focus. Both casual observation and formal econometric analysis[2] suggest the existence of an empirical link between financial turmoil and currency crashes. Moreover, whether or not central banks should defend their currencies against a speculative attack has emerged as a key and controversial aspect of the policy response, and this choice is increasingly governed by possible effects on the financial sector. Some analysts, such as Furman and Stiglitz (1998) and Radelet and Sachs (1998) have called for monetary expansion and depreciation in response to adverse shocks, reaffirming the validity of prescriptions derived from the conventional Mundell-Fleming analysis. Others, such as Calvo (2000), Dornbusch (1999) and Stein et al (1999), have argued that in the presence of sizeable dollar debts a sudden depreciation may do more harm than good.

In a previous paper (Céspedes, Chang, and Velasco 2000, henceforth CCV) we made an attempt to identify the role of financial imperfections in the design of exchange rate policy within a dynamic stochastic model with explicit micro-foundations. CCV's model focuses on a small open economy that borrows in the world market to finance investment. Crucially, information frictions imply that the economy's borrowing, and hence aggregate demand, is constrained by its *net worth*, as emphasized by Bernanke and Gertler (1989). Exchange rate behavior may then exacerbate net worth effects because domestic residents borrow in foreign currency, while domestic income depends on the value of domestic money; or, in Calvo's (1999) parlance, the economy's liabilities are *dollarized*. In such a scenario a devaluation exerts, in addition to its conventional effects, a contractionary effect hitherto ignored in conventional literature. By weakening the economy's balance sheet, a devaluation exacerbates the effect of financial frictions, pushing down aggregate demand, output, and employment.

CCV's analysis yields at least two suggestions for the theory of exchange rate regimes. First, under reasonable parameter values, the coexistence of a net worth channel and liability dollarization may well imply a potentially contractionary channel of devaluation. Second, and somewhat surprisingly, the existence of such a

[1] See Chang and Velasco (2000) for a detailed discussion of recent developments on this front.
[2] The standard reference is Kaminsky and Reinhart (2000).

channel does not justify defending the exchange rate against exogenous shocks, in particular real shocks from abroad. The reason is that adjustment to an exogenous shock requires a *real* devaluation, which will take place regardless of nominal exchange rate behavior. And it is real, not nominal, devaluation which determines the net worth effect. Hence the unwanted effect of real devaluation on balance sheets will take place one way or the other, and exchange rate policy can only affect the manner and timing of the adjustment. In fact, under CCV's assumptions, fixed exchange rates turn out to be more contractionary than flexible rates, since the former imply that a real devaluation can only take place via price deflation which, if nominal wages are rigid, exacerbates the contraction in employment and output.

To obtain analytically tractable closed-form solutions, in CCV we imposed very strong and simple assumptions about monetary policy. We compared a completely fixed exchange rate regime against a flexible rate regime that kept the price level fixed. Such a focus left unanswered the question of what is the *optimal* exchange rate regime in the presence of balance sheet effects and liability dollarization. That question can only be answered by specifying a social loss function and computing the optimal policy function under alternative shocks.

A related issue is that of *credibility* of policy –that is, ensuring that the monetary authority will not want to renege on an ongoing date and state contingent plan for the setting of its instruments. Optimal policy is meaningless unless it is also credible; this means that, in the absence of commitment devices, the relevant optimal policy is that computed under discretion. On the other hand, it is often argued that fixed exchange rates enjoy the advantage of serving as a commitment device. This is relevant insofar as our result in CCV, that price-targeting rules are superior in welfare terms to exchange rate-targeting rules, could be meaningless if the latter are for some reason more credible than the former. The appropriate comparison then would be that of a fixed exchange rate regime against a credible (discretionary) policy of flexible rates.

The purpose of the present paper is to shed light on these questions. We study the determination of the optimal monetary and exchange rate policy with and without commitment, and compare its implications (including welfare implications) to those of fixed exchange rates. Since it is key to tackle these questions in the presence of financial imperfections, our framework is a version of the CCV model, extended to introduce money demand explicitly and to allow for staggered nominal wage-setting à la Calvo (1983).

To characterize optimal policy we assume that the central bank minimizes social loss, which is taken to be a function of income, inflation, and possibly real exchange rates. We compute the optimal policy with commitment, so that the monetary authority decides at the start of all time on the optimal policy path. More importantly, we also compute optimal policy under discretion, allowing the central bank to reoptimize and choose current policy at every point along the way. Under discretion and assuming rational expectations, market behavior must be consistent with future central bank strategy, which itself responds to market behavior. The outcomes of this interaction are given by the time consistent equilibrium of the model, defined as in Oudiz and Sachs (1985) and Svensson (2000).

Under discretion, we consider three possibilities: the benchmark *flexible inflation targeting*, in which inflation and output fluctuations matter for social loss; *strict inflation targeting*, in which social loss depends only on inflation; and *flexible-inflation–cum-real exchange-rate targeting*, in which real exchange rate fluctuations are also present in the social loss function. We study the dynamic outcomes under the three discretionary regimes as well as under fixed exchange rates. Finally, we compare the social loss under commitment to the social loss under each discretionary regime, and against the loss under fixed rates.

A main finding is that when the policymaker engages in flexible inflation targeting, whether under commitment or discretion, monetary policy relies on large changes in nominal and real exchange rates to deal with foreign shocks, a result that is similar to that obtained by Svensson (2000) in a very different model. Exchange rate flexibility is effective in stabilizing output fluctuations in our model, in spite of the presence of balance sheet effects and liability dollarization, and optimal policy exploits that effectiveness.

A second result is that fixed rates imply a larger loss not only than optimal policy under commitment, but than each of the three discretionary regimes. The gains in output stabilization outweigh the losses from higher wage inflation. Hence our model simulations provide no support for those that argue that, while an idealized floating regime might be desirable, real-life floating under discretion (and the attendant higher inflation) render a simple fix superior in terms of welfare.

The quantitative results of the paper are also useful in assessing the validity of some commonly-made claims about why emerging market countries "float the way they do," raising nominal interest rates in response to adverse shocks and apparently engaging in pro-cyclical monetary policy.[3] We find below that in a policy of pure fixing the required nominal rate increase is smaller, when responding to adverse export and foreign interest rate shock, than under discretion and flexible

[3] See Calvo (2000), Calvo and Reinhart (2000) and Stein et al (1999).

inflation targeting. A short-sighted analysis would interpret this as evidence of "fear of floating." But that interpretation is wrong for two reasons. First, because inflation is higher under floating, and hence the nominal rate is an uninformative indicator of the policy stance. Indeed, correcting for expected inflation reveals an expansionary, not deflationary, interest rate policy under flexible inflation targeting. Second, because the optimal policy rule [4] also adjusts the home interest rate down whenever investment is below its steady state level. Since investment falls persistently after a bad shock from abroad, the initial rise in the nominal rate is typically very short-lived, and often does not go beyond an initial impact period. In short, highly variable nominal interest rates, or nominal rates that rise when adverse shocks hit, are not an indication of "fear of floating."

The paper is organized as follows. Section 2 describes the economic environment. Section 3 computes benchmark optimal policy under discretion. Perfect commitment and fixed exchange rates are discussed and compared with the discretionary, flexible rate cases are discussed in Section 4. Section 5 studies alternative specifications of the central bank objective function, and Section 6 concludes.

2. The Model

As already mentioned, our basic environment is taken from CCV, extended to explicitly include money demand and to allow for overlapping wage contracts of the Calvo (1983) type. For the sake of brevity, here we only sketch the main aspects of the model and describe the two extensions just mentioned. For a more detailed exposition, the interested reader is referred to CCV.

We focus on a small open economy that produces a single good using domestic labor and domestic capital. These two factors of production are owned by distinct agents called workers and capitalists. Workers consume and capitalists invest an aggregate of the home good and a single imported good. For simplicity, capitalists are assumed to consume only imports.

A crucial aspect of the model is that capitalists can invest in excess of their own net worth by borrowing abroad but, because of informational asymmetries, the cost of borrowing exceeds the world interest rate and depends on the ratio of net worth to investment. Hence the model features balance sheet effects of the kind stressed by Bernanke and Gertler (1989) that may be quantitatively important.

[4] Again under discretion and flexible inflation targeting.

2.1. Domestic Production

The home good is produced by competitive firms with a common Cobb Douglas technology which, in the neighborhood of the steady state, can be written as

$$y_t = \alpha k_t + (1-\alpha) l_t, \;\; 0 < \alpha < 1 \tag{2.1}$$

Here and in the rest of the paper, lowercase letters denote (except when noted) percentage deviations of the corresponding uppercase variables from their non-stochastic steady state levels[5]; for instance, if Y_t denotes the level of output in period t and Y its steady state level, $y_t = (Y_t - Y)/Y$. Hence 2.1 is simply a log-linear version of the production function $Y_t = AK_t^a L_t^{1-\alpha}$, where K_t and L_t denote capital and labor inputs in period t.

As in Obstfeld and Rogoff (2000), workers are heterogenous. Correspondingly, L_t is assumed to be a CES aggregate of the services of the different home workers, and the market for labor exhibits monopolistic competition as in Dixit and Stiglitz (1977). The representative firm, however, takes all prices as given, and chooses output and factor demands to maximize profits in every period. The main implication is that, in equilibrium, factor prices must equal marginal productivities, which (in percentage deviations from steady state) can be expressed as:

$$r_t - p_t = y_t - k_t \tag{2.2}$$

$$w_t - p_t = y_t - l_t \tag{2.3}$$

where p_t denotes the price of the home good, r_t the rental rate of capital, and w_t the *aggregate* wage (that is, W_t is the minimum cost of obtaining a unit of L_t), all expressed in terms of the domestic currency (the *peso*).

The solution to the representative firm's problem also implies a downward sloping demand curve for each worker's labor. Such a demand schedule is described later, when we discuss workers and the maximization problem they face. Finally, firm profits are zero in equilibrium.

2.2. Capitalists

Capitalists finance investment with their own net worth and with foreign loans. However, because of informational asymmetries, foreign borrowing is subject to agency costs of the kind emphasized by Bernanke and Gertler (1989). This is the key ingredient for the model to feature balance sheet effects.

[5] See CCV for a proof of the existence and uniqueness of the steady state.

In every period, capitalists must invest for next period's capital, which is assumed to be a Cobb Douglas aggregate of home goods and imports. Imports have a fixed price in terms of a world currency, called the *dollar*. The Law of One Price holds and implies that the peso price of imports is equal to the nominal *exchange rate*. The implication is that the peso price of capital satisfies

$$q_t = \gamma p_t + (1-\gamma)s_t \tag{2.4}$$

where γ is the share of home goods in the Cobb Douglas aggregator and s_t is the nominal exchange rate.

To finance investment, capitalists use their net worth and also borrow from a world capital market where the *safe* interest rate for dollars between t and $t+1$ is random but known at t. However, the cost of borrowing abroad will be higher than the world interest rate because of informational problems. We follow Bernanke, Gertler and Gilchrist (1998) and assume that the yield on investment is subject to idiosyncratic shocks that can be monitored by lenders only at a positive cost. This results in a costly state verification problem as in Townsend (1979) and Williamson (1987). The optimal contract to deal with this problem implies that there will be a divergence between the expected return on investment and the world interest rate, which can be written as:

$$\eta_{t+1} = [{}_t(r_{t+1} + k_{t+1} - s_{t+1}) - (q_t + k_{t+1} - s_t)] - \rho_t \tag{2.5}$$

For any variable z_{t+j}, the expression ${}_t z_{t+j}$ will denote the expectation of z_{t+j} conditional on period t information. Hence, in the RHS of 2.5, the term in square brackets is the expected *dollar* return on capital, given by the (log) difference between the dollar revenue from capital investment and the dollar cost of the investment. On the other hand, ρ_t is the world interest rate on dollars loans between t and $(t+1)$, expressed as a difference from its steady state value. η_{t+1} thus represents the agency costs associated with external finance or, for short, a *risk premium.*

In turn, the optimal contract implies that

$$\eta_{t+1} = \mu(q_t + k_{t+1} - p_t - n_t) \tag{2.6}$$

where (close to the steady state) μ is a positive constant, and n_t is the capitalists net worth, expressed in terms of home goods. In words, 2.6 says that the risk premium is higher the larger the value of investment relative to net worth.

That investment is financed via foreign loans and net worth implies that

$$q_t + k_{t+1} = \omega(s_t + d_{t+1}) + (1-\omega)(p_t + n_t) \tag{2.7}$$

where d_{t+1} is the amount borrowed at t and due for repayment at $(t+1)$, and ω is the steady state ratio of foreign borrowing to the dollar value of investment.

Next we describe the evolution of net worth. At the beginning of each period, capitalists collect the income from capital and settle their foreign debts. Then, a fraction $(1-\delta)$ of the capitalist population dies and is replaced by new capitalists. The dying capitalists consume their wealth; to simplify, we assume that they only consume imports. Consequently, n_t is the aggregate net worth of the surviving capitalists, and its evolution is given by

$$\begin{aligned} n_t &= \chi(r_t + k_t - p_t) - (1-\chi)(\rho_{t-1} + s_t - p_t + d_t) - \zeta\eta_t \\ &= \chi y_t - (1-\chi)(\rho_{t-1} + s_t - p_t + d_t) - \zeta\eta_t \end{aligned} \tag{2.8}$$

where χ and ζ are positive constants that depend on the steady state. Intuitively, net worth increases with capital income and falls with debt repayments due at t. In addition, the term $\zeta\eta_t$ captures the fact that agency costs, which are directly related to the risk premium, raise the cost of servicing the debt due at t, and hence reduce net worth.

The second line of equation 2.8 implies that, *ceteris paribus*, a *real* devaluation of the peso (an increase in $s_t - p_t$) reduces net worth by increasing the relative burden of debt due at t. This is the crucial aspect of the model in CCV and implies that, in contrast with conventional analysis, a devaluation may have contractionary effects.

2.3. Workers

As mentioned earlier, labor services provided by individual workers are imperfect substitutes of each other. Consequently, each worker enjoys some monopoly power over the services he provides and, as in CCV, the labor market is monopolistically competitive as in Dixit and Stiglitz (1977). We depart from CCV here, by assuming that, as in Calvo (1983) only a random subset of the workers can set a new nominal wage each period. Moreover, we model money demand explicitly, which is useful to allow for different specifications of monetary policy. Because of these changes, we will be more detailed in our discussion of workers than in the rest of the model.

Workers are indexed by $i \in [0,1]$, and worker i's preferences are given by the expectation of

$$\sum_{t=0}^{\infty} \beta^t \left[\log C_{it} - \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{1}{\nu}\right) L_{it}^{\nu} + \left(\frac{1}{1-\phi}\right)\left(\frac{M_{it}}{Q_t}\right)^{1-\phi} \right] \tag{2.9}$$

In this expression C_{it} is an aggregate of home goods and imports; note that for simplicity we assume the same Cobb Douglas aggregator as the one relevant for investment, which implies that the peso price of consumption is Q_t. The variable L_{it} denotes i's supply of labor and M_{it} his peso holdings at the end of period t. Hence 2.9 simply says that worker i enjoys consumption and money holdings, and dislikes working.

Worker i's choices include what to consume, how much to charge for the labor he supplies, and how many pesos to hold. In addition, each worker will hold a portfolio of securities, as will be described shortly. His constraints are of three types. First, he faces a downward demand curve for his labor services:

$$L_{it} = \left(\frac{W_{it}}{W_t}\right)^{-\sigma} L_t \tag{2.10}$$

where W_{it} is the peso price of i's labor services, that is, i's wage rate. As in Dixit and Stiglitz (1977), the worker is small enough so that he takes the evolution of W_t and L_t as given.

The second constraint is that, as in Calvo (1983), worker i sets wages in pesos, and he can change his wage in period t only with some probability $(1-\theta)$. Hence, with probability θ, his nominal wage must be the same as in the previous period, and it is assumed that he must satisfy any demand forthcoming (as given by 2.10) at that wage.[6]

Third, worker i is restricted by his budget constraint. Note that, because different workers change wages at different times, workers are subject to idiosyncratic uncertainty. We assume that workers cannot borrow from abroad to smooth such uncertainty. However, and following Woodford (1996), we assume that workers can trade enough contingent securities among themselves so as to, in effect, insure completely against idiosyncratic shocks. This implies that the flow budget

[6] More precisely, the worker will provide labor elastically as long as the real wage is no smaller than the marginal disutility of working; beyond that labor would be rationed. In what follows we assume that we are always in the non-rationing range. This can be ensured by considering exogenous shocks that are not "too large."

constraint of worker i can be written as

$$Q_tC_{it} + M_{it} + \ {}_t(\Delta_{t,t+1}H_{i,t+1}) = W_{it}L_{it} + M_{i,t-1} + H_{it} + T_t \tag{2.11}$$

where T_t is a peso transfer from the government, H_{it} is the peso value, at t, of the portfolio of contingent securities chosen at $(t-1)$, and $\Delta_{t,s}$ is the *pricing kernel*, such that the value at t of a portfolio delivering the random payoff H_s in period $s \geq t$ is ${}_t(\Delta_{t,s}H_s)$.

As discussed by Woodford (1996), under our assumptions (together with a technical assumption to rule out Ponzi games), the budget constraint can be written in present value form. Assuming, in addition, that workers have identical initial wealth, it follows that they will completely pool their idiosyncratic risk, and choose identical consumption plans and peso holdings.

One consequence is that the pricing kernel is given by the marginal rate of substitution between consumption at different dates and states:

$$\Delta_{t,s} = \beta^{s-t}\frac{Q_tC_t}{Q_sC_s}$$

where C_t denotes the consumption level common to all workers in period t. This implies, in particular, that the *nominal interest rate* at t, which we denote by i_t', must satisfy:

$$\frac{1}{1+i_t'} = \ {}_t\Delta_{t,t+1} = \beta \ {}_t\left(\frac{Q_tC_t}{Q_{t+1}C_{t+1}}\right) \tag{2.12}$$

as the inverse of $(1+i_t')$ is the price at t of a sure peso at $t+1$.

Another consequence is that peso demand is given by

$$\left(\frac{M_t}{Q_t}\right)^{-\phi} = (\frac{1}{C_t})\frac{i_t'}{1+i_t'} \tag{2.13}$$

which has the familiar interpretation that the marginal rate of substitution between money balances and consumption must equal its relative cost.

We assume that pesos are held only by workers and that the lump sum transfer T_t is the only way in which pesos are introduced in the economy. Hence the supply of pesos satisfies $M_t = M_{t-1} + T_t$. Then, adding up 2.11 over i, and recognizing the fact that the net supply of contingent securities is zero, implies that

$$Q_tC_t = W_tL_t \tag{2.14}$$

In other words, the value of workers' consumption in every period must equal the aggregate wage bill.

Note that, log-linearizing 2.12 and 2.14 around the steady state, and using 2.3, the deviation of i'_t from its steady state level can be written as

$$i_t = \ {}_t y_{t+1} - y_t + ({}_t p_{t+1} - p_t) \tag{2.15}$$

which is an equation of the Fischer type.

Finally, worker i must decide what wage to set in period t, assuming he is allowed to. This is a tedious problem discussed at length by Woodford (1996). The upshot is that the evolution of the aggregate wage is given by:

$$w_t - w_{t-1} = \left[\frac{1-\beta\theta}{1+\sigma(\nu-1)}\right]\left[\frac{\nu(1-\theta)}{\theta}\right] l_t + \beta \ \ ({}_t w_{t+1} - w_t) \tag{2.16}$$

This is a wage Phillips curve: wage inflation increases with expected future wage inflation as well as with labor employment. Intuitively, the reaction of the current aggregate wage to labor demand pressure is faster if nominal wages are less rigid, as given by a smaller θ.

2.4. Competitive Equilibrium

To define equilibrium it remains to impose market clearing for home goods. Under our assumptions, domestic expenditure in home goods is a fixed fraction of final home expenditures. In addition, the home good can be sold to foreigners. As in Krugman (1999) and CCV, we assume that the value of home exports in dollars is exogenous. Clearing of the market for home goods then implies

$$p_t + y_t = \lambda(q_t + k_{t+1}) + (1-\lambda)(s_t + x_t) \tag{2.17}$$

We must finally specify the stochastic processes driving the exogenous variables. Dollar exports are given by an AR(1) process:

$$x_t = a_x x_{t-1} + \varepsilon_t^x \tag{2.18}$$

where a_x is between zero and one, and ε_t^x is white noise. Assume also that the world interest rate follows an AR(1) process

$$\rho_t = a_\rho \rho_{t-1} + \varepsilon_t^\rho \tag{2.19}$$

where again a_ρ is between zero and one, and ε_t^ρ is white noise.

This completes the description of the economic environment. Once monetary policy is specified, the system of equations 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.15, 2.16, 2.18, 2.17, and 2.19 suffice to determine the dynamic behavior of y, k, l, r, p, w, s, q, η, n, d, x, i, and ρ. We can, therefore, turn to the study of monetary policy.

3. Computing Optimal Policy

In this section we analyze the policy choices of a monetary authority whose objective is to minimize expected social loss. Social loss is, in turn, assumed to depend on the deviations of output and inflation from their steady state values, and possibly on other variables. Our assumptions about the preferences of the policymaker are, we believe, realistic, and may in particular reflect the existence of an inflation targeting regime (as in Svensson, 2000). Alternatively, our assumptions on social loss may be seen as an approximation to (some aggregate of) the welfare of workers and capitalists.[7]

As in much of the recent literature, we shall assume that the instrument of the monetary authority is the short nominal interest rate i_t. This implies that the behavior of monetary aggregates plays no essential role in the analysis: the money, in particular, adjusts passively as given by equation 2.13 and can be ignored.

As in Svensson (2000), the monetary authority's loss function is the unconditional expectation of a period loss function[8] of the form

$$\psi_\pi \pi_t^2 + \psi_y y_t^2 + \psi_e e_t^2$$

where e_t corresponds to the real exchange rate, or $s_t - p_t$. Hence, after taking expectations, the loss function becomes

$$\psi_\pi Var(\pi_t) + \psi_y Var(y_t) + \psi_e Var(e_t) \tag{3.1}$$

In the previous expressions, π_t denotes the deviation of a measure of inflation from its steady state value. In our benchmark computations, such a measure is given by wage inflation. The fact that we attribute social costs to wage inflation can be

[7] Although such an interpretation may require some additional assumptions to be accurate. See Kim and Kim (1999) and Benigno and Benigno (2000).

[8] It is well known that such an objective is the limit, as the discount factor goes to zero, of a scaled discounted sum of expected losses in all periods.

easily justified in the context of the Calvo (1983) staggering context. As Woodford (1996, 2000) shows in detail, with staggering inflation causes the dispersion of relative prices (or wages), and this is in turn costly for output and welfare. Since in our model it is wages that are sticky and staggered, it is ongoing wage inflation that causes such relative price distortions.

Notice that under this specification, the policymaker attempts to minimize the deviations of output from its steady state or "natural rate" level, not from some higher threshold as in some of the literature. This means that the "inflation bias" problem familiar from Barro and Gordon (1983) and related work is absent here. But this does not mean that there is no time consistency problem: optimal policy computed under discretion and under commitment will in general not coincide. This is because, to the extent that wage-setting depends on future economic conditions, a monetary policy that can commit to future actions may face an improved inflation-output trade-off in the short-run.[9]

We begin with a benchmark regime corresponding to what Svensson (2000) terms *flexible inflation targeting*: $\psi_\pi = 1$, $\psi_y = 0.5$, and $\psi_e = 0$. Social loss depends on inflation, but also on domestic output. Later we analyze other regimes.[10]

3.1. Parametrization

We set the model parameters to ensure that the steady state is empirically plausible. Thus, the steady state world real interest rate is 4 percent in annual terms. The share of the home good in the production of capital and in the consumption index, γ, is set at 0.75, which is consistent with observed shares of imported goods in total output. The capital share in the production of the home good, α, is assumed to be 0.35.

We set θ, the probability of non-adjustment in wages, to 0.75, which implies that on average wages are adjusted every four quarters. The elasticity of demand for worker services, σ, and the elasticity of labor supply, ν, are both set to be 2.

We choose the rest of the parameters in the model to generate a steady state risk premium of six hundred basis points, a ratio of investment expenditures to debt that equals to 1.8, and an annualized business failure rate of 8.8 percent. The monitoring costs are assumed to be 15 percent of the total assets of the firm in case of bankruptcy. Additionally, the fraction of capitalists that survives to

[9] See Clarida, Gali and Gertler (1999).

[10] Notice that we follow Svensson's (1999) somewhat special terminology, which defines a regime not by the actions it involves, but by the loss function it minimizes.

the next period, δ, is set to 0.9615, while the idiosyncratic shock to the return of capital is assumed to be distributed log-normally with a standard deviation equal to 0.28. Finally, the persistence parameter of the world interest rate and the export demand shocks is assumed to be 0.9.

3.2. Discretionary Policy

In analyzing the policy problem, it turns out to be crucial to specify when the monetary authority can commit to a particular choice. Start out with the case of *discretion*: the monetary authority sets i_t in period t, after observing shocks in that period. The discretionary case is arguably the most relevant in practice. But, perhaps more importantly in our context, much of the recent debate on fixed versus flexible rates is based on the view that fixed rates may improve upon discretion by serving as an imperfect commitment device. Hence evaluating such a view requires comparing outcomes under fixed rates against discretionary outcomes.

The policymakers problem is to minimize social loss by choosing a strategy for setting i_t in every period t, after observing the state of the economy and all shocks up to period t. To formalize this problem, it is useful to note that the dynamical system that determines the economy's equilibrium has a convenient state space representation. Letting $b_t = d_t + \rho_t$ denote aggregate debt repayment in period t, and $\pi_t = w_t - w_{t-1}$ denote wage inflation, one can write the model in the form

$$\begin{pmatrix} Z_{t+1} \\ {}_tJ_{t+1} \end{pmatrix} = A_1 \begin{pmatrix} Z_t \\ J_t \end{pmatrix} + A_2 i_t + \varepsilon_{t+1} \tag{3.2}$$

where $Z_t = (\rho_t, x_t, k_t, \eta_t, b_t, w_{t-1})'$ is a vector of predetermined variables at t, $J_t = (s_t, p_t, \pi_t)'$ is a vector of jumping variables, $\varepsilon_t = (\varepsilon_t^\rho, \varepsilon_t^x, 0, 0, .., 0)'$ is a vector of exogenous shocks, and A_1 and A_2 are matrices whose coefficients are determined by the equilibrium system.

Given the state space representation 3.2, the techniques of Oudiz and Sachs (1985) and Backus and Driffill (1986) can be used to compute a discretionary outcome summarized by two linear maps. First, market behavior is given by a map

$$J_t = JZ_t \tag{3.3}$$

where J is a matrix defining values for the jumping variables at t as a linear function of the predetermined ones.

Second, policy choices are given by

$$i_t = fZ_t \tag{3.4}$$

where f is a row vector defining the interest rate at t as a linear combination of the predetermined variables.

The two linear maps thus defined have the property that (i) given the policy map 3.4, the market behavior defined by 3.3 defines a rational expectations equilibrium of the economy given by 3.2, and (ii) given the system 3.2 and the market behavior 3.3, the policy given by 3.4 in fact minimizes social loss subject to 3.2 and 3.3.

Once the maps 3.3 and 3.4 are obtained, they can be used in 3.2 to arrive at the law of motion for the vector Z_t. Then it is straightforward to obtain variances and covariances for all the variables in the model, and therefore to compute the value of the social loss function.

The solution for the optimal policy rule turns out to be:

$$i_t = 0.79\rho_t - 0.20x_t + 0.53k_t + 0.02\eta_t + 0.07b_t - 0.0w_{t-1} \tag{3.5}$$

Several aspects of this rule warrant attention. The first is that the exchange rate floats, and considerably. The nominal interest rate adjusts to exogenous shocks, but not to the extent that would be necessary to stabilize the nominal and real exchange rates. Indeed, it is possible to solve for the exchange rate as a function of predetermined variables; the discretionary solution implies that the coefficients are nonzero. Equivalently, that optimal policy requires flexible exchange rates is apparent from the impulse responses below.

In response to an increase of one hundred basis points in the world interest rate ρ_t, the monetary authority *increases* the nominal interest rate by almost eighty basis points. At first glance, one may conjecture that this reflects that the monetary authority is partially defending the exchange rate. But such an interpretation would be misleading for two reasons. First, i_t is a *nominal* rate, and hence an increase in i_t may just be compensating for an increase in expected domestic inflation (see 2.15). Indeed, we shall see that domestic inflation increases after a rise in ρ_t. Second, the response of i_t cannot be understood independently of the full dynamics of the model. This is because, when policy is given by 3.5, interest rates increase by more than fifty five basis points if domestic capital is one percent above its steady state value. Since an unexpected increase in the world interest rate will cause a fall in domestic investment and capital in subsequent periods, i_t will increase very little, except for the very first period.

In response to an unexpected one percent increase in the demand for exports, the discretionary policy implies that the interest rate must fall on impact. Again, this is only the very short run response and should not be taken as an indication of a pro-cyclical monetary policy. In particular, a rise in x_t will increase capital accumulation, which then will push interest rates up under the discretionary policy.

Table 3.1 shows the standard deviations of the variables of ultimate relevance for welfare. Under the discretionary policy 3.5, the standard deviation of the real exchange rate is 2.77, and the standard deviations of the nominal exchange rate and the price of the home goods are much higher. Hence the optimal discretionary policy actively takes advantage of the ability to change the exchange rate, a finding similar to that of Svensson (2000). The main payoff is that output is stabilized almost completely. The standard deviation of (wage) inflation is also low (0.44 percent) but certainly not negligible, and is consistent with the high variability of the exchange rate.

Some further intuition can be obtained by studying the impulse response functions associated with 3.5, the discretionary solution. Figure 1 displays the responses to a one percent increase in the world interest rate. As we saw above, on impact the interest rate increases by 0.79 basis points over its steady state value, but this increase is only temporary: after one period, the interest rate has fallen to only two and a half basis points over its steady state value, and from then on it converges slowly to the steady state.

Table 3.1: **Unconditional Standard Deviations**

Variables	π_t	y_t	e_t
Flexible Inflation Targeting			
Discretion	0.44	0.04	2.77
Commitment	0.24	0.07	2.68
Fixed Exchange Rate	0.27	2.07	1.33

Since capital depreciation is complete, the dynamic behavior of i_t mirrors the adjustment of capital, which in turn responds to the real interest rate on loans.

On impact, investment and capital fall more than one for one with the increase in the world interest rate. Investment then recovers gradually, as the real cost of loans falls.[11] The latter reflects not only the return of the world interest rate to its steady state, but also a gradual *fall* in the risk premium below its steady state level, after an initial increase. The risk premium falls, in turn, because the interest rate increase reduces investment and foreign borrowing, which is apparent from Figure 1. In fact, the reaction of foreign debt is quite strong, falling by almost two and a half percent in the first six periods and then recovering slowly.

Finally note that since capital adjusts towards the steady state only gradually, the discretionary rule 3.5 limits the deviation of the home interest rate from its steady state. This confirms our previous observation that the optimal policy can only be interpreted in the context of the model's dynamic properties.

The impulse responses to a one percent *decrease* in export demand are given in Figure 2. The shape of the response is the same as in the case of a world interest rate shock, although the magnitudes are smaller. The shock leads to a depreciation of the real exchange rate and to a fall in investment of a quarter of percentage point. Monetary policy almost perfectly stabilizes output. The shock and the associated monetary policy also lead to an increase in wage inflation.

4. How Costly is the Inability to Precommit?

We now turn to the issue of quantifying the welfare loss associated with the absence of commitment. We start with a case of full commitment, in which the monetary authority can implement a date and state contingent policy specified at the start of time. We treat that case briefly, since it is unlikely to be of much relevance in practice. It is helpful, however, in providing a benchmark of how costly lack of commitment can be. We then turn to fixed exchange rates, considered as an imperfect but feasible commitment device. This is of interest since one may believe that some simple rules, including fixed exchange rate regimes, may be implementable even if they are time inconsistent. In such a case fixed exchange rates may in principle be superior to the optimal policy under discretion, reflecting the stronger commitment associated with fixing.

[11] The real cost of loans corresponds to the world interest rate plus the risk premium and the expected real devaluation.

4.1. Optimal Policy under Full Commitment[12]

Under full commitment, the optimal rule is generally not simply a map from period t's exogenous or predetermined variables the policy or control variable i_t. That is because the monetary authority takes into account the whole future expected path of the economy. But in period 0 it is indeed possible to write down such a representation, which turns out to be[13]

$$i_t = 0.69\rho_t - 0.16x_t + 0.54k_t + 0.02\eta_t + 0.06b_t - 0.0w_{t-1} \tag{4.1}$$

This rule is remarkably similar to the one under discretion. In particular, the exchange rate is again floating, in the sense that the domestic interest rate does not eliminate exchange rate fluctuations in response to shocks in external borrowing costs.

The main difference is that now the initial reactions of the nominal interest rate to foreign interest rate and export shocks are significantly smaller. Under commitment, less "toughness" is required from the central bank when facing adverse circumstances. This is because a precommitting central bank can promise to engineer less inflation in the future; since price-setting is forward looking, less expected inflation in the future means less actual inflation today, which in turn allows the central bank to choose a less restrictive level for domestic interest rate today.

Table 3.1 reveals that under commitment the standard deviation of output is slightly higher than under discretion, while the that of inflation is much lower: 0.24 versus 0.44 percent. Interestingly, the policy maker who can commit also takes full advantage of the flexibility in relative prices implied by floating: now the standard deviation of the real exchange rate is 2.68 percent, only slightly below the 2.77 percent obtained under discretion. Moreover, the standard deviations of the nominal exchange rate and the price of the home good are significantly smaller compare to the discretionary case.

This general analysis can be enriched by examining the impulse response functions in Figures 3 and 4. For concreteness focus on the latter figure, which contains

[12] The calculations in this section follow Söderlind (1999).

[13] The difference is that actions at period 0 are by definition unexpected, and hence the central bank does not have to worry about the effect of such actions on expectations along the equilibrium path. The same is not true of actions to be taken in some future period T, which affect expectations in all periods $t \leq T$. Technically, the difference is that for periods after $t = 0$ the policy rule also contains a number of Lagrange multipliers, which are set to zero at time $t = 0$.

the case of a 1 percent adverse export shock. The main difference with discretion is in the behavior of wage inflation, which now peaks at half the value of the discretionary case. The lower inflation allows the monetary authority initially to raise nominal interest rates by less: 158 basis points, compared to 197 under discretion. As suggested by the standard deviation calculations, output falls by more and stays below the steady state longer under commitment. But the size of these deviations is fairly small. And under commitment the output fall is more gradual and comes later than under discretion.

Notably, the response of the risk premium is identical to that in the discretionary case. This may seem surprising, although not unexpected given our previous work. In the context of CCV we showed that, in equilibrium, the response of the risk premium was the same under fixed exchange rates and under a flexible rate, price-targeting policy. Our finding here is similar, although it refers to the response of the risk premium to different monetary rules. Indeed, we will see below that the change in the risk premium is the same across regimes, contrary to the conjectures in much of the recent policy literature.

The explanation for this result is straightforward: it can be shown with a bit of algebra (the details are in CCV) that movements in the risk premium depend on the response of overall dollar output. This is natural, as the risk premium depends on net worth relative to the value of investment, both of which depend on dollar output. And it turns out that in response to shocks dollar output changes by the same amount independently of interest and exchange rate policy. What policy does is determine the split between movements in real output and movements in the real exchange rate.

4.2. Fixed Exchange Rates

Next we analyze the outcomes of the model under a fixed exchange rate regime. This is achieved by setting $s_t = 0$, all t, as an equilibrium condition. Note that the nominal interest rate then responds passively to the resulting dynamic equilibrium and follows 2.15.

Under this policy the standard deviation of wage inflation falls to 0.27 percent, which reduces social loss relative to the discretionary solution. However, this is achieved at the price of an increase in the standard deviation of output from virtually zero in the flexible inflation targeting case to 2.07 percent.

Figure 5 shows the responses of the fixed rate regime to a one percent increase in the world interest rate. The nominal interest rate increases, on impact, by less than 15 basis points. It is interesting to note here that this increase is much less than the discretionary impact response, but this observation says little about the stance of monetary policy. With fixed rates the interest rate is endogenous, and the fact that the increase in the interest rate is relatively mild reflects the fact that, following the shock, there is strong price deflation and a fall in output.

Indeed, output falls by almost one half of one percent on impact, and by more than 0.85 percent in the second period, relative to its steady state value. The response of investment and capital is even stronger: the short run contraction is about one and a half percent, and the recovery is relatively slow. In this case, inflation is negative the first few periods and slightly positive in the medium run.

Finally, Figure 6 presents the impulse responses of the economy to a one percent decrease in export demand. Again, output and investment reactions are stronger and more persistent that in the full commitment and discretionary policy cases.

These impulse responses suggest that, once the analysis goes beyond impact effects, fixed exchange rates exacerbate rather than ameliorate the adverse effects of financial frictions. This conjecture clearly warrants more research, if only because it contradicts the current conventional wisdom based on the existence of liability dollarization.

4.3. Welfare Comparisons

Table 4.1 compares the social loss associated with commitment, the discretionary case and fixed exchange rates. By construction, welfare is highest under commitment. The main result is that welfare is lowest under fixed exchange rates, and the difference is large: social loss is 11 times larger than under discretion and flexible inflation targeting. That is, the commitment gain associated with fixing does not even come close to offsetting the benefits of greater output stabilization under floating.

5. Alternative Objective Functions

What we have termed *flexible inflation targeting* is a plausible and practically relevant policy stance, but certainly not the only one. To make sure our results –particularly the conclusion that flexible rates under discretion are preferable to fixed rates– do not depend on the particular specification of the loss function minimized by the central bank, we now analyze two alternative formulations:

Table 4.1: **Loss Function**

Flexible Inflation Targeting	
Discretion	0.20
Commitment	0.06
Fixed Exchange Rate	2.21

one with no concern for output stabilization and one in which the central bank attempts to stabilize the real exchange as well as the other two more conventional targets. For the sake of brevity, in what follows we omit the full commitment case.

5.1. Strict Inflation Targeting

Under a stance of *strict inflation targeting* the parameters of the loss function are $\psi_\pi = 1$, $\psi_y = 0$, and $\psi_e = 0$. In other words, the monetary authority's sole objective is to stabilize wage inflation.

It turns out that under strict inflation targeting the monetary authority finds it optimal to keep the interest rate unchanged in response to shocks. The intuition is that, given the wage Phillips curve 2.16, wages and wage inflation can be held to their steady state values if labor demand can also be held at its steady state value. The latter can be achieved, by 2.3, if home nominal output is constant. But 2.15 implies that home nominal output must be constant if the domestic short interest rate is constant.[14]

Table 5.1 confirms that, if inflation targeting is strict, the discretionary solution indeed manages to keep wage inflation constant. The change with respect to the flexible inflation targeting case is that output becomes more variable: the standard deviation of the output is almost 1 percent. But this is intuitive, as output variability implies no loss under strict inflation targeting. The standard deviation of the real exchange rate turns out to be 2.29 percent, somewhat lower

[14]Note that, in this sense, a policy of keeping i_t at its steady state value is equivalent to a policy of "nominal GDP targeting," as studied by Frankel (1995).

than under flexible inflation targeting.

Figure 7 shows the response of the economy to a one percent increase in the world interest rate for the case of strict inflation targeting. As one might expect, output and investment exhibit stronger and more persistent falls under strict inflation targeting than in the flexible targeting case. Interestingly, output has a hump-shaped response, which replicates some existing VAR evidence without relying on assumptions about the timing of investment. Even though the increase on impact of the real exchange rate under strict inflation targeting is similar to that in the flexible case, its persistence is lower.

The response of the economy to a one percent fall in export demand appears in Figure 8. Again, monetary policy completely stabilizes inflation. Compared to flexible inflation targeting, strict inflation targeting results in a deeper contraction in output and investment. While the reaction of the real exchange rate is rather similar in shape and magnitude, the depreciation (increase) of the nominal exchange rate (price of the home goods) is smaller under strict inflation targeting.

Table 5.1: **Unconditional Standard Deviations**

Variables	π_t	y_t	e_t
Flexible Inflation Targeting	0.44	0.04	2.77
Strict Inflation Targeting	0.00	0.96	2.29
Flexible Inflation-RER targeting	0.49	1.39	1.42
Fixed Exchange Rate	0.27	2.07	1.33

5.2. Flexible Inflation and Real Exchange Rate Targeting

In a third and last case under discretion, we allow the variance of the real exchange rate to affect the monetary authority's loss function. This can be termed *flexible-inflation-cum-real-exchange-rate targeting*. Assuming that the exchange rate objective is as important to the central bank as the output objective, we chose $\psi_\pi = 1$, $\psi_y = 0.5$, and $\psi_e = 0.5$ to represent this case. Under dollarization of liabilities there are specially powerful reasons why the monetary authority may want to stabilize the real exchange rate, since we have seen that sharp sudden devaluations typically have nasty effects on balance sheets.

The solution for the policy rule is:

$$i_t = 0.93\rho_t - 0.22x_t + 0.53k_t + 0.02\eta_t + 0.08b_t - 0.0w_{t-1} \qquad (5.1)$$

Now in response to an increase of one hundred basis points in the world interest rate the monetary authority increases the nominal domestic interest rate by more than ninety basis points. Naturally, this reaction is stronger than in the flexible inflation targeting case. The rest of the coefficients are quite similar to the ones in that case.

As can be seen from Table 5.1, flexible inflation-exchange rate targeting implies that inflation and output are more variable and the real exchange rate less variable than in the two previous cases. This is not surprising, since the monetary authority now prefers to reduce exchange rate volatility at the cost of more variable inflation and output. In fact, the standard deviation of output in this regime is almost 50 percent higher than strict inflation targeting and more than 35 times higher than under flexible inflation targeting. The standard deviation of the real exchange rate is half the standard deviation under flexible inflation targeting and 40 percent lower than under strict inflation targeting.

Figure 9 presents the impulse responses to a one percent increase in the world interest rate. The initial fall of output is stronger compared to both flexible and strict inflation targeting. Investment is also lower. However, the initial response of the real exchange rate is reduced by almost half. Wage inflation is lower than in the flexible inflation targeting but higher than the strict inflation targeting. The response of the risk premium is identical to that in the two previous cases.

Finally, Figure 10 displays the response of the economy to a one percent decrease in export demand. Notice that in the first period the interest rate increases, but thereafter monetary policy turns clearly expansionary. Moreover, output and investment exhibit a stronger fall compared to the previous cases under discretion. The real exchange rate reaction is less pronounced and inflation is in fact negative under this particular specification of the central bank objectives.

5.3. Welfare Comparisons

Table 5.2 compares the social loss associated with both these discretionary cases with the loss under fixed exchange rates. For each discretionary alternative, the loss under fixed rates is evaluated using the weights in the welfare function associated with that alternative.

Again, social loss is larger under fixed rates than under either discretionary solution. The disadvantages of fixed rates appear to be larger if output enters the social loss function. Conversely, fixed rates seem almost as good as flexible rates if in the latter case there is strict inflation targeting.

Table 5.2: **Loss Function**

Flexible Inflation Targeting vs Fixed Exchange Rate	0.20	2.21
Strict Inflation Targeting vs Fixed Exchange Rate	0.00	0.07
Flexible Inflation-RER targeting vs Fixed Exchange Rate	2.21	3.10

6. Final Remarks

We have found that, even if fixed exchange rates enjoy a credibility advantage, they do not yield higher welfare than does optimal floating under discretion. Fixing turns out to have adverse consequences for aggregate real variability, particularly of output. This outweighs the inflation gains associated with fixed rates. This conclusion does not depend on –instead, it seems reinforced by– the existence of financial imperfections that interact with net worth effects. Naturally, these findings have to be checked further for robustness, under alternative parameters and model specifications. However, it is notable that they are consistent with our previous theoretical analysis in CCV.

Of the many extensions suggested by the analysis, perhaps the most obvious one is to drop the *ad hoc* specification of the monetary authority's loss function in favor of a true social welfare function derived from microfoundations, as in Woodford (1996, 2000) and Rotemberg and Woodford (1998). This involves not only aggregating the interests of agents in the home population, but also finding a tractable way to do so. This task is not trivial, since here there are a number of distortions (financial frictions in addition to sticky prices and monopoly power) and therefore Taylor approximations to the social objective function may not always yield the quadratic forms we have relied on. On the other hand, the recent work of Chang (1998), Phelan and Stachetti (1999), and Sleet (2000) suggests that there may be computationally feasible ways to tackle directly the nonlinear discretionary policy problem, without relying of linear-quadratic approximations.

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Figure 1
Impulse Responses to a World Interest Rate Shock
Discretion: Flexible Inflation Targeting

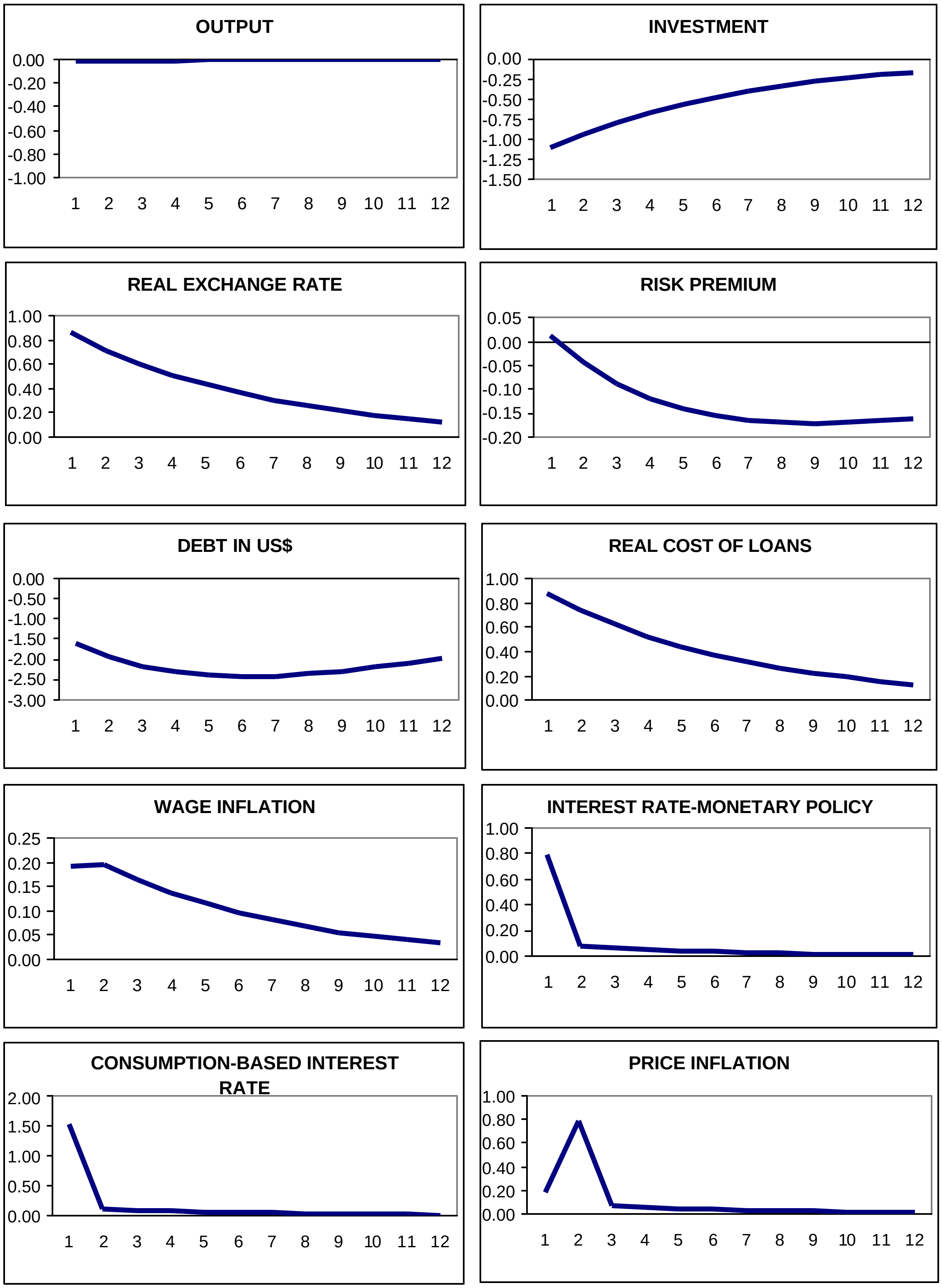

Figure 2
Impulse Responses to an Export Demand Shock
Discretion: Flexible Inflation Targeting

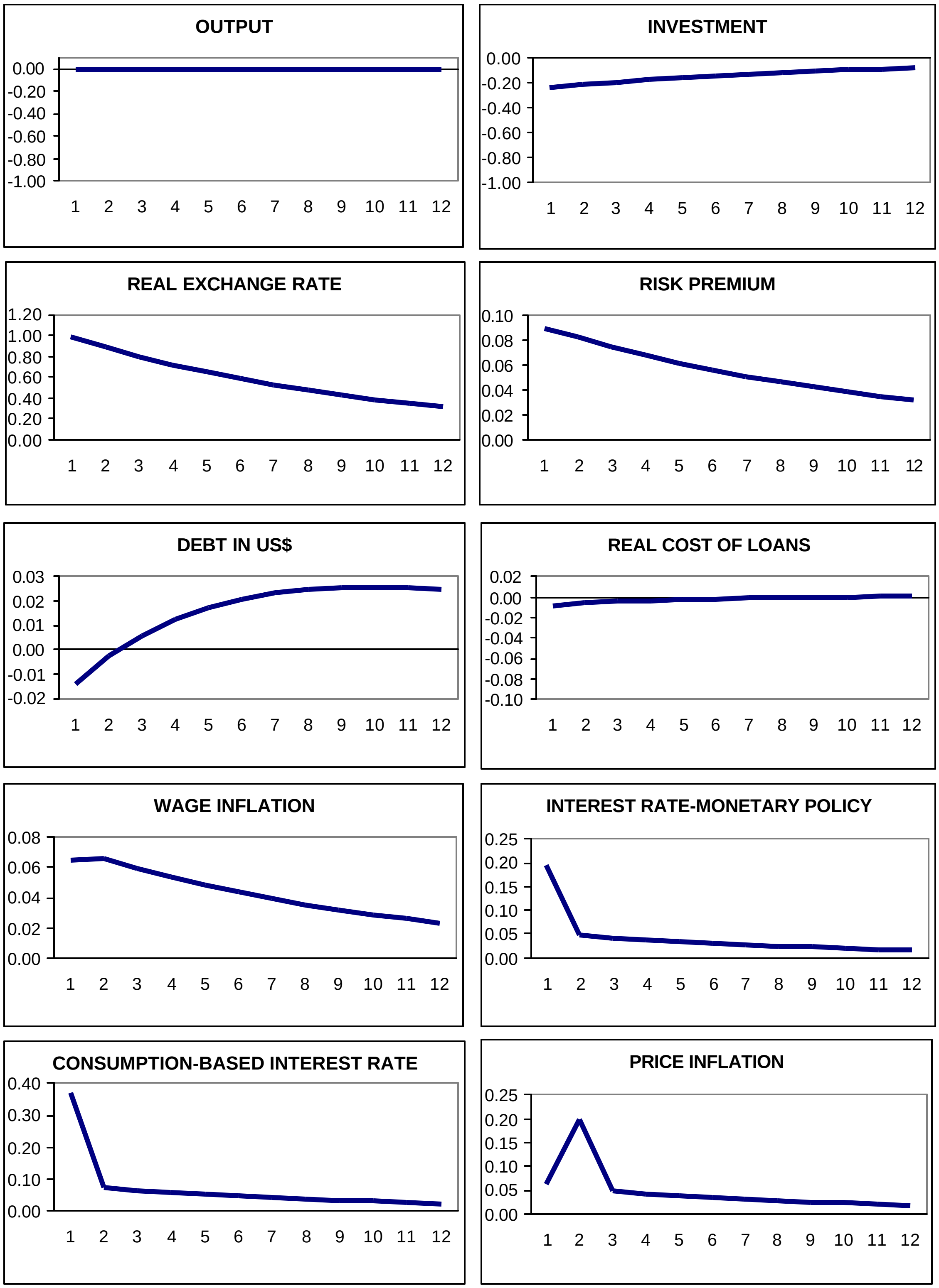

Figure 3
Impulse Responses to a World Interest Rate Shock
Commitment: Flexible Inflation Targeting

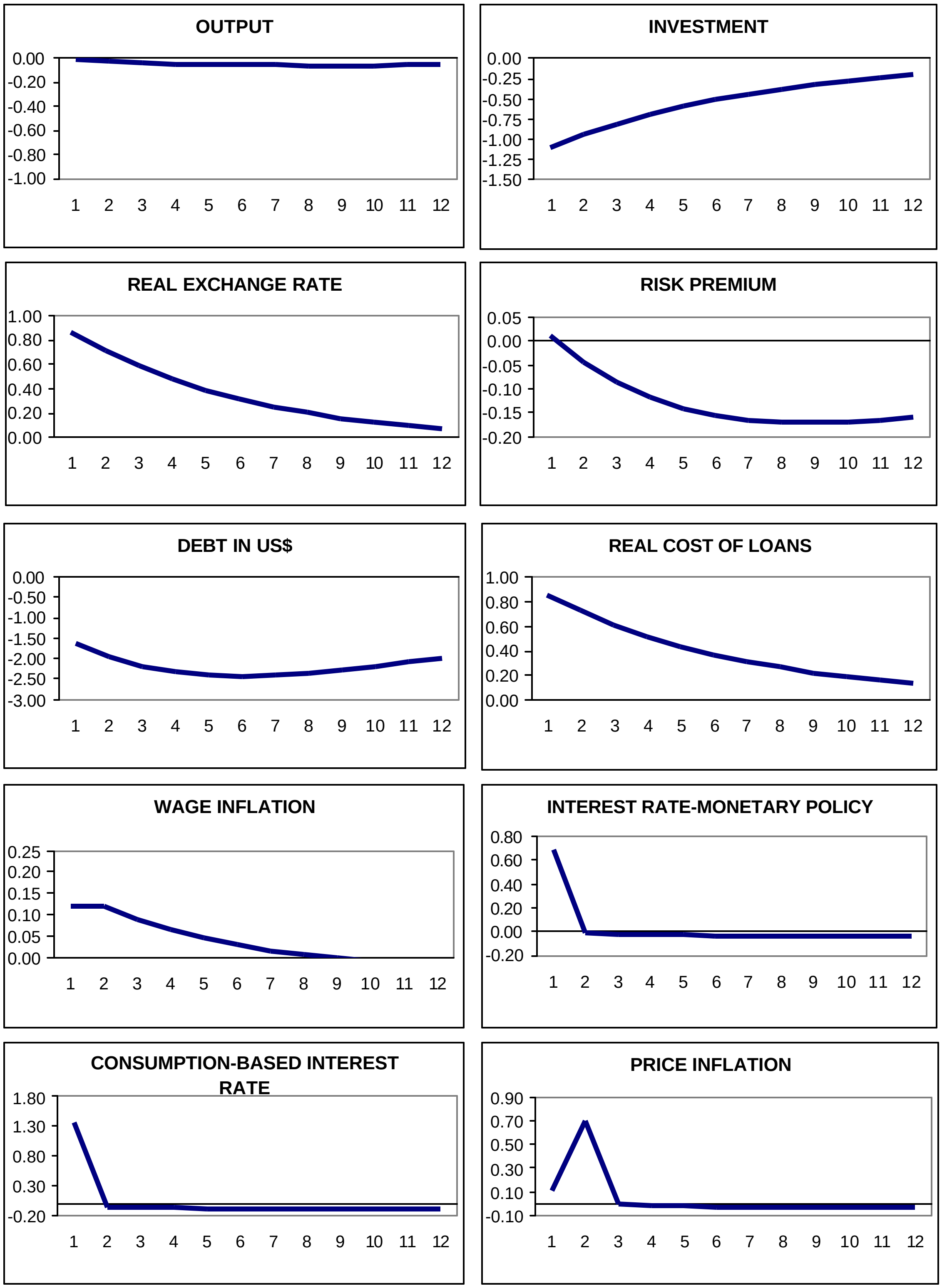

Figure 4
Impulse Responses to an Export Demand Shock
Commitment: Flexible Inflation Targeting

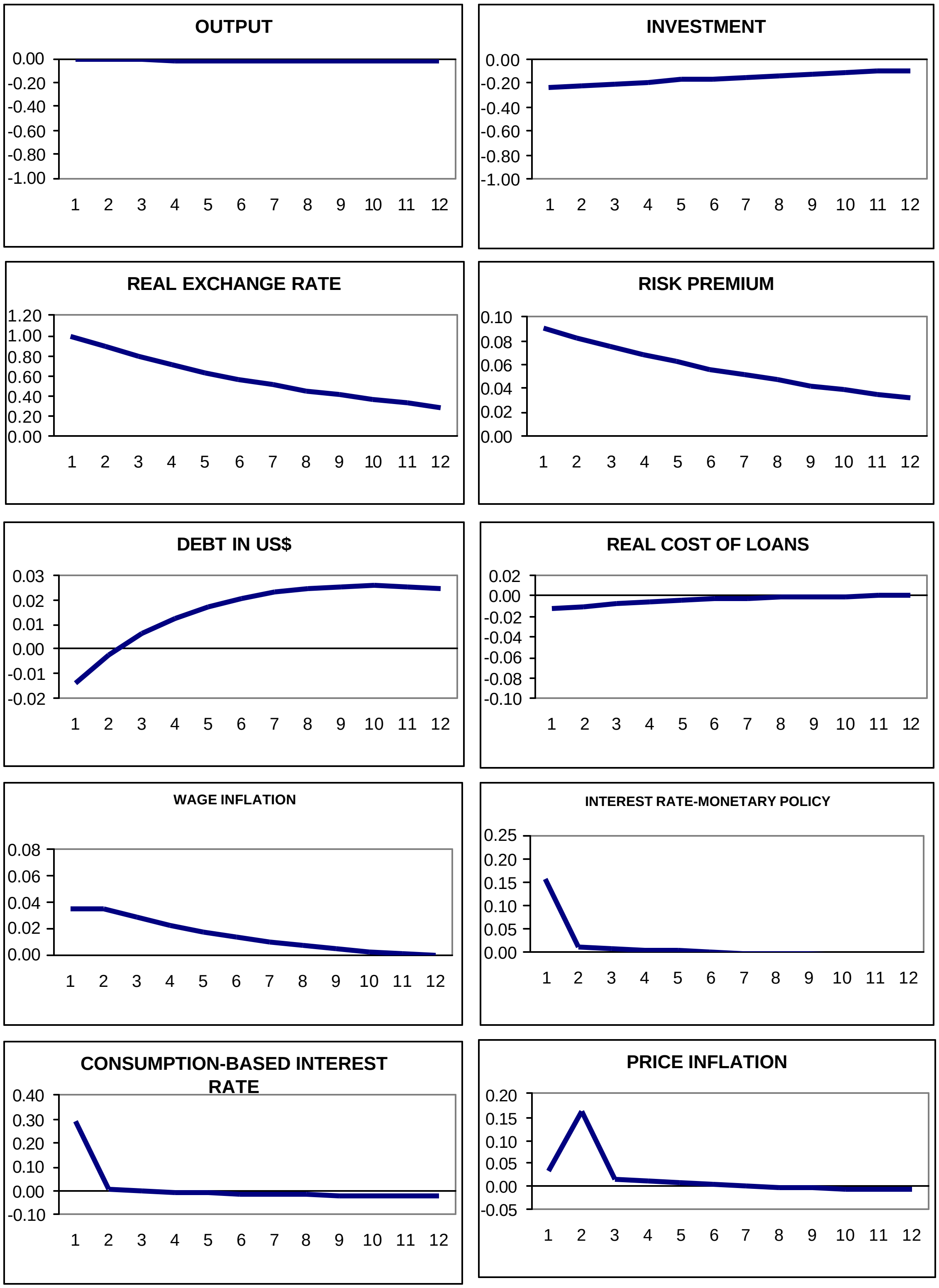

Figure 5
Impulse Responses to a World Interest Rate Shock
Fixed Exchange Rate

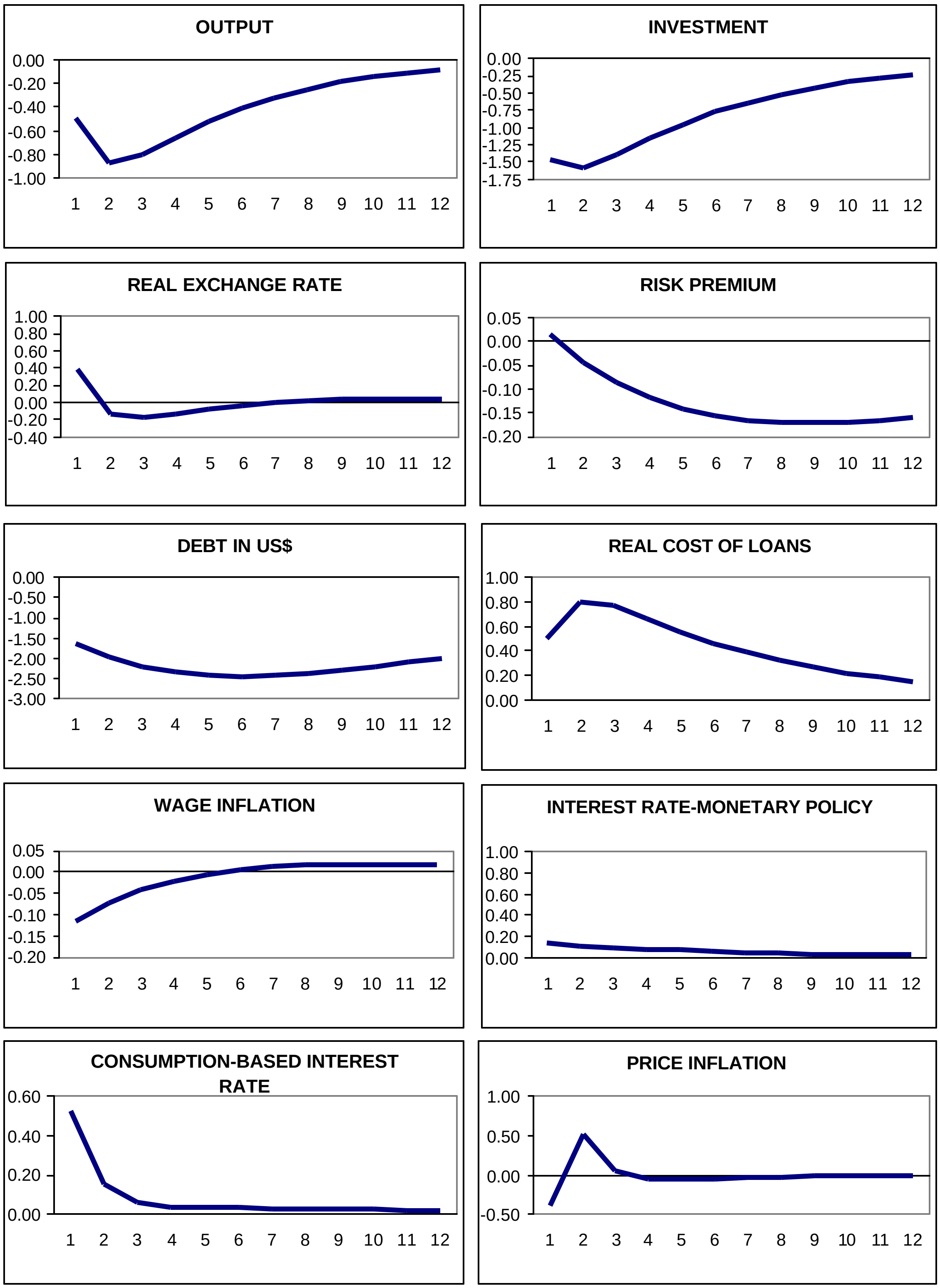

Figure 6
Impulse Responses to an Export Demand Shock
Fixed Exchange Rate

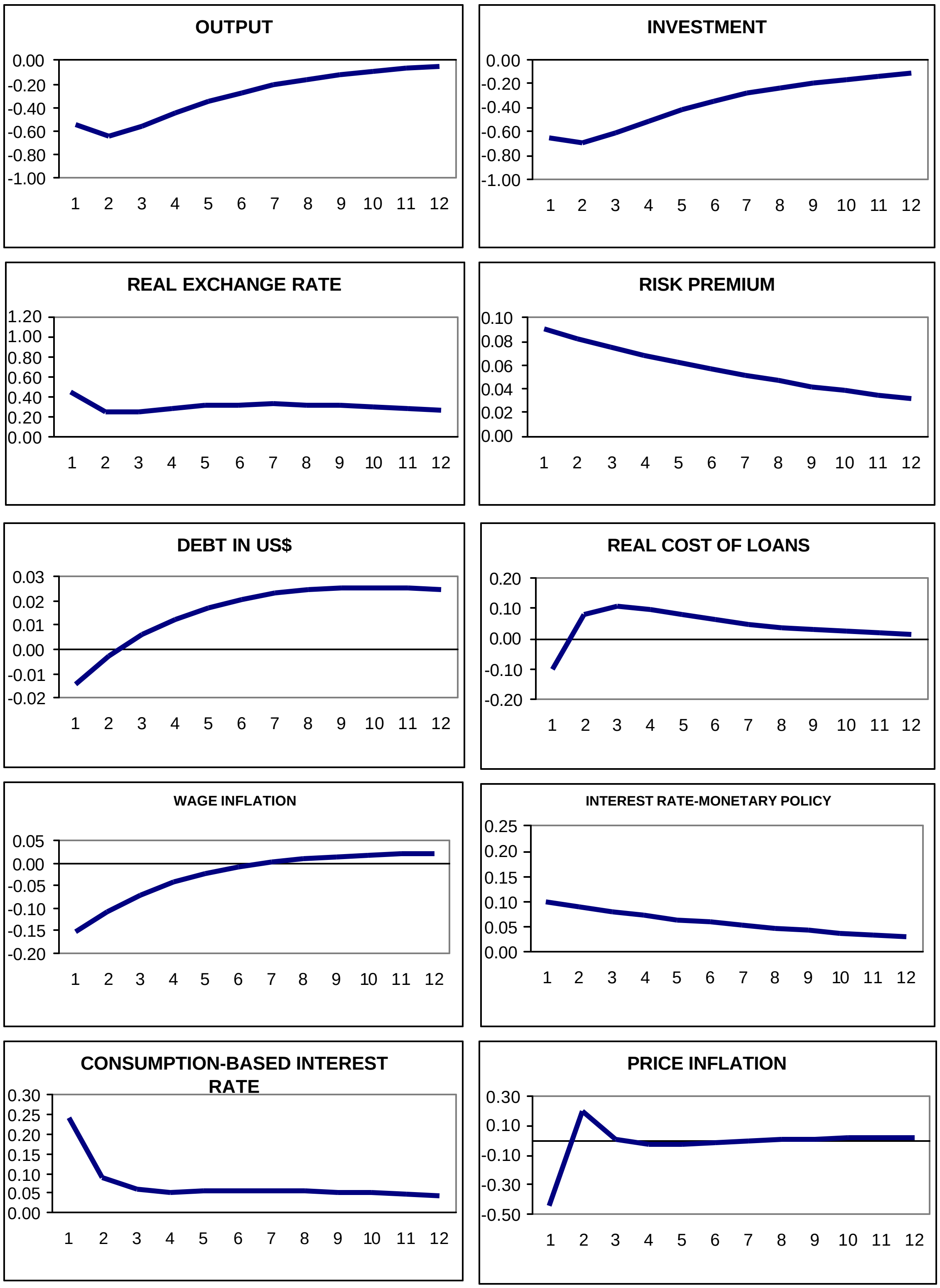

Figure 7
Impulse Responses to a World Interest Rate Shock
Strict Inflation Targeting

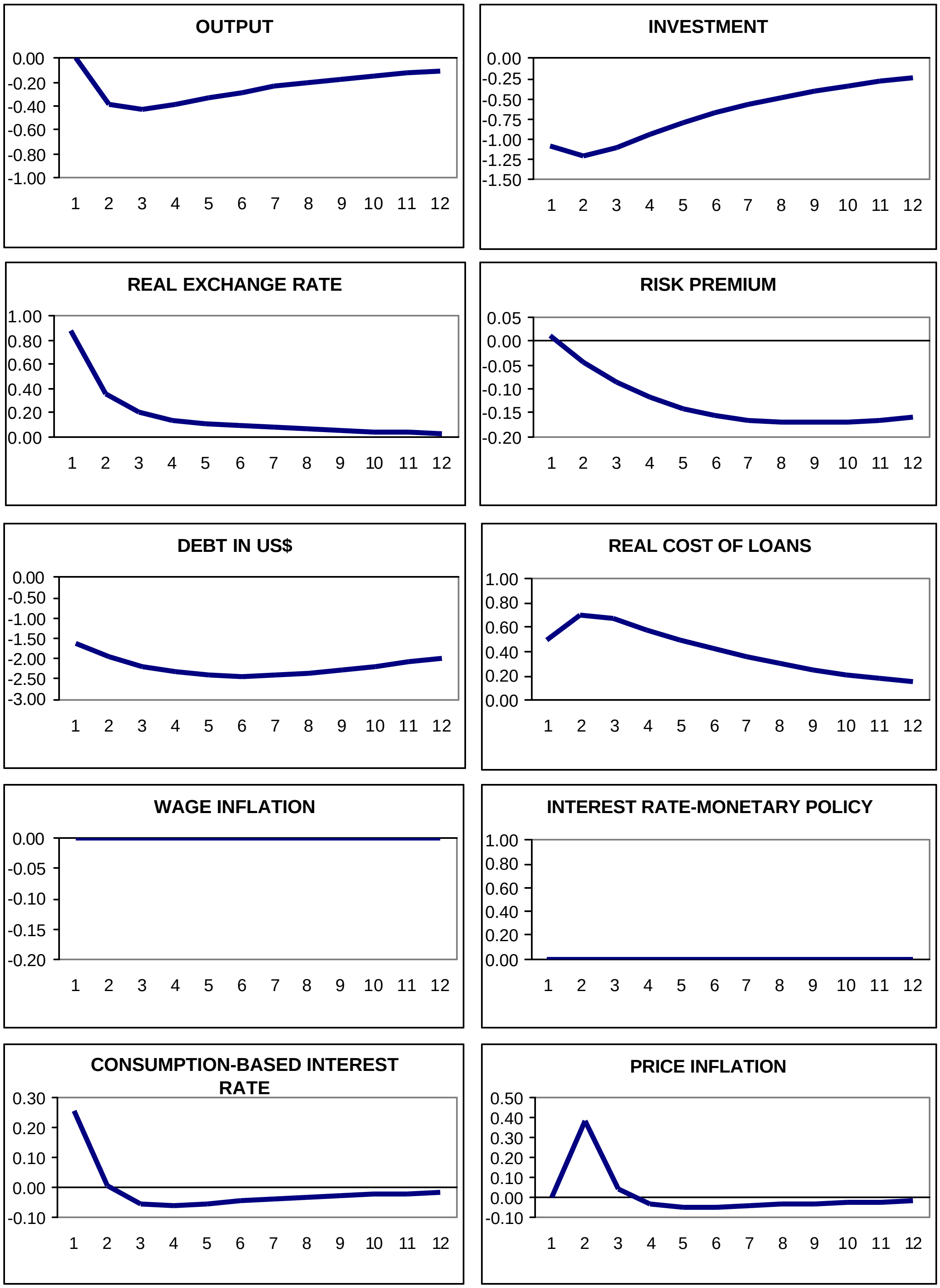

Figure 8
Impulse Responses to an Export Demand Shock
Strict Inflation Targeting

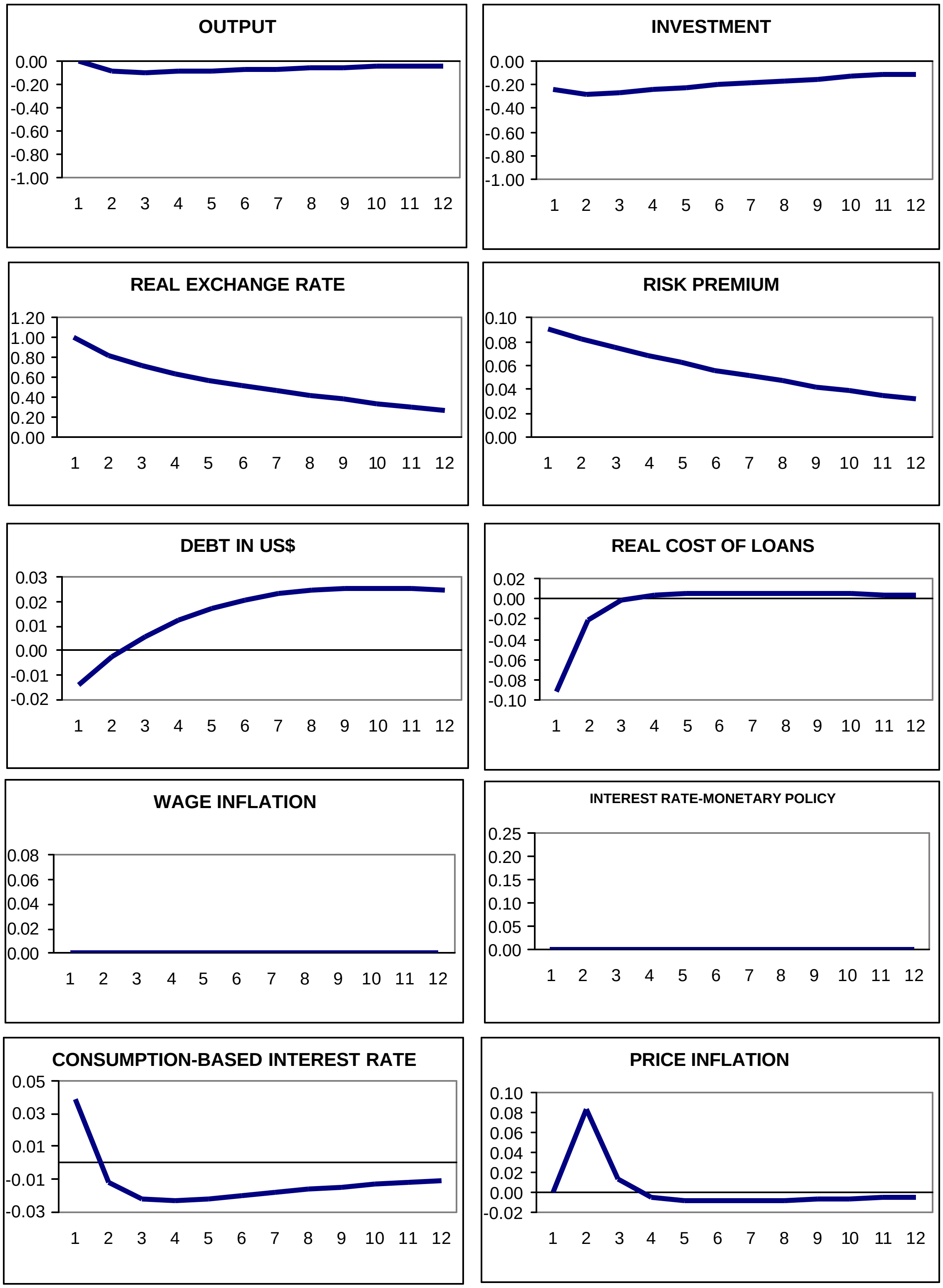

Figure 9
Impulse Responses to a World Interest Rate Shock
Flexible Inflation-Real Exchange Rate Targeting

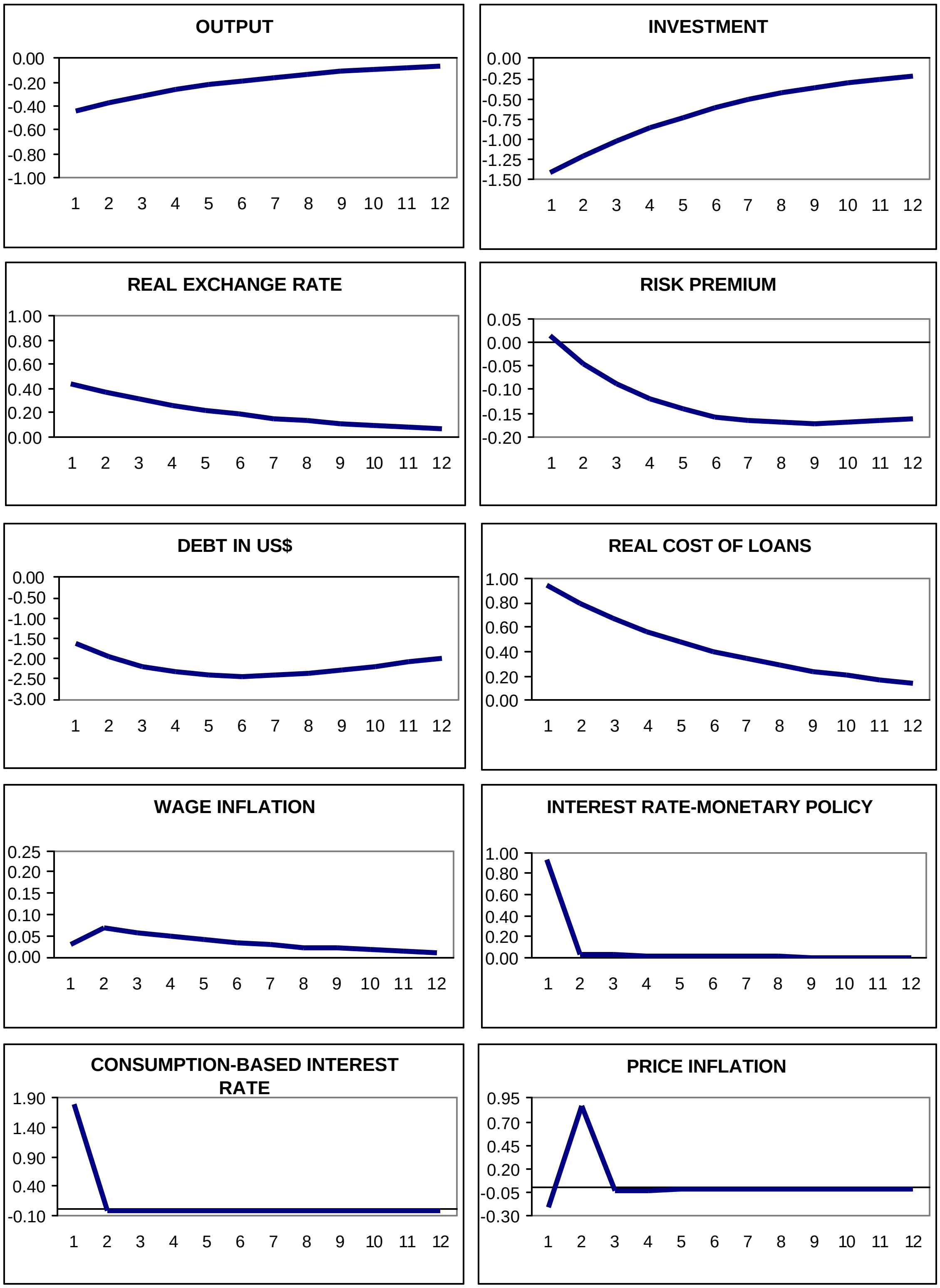

Figure 10
Impulse Responses to an Export Demand Shock
Flexible Inflation-Real Exchange Rate Targeting