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The mechanics of devaluations and the output response in a DSGE model: how relevant is the balance sheet effect?

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Abstract

The relative importance of different mechanisms through which devaluations affect output are analyzed using a dynamic stochastic general equilibrium model for a small open economy with imperfect competition and nominal rigidities. Devaluations are defined as an increase in the central bank's nominal exchange rate target, which induces a decrease in the nominal interest rate. Three main mechanisms through which devaluations affect output are considered: The traditional expansionary expenditure-switching effect, the balance sheet effect which allows the possibility of contractionary effects when firms' debt are dollar-denominated, and a monetary channel associated with an interest rule that targets the nominal exchange rate. The model is calibrated and simulated under alternative scenarios of exchange rate regimes and shocks. Devaluations are found to be expansionary despite the contractionary balance sheet effect. In response to adverse external shocks the economy's output response improves with a devaluation the less flexible the exchange rate regime is.

JEL classification: F31, F41

Keywords: Devaluations, Balance Sheet Effect, Interest Rate Rule, Exchange Rate Target, New Open Economy Macroeconomics.

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INTRODUCTION

There is a strong presumption among economists that devaluations of the nominal exchange rate are contractionary in terms of output. However, existing empirical evidence has been unable to provide a conclusive answer in this direction. For instance, Gupta, Mishra and Sahay (2003) have shown that nearly half of all devaluationary episodes experienced in developing countries during the last three decades have been contractionary while the remaining portion have been expansionary. Furthermore, Magenzo (2002), after controlling for factors that determine large devaluations, found no significant statistical association between devaluations and output. These empirical results are at odds with the standard Mundell-Fleming framework, which assigns to nominal devaluations an expansionary impact associated with the expenditure-switching effect.[1] As a result, economists have started to review the manner in which they understand the transmission mechanisms through which devaluations affect output. Certainly, the debate is not new, as reflected by the extensive literature written during the late 1970s and 1980s.[2]

The main purpose of this paper is to shed some light on this debate. Certainly, empirical analyses should help find an appropriate answer. However, studies such as those mentioned above are not structural and lack the ability to identify and quantify different transmission channels highlighted by theoretical models. As a result, it is reasonable to use well defined structural models to disentangle the expansionary or contractionary nature of devaluations. The main benefit of this is that it allows a closer look into the role of the different transmission mechanisms involved. Recent theoretical developments built from solid microfoundations which allow for imperfect competition as well as for nominal or real rigidities provide an improved framework to study some of these old issues in macroeconomics. For this reason I employ a New Open Economy Macroeconomic (NOEM) model to carry out the analysis.[3] The setting is general enough to consider standard Mundell-Fleming expansionary effects of devaluations as well as contractionary effects associated with the balance sheet transmission mechanism. This contractionary mechanism has only recently been incorporated into theoretical models of open economies.[4] It emphasizes the role of companies' balance sheets in determining their capacity to invest. According to this model, if firm's debts are dollar-denominated while their revenues are denominated in domestic currency then unexpected changes in relative prices will affect firms' balance sheets, and thus will put a constraint on new investment by limiting entrepreneurs' capacity to borrow from abroad. Furthermore, the impact of deteriorating balance sheets can be magnified if a devaluation increases the cost of foreign borrowing via an increase in the country's risk premium.

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1 See Obstfeld and Rogoff (1996) for a state-of-the art presentation of the Mundell-Fleming framework.

2 For a literature review, see Agenor and Montiel (1999). A classical study is Edwards (1989).

3 This literature was stimulated by the seminal work by Obstfeld and Rogoff (1995 and 2000). See Engel (2002), Lane (2001) and Sarno (2001) for a survey.

4 The balance sheet transmission mechanism has been highlighted by some as a new modeling feature (third-generation) to explain financial crises. Krugman (1999), Cespedes, Chang and Velasco (2004, 2003), Gertler, Gilchrist and Natalucci (2003), Devereux and Lane (2003), Choi and Cook (2004) and Faia and Monacelli (2002) are recent examples.

Despite the important theoretical role assigned to the balance sheet transmission mechanism in the new literature, very little is known about its quantitative implications. In this sense, an objective of the paper is to construct a flexible model to analyze quantitatively the relevance of this mechanism in explaining output behavior in the aftermath of a devaluation. For such purpose I adapt Cespedes, Chang and Velasco's (2004, 2003) (CCV henceforth) small open economy model with the purpose of analyzing through calibration and simulations the quantitative response of the model's key variables under different shocks. With this in mind, several modifications and extensions are built into the model. First, I allow for an endogenous determination of nominal rigidities; i.e. wage and price stickiness. For simplicity, a menu cost approach based on quadratic adjustment costs in prices and wages is adopted.[5] This structure allows for richer dynamics than those found when one-period advance price setting is adopted. As a result, the simplifying and tractable two-period framework used by CCV is replaced by a general multi-period dynamic stochastic general equilibrium (DSGE) model.

Second, monetary policy is modeled in terms of an interest rate rule that targets, among other traditional variables, the nominal exchange rate.[6] This rule turns out to be key as it allows a very precise definion for a nominal devaluation, which is defined as an increase in the central bank's nominal exchange rate target. An implication of this formulation is that it introduces an additional mechanism, a monetary channel, through which devaluations affect output. In particular, a nominal exchange rate devaluation induces, *ceteris paribus*, a decrease in the interest rate. This affects the economy's real returns, consumption, investment, and therefore output. As a result a devaluation has an expansionary effect. The interest rate rule specification is also very versatile as it allows us to consider a continuum of exchange rate regimes through the one parameter that determines the weight of the nominal exchange rate on the interest rate rule. Finally, in a broader context, the use of an interest rate rule is relevant given that most contributions in the literature have focused on closed economies and it is of no less importance to understand the effect of such rules in open economies, in particular, because monetary policy becomes an independent source of economic fluctuations.[7]

Third, the model incorporates several sources of shocks. These complement the international interest rate and export demand shocks originally considered by CCV. The first new shock is a preference shock, usually considered to have an impact on the expectational IS curve. The second is an economy wide technology shock, frequently employed in the real business cycle literature. In addition, a mark-up or cost-push shock which affects the Phillips curve is considered. Finally, a shock on the interest rate policy rule is incorporated.

Despite the complexity of the model, some "tractable" equations such as an "IS curve" and a "BP curve", both augmented with expectations, are derived. This makes it possible to establish a link to the simpler analytical results of CCV (2003). Based on highly stylized structures, these authors derive exact closed-form solutions. In contrast, the model is solved numerically here. The paper then proceeds to simulate the model under reasonable parameters found in the literature and analyzes the impact of different

5 Kollman (2001) studies a model of a small open economy with price and wage rigidities. However, he uses staggered price and wage settings.

6 For this reason an LM analysis that specifies money demand and money supply is unnecessary.

7 See Clarida, Gali and Gertler (1999) for a survey of this literature in closed economies and Clarida, Gali and Gertler (2001) for an extension to open economies.

shocks to the economy. Alternative scenarios of exchange rate regimes and for varying degrees of strength of the balance sheet mechanism are considered. In particular, the effect of a devaluationary policy shock (i.e. a shock that increases exogenously the nominal exchange rate target) is analyzed in isolation from any other shock to the economy. This is an important dimension in which this paper differs from related literature. Its motivation is that during a period of exchange rate crisis, the focus of monetary policy is to stabilize the exchange rate, and thus a reasonable policy response is for the authorities to give up the exchange rate target.

The paper also considers the behavior of the economy under two alternative adverse external shocks (on the international interest rate and export demand). The analysis of these shocks is then complemented so as to consider the combined effects of each of these external shocks jointly with a devaluationary policy shock induced by the central bank. In this case, the main question to answer is whether a devaluationary exchange rate policy can have a stabilizing role when the economy faces adverse external shocks.

Simulation results show that, all else equal, devaluations are expansionary in terms of output despite the contractionary effects associated with the balance sheet mechanism. Furthermore, the output response is found to be larger as the exchange rate regime becomes less flexible. In addition, adverse external shocks are found to have a contractionary effect. In such cases, exchange rate policy, through a devaluation of the nominal exchange rate, can play a stabilizing role that mitigates output contraction. The effect is more significant under less flexible exchange rate regimes.

The rest of the paper is organized as follows. The model is set up in Section 1. Then the solution method and the parameterization of the model are discussed in Section 2. The quantitative implications of the model are then presented. For this purpose, an intuitive discussion on how the mechanics of the model work is presented in Section 3. In 4 I analyze the impulse response function of a monetary policy shock so that the impact of the interest rate rule in the model can be disentangled from other shocks to the economy. Section 5 analyzes the effects of a pure exogenous devaluationary policy shock, while the impact of external shocks on the economy in isolation and jointly with a devaluationary policy are analyzed in Section 6. Finally, some concluding remarks are discussed in Section 7.

1. THE MODEL

The framework used here extends Cespedes, Chang and Velasco (2004, 2003). The model considers a small open economy that consists of four types of agents: firms, households, entrepreneurs, and a monetary authority. There is a continuum of monopolistically competitive firms that rent capital from entrepreneurs and labor from households, and produce in each period a distinct perishable good. Each household has monopoly power over its own type of labor and faces a demand for its labor from firms. Thus, households set wages. Entrepreneurs rent capital to firms and borrow from abroad to finance new capital.

The economy faces no barriers to trade. Capital flows are allowed, but due to informational asymmetries there is a risk premium that must be paid in addition to the international risk free interest rate in order to borrow money. The monopolistic nature of households and firms in the labor and goods markets, respectively, gives rise to the possibility of nominal rigidities,[8] which take the form of price and wage adjustment costs.[9] In contrast with CCV's models, these rigidities are endogenously determined.

The economy is affected by six type of shocks. Firms are affected by technology and cost-push or mark-up shocks, and households are subject to a preference shock. Shocks to the monetary policy rule, international interest rates, and export demand are also introduced.

1.1 Domestic Production: The Firms' Problem

The production of each variety of domestic goods is carried out by a continuum of monopolistically competitive firms indexed by $j \in [0,1]$. Each firm rents capital, K_{jt}, at a rental rate R_t, and hires labor services, L_{it}, from a continuum of heterogeneous workers indexed by $i \in [0,1]$, at a nominal wage rate W_{it} to produce home goods. Each firm chooses the price of the good it produces and its labor and capital demands, given the demand function for its own good, aggregate demand and the aggregate price level.

It is assumed that it is costly for firms to reset prices due to the presence of quadratic adjustment costs, as captured by equation (5) below.[10] The specification adopted shows the percentage cost in terms of output of changing the price level. The cost size is a function of the parameter, ψ_p, and increases with the size of the price change and overall level of economic activity.[11] Intuitively, firms pay an adjustment cost if the increase in the price exceeds the steady-state gross inflation rate of domestic goods, $\bar{f}^p$. For simplicity, these adjustment costs are set to zero at steady state. The problem faced by each firm is summarized by:[12]

$$\underset{L_{jt},K_{jt}}{Max}\, E_o \sum_{t=0}^{\infty} \Delta_t \left(P_{jt}Y_{jt} - \int_0^1 W_{ijt}L_{ijt}di - R_t K_{jt} - P_t AC_t^P \right) \tag{1}$$

8 The empirical literature has also employed capital adjustment costs to introduce real rigidities. Kim (2000) shows that this is important to improve the model's fit to the data. In his paper, this explains both the product and liquidity effects that arise when the economy is exposed to a monetary shock. Dib (2001) introduces real rigidities through adjustment costs on labor. In this paper, real effects arise due to the balance sheet effect on investment.

9 Monetary policy only has small real effects in an environment of perfect wage and price flexibility. So rigidities are important for the monetary transmission mechanism. As discussed by Woodford (2003, 140), a "more empirically realistic model is likely to involve both wage and price stickiness". Kim (2000) also argues that these rigidities are essential to capture the "output effect" of monetary policy, i.e. the output increase in response to an expansionary monetary policy.

10 An alternative approach to model price rigidities is Calvo's (1983) staggered price setting. However, Rotemberg (1982) shows that a model with quadratic adjustment costs is equivalent, as far as aggregates are concerned, to a model such as Calvo's (1983). See Rotemberg (1996) and Hairault and Portier (1993) for models with convex costs of price adjustment. Empirical papers such as Kim (2000), Bergin (2004 and 2003) and Ireland (2004a,b and 2001) all use this quadratic adjustment approach.

11 One could ask why prices, and not quantities, are the ones that incur adjustment costs. The explanation is one of information costs. Price changes must be made known to consumers, which need not be the case for quantity changes (see Kim, 2000).

12 The present formulation implies a dynamic profit maximization problem associated with the presence of price stickiness rather than the static profit maximization problem in CCV's paper.

s.t.

$$Y_{jt} = A_t K_{jt}^{\alpha} L_{jt}^{1-\alpha}, \quad 0 < \alpha < 1 \tag{2}$$

$$L_{jt} = \left[\int_0^1 L_{ijt}^{\frac{\sigma-1}{\sigma}} di\right]^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1 \tag{3}$$

$$P_{jt} = \left[\frac{Y_{jt}}{Y_t}\right]^{-\frac{1}{\theta_t}} P_t, \quad \theta_t > 1 \tag{4}$$

$$AC_t^P = \frac{\psi_p}{2}\left[\frac{P_{jt}}{P_{jt-1}} - \bar{f}^p\right]^2 Y_t \tag{5}$$

where Δ_t is the firm's stochastic discount factor. The production function captured by equation (2) is Cobb-Douglas with a multiplicative technology shock captured by the parameter A_t, which is assumed to be common to all firms in the country and subject to shocks. As in the real business cycle literature, A_t follows a first-order autoregressive process:

$$\ln A_t - \ln \overline{A} = \zeta_A \left(\ln A_{t-1} - \ln \overline{A}\right) + \varepsilon_{At} \tag{6}$$

where $0 < \zeta_A < 1$ and $\varepsilon_{At} \sim N\left(0, \sigma_A^2\right)$ are serially uncorrelated. A_t is observed at the beginning of period t.

The labor input captured by eq.(3) is a C.E.S. aggregate of heterogenous labor services. Hence, σ is the elasticity of demand for worker i's services. In addition, firms face a demand for their product from domestic consumers, entrepreneurs and foreign consumers captured by (4). P_t stands for the aggregate price index for domestically produced goods. The index is defined in the next subsection.

There is a random shock to the elasticity of substitution between different varieties of goods, θ_t. This shock, also known as a mark-up or cost-push shock, follows a first-order autoregressive process[13]:

$$\ln \theta_t - \ln \overline{\theta} = \zeta_\theta \left(\ln \theta_{t-1} - \ln \overline{\theta}\right) + \varepsilon_{\theta t} \tag{7}$$

where $0 < \zeta_\theta < 1$ and $\varepsilon_{\theta t} \sim N\left(0, \sigma_\theta^2\right)$ is serially uncorrelated. The relevance of this shock is that it provides an additional source of output and inflation fluctuations different to that of a technology shock alone. Ireland (2004b) has found for the US that these shocks are more important than technology ones in explaining output, inflation and interest rates.

Observing that P_{jt} is a function of output, which in turn is a function of capital and labor, and defining for convenience $r_t \equiv \frac{R_t}{Q_t}$ and $w_t \equiv \frac{W_t}{Q_t}$, where Q_t is the economy's overall price index (defined in the next subsection), yields the first-order conditions for this problem with respect to capital and labor, respectively:

$$r_t = \alpha \left[1 - \frac{1}{e_{jt}^Y}\right] \frac{Y_{jt} P_{jt}}{K_{jt} Q_t} \tag{8}$$

$$w_t = (1-\alpha) \left[1 - \frac{1}{e_{jt}^Y}\right] \frac{Y_{jt} P_{jt}}{L_{jt} Q_t} \tag{9}$$

---

13 Clarida, Gali and Gertler (1999) refer to cost-push shocks as anything different to variations in excess demand that might affect expected marginal costs. Ireland (2004b) introduces an additional shock that affects the Phillips curve specification, which is originated as an exogenous disturbance to the firm's desired mark-ups of price over marginal cost. This is the interpretation followed here.

where the minimum cost of a unit of aggregate labor L_{jt} and aggregate labor cost are given respectively by:

$$W_{jt} = \left[\int_0^1 W_{ijt}^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} \quad ; \quad W_{jt}L_{jt} = \int_0^1 W_{ijt}L_{ijt}di \tag{10}$$

and where e^Y_{jt} is the output demand elasticity augmented with adjustment costs. Formally,

$$e^Y_{jt} \equiv \theta_t \begin{bmatrix} 1 - \psi_p \left(\frac{P_{jt}}{P_{jt-1}} - \bar{f}^p\right) \frac{P_t}{P_{jt-1}} \frac{Y_t}{Y_{jt}} \\ +\psi_p E_t \left[\frac{\Delta_{t+1}}{\Delta_t} \left(\frac{P_{jt+1}}{P_{jt}} - \bar{f}^p\right) \frac{P_{jt+1}}{P_{jt}^2} \frac{P_{t+1}}{Y_{jt}} Y_t\right] \end{bmatrix}^{-1} \tag{11}$$

Both equations (8) and (9) are the standard conditions equating the marginal cost of capital and labor to their marginal revenue after considering the mark-up wedge between them, i.e. $\frac{e^Y_{jt}}{e^Y_{jt}-1}$.[14] They imply an optimal trade-off between capital and labor inputs that depends on the relative cost of each:

$$w_t L_{jt} = \left(\frac{1-\alpha}{\alpha}\right) r_t K_{jt} \tag{12}$$

1.2 The Household's Problem

There is a continuum of heterogeneo households indexed by $i \in [0,1]$, who supply labor in a monopolistically competitive manner. Households have additively separable preferences over consumption, C_{it} and labor supply, L_{it}, in each period. Future utility is discounted at a rate of time preference β, and preferences are subject to a shock, a_t. Households derive income by selling labor at a nominal wage rate, W_{it} and hold two type of assets: non-contingent domestic bonds B_{it}, and non-contingent tradable foreign bonds, B^*_{it}. These bonds are denominated in home and foreign currency and yield a nominal return i_t and i^*_t, respectively.

Each household chooses the wage at which to sell its differentiated labor. They take as given the labor demand function for their labor type, as captured by eq.(17) below, as well as the aggregate variables. Therefore, households care about their wage relative to the aggregate wage index. In addition, they face an adjustment cost of changing wages captured by eq.(18) below, which depends on the parameter ψ_w.[15] As specified, the cost is increasing in deviations of actual wage inflation from its steady state and in the overall wage level of the economy, and this introduces the possibility of wage rigidities.

The optimization problem faced by each household is expressed as follows:[16]

$$\underset{C_{it},L_{it},B_{it},B^*_{it}}{Max} E_o \sum_{t=0}^{\infty} \beta^t a_t \left(lnC_{it} - \left(\frac{\sigma-1}{\sigma}\right)\frac{1}{\nu} L^{\nu}_{it}\right) \tag{13}$$

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14 In the absence of adjustment costs, the elasticity of output demand equals the elasticity of substitution between different varieties of domestic output. In such case, firm's problem FOCs yield the standard condition that in a symmetric monopolistic competition model equilibrium prices are set so that there is a mark-up over marginal costs.

15 The quadratic specification follows Kim (2000). It captures imperfections in the labor market as it contains elements of a search process. Similar specifications are found in Ireland (2001) and Bergin (2004 and 2003).

16 The standard utility function used in the literature is adopted here (see Obstfeld and Rogoff, 2000).

$$0 < \beta < 1; \varepsilon > 0 \text{ and } \nu > 1$$

s.t.

$$C_{it} = \kappa \left(C_{it}^H\right)^\gamma \left(C_{it}^F\right)^{1-\gamma}, \ 0 < \gamma < 1 \tag{14}$$

$$P_t C_{it}^H + S_t C_{it}^F = Q_t C_{it} \tag{15}$$

$$B_{it} - B_{it-1} + S_t \left(B_{it}^* - B_{it-1}^*\right) = i_{t-1} B_{it-1} + S_t i_{t-1}^* B_{t-1}^* + W_{it} L_{it} - AC_t^w - Q_t C_{it} \tag{16}$$

$$W_{it} = \left(\frac{L_{it}}{L_t}\right)^{-\frac{1}{\sigma}} W_t \tag{17}$$

$$AC_t^w = \frac{\psi_w}{2} \left[\frac{W_{it}}{W_{it-1}} - \bar{\Omega}\bar{\pi}\right]^2 W_t \tag{18}$$

where γ is the share of home produced goods in total consumption, $\bar{\Omega}$ and $\bar{\pi}$ are the steady-state real wage inflation and consumer price inflation respectively. $\kappa = \left[\gamma^\gamma (1-\gamma)^{1-\gamma}\right]^{-1}$ is an irrelevant constant. The elasticity of labor supply is captured by ν, and $\frac{\sigma-1}{\sigma}$ determines the marginal disutility of labor.[17] The preference shock a_t follows an autoregressive process:

$$\ln a_t = \zeta_a \ln a_{t-1} + \varepsilon_{at} \tag{19}$$

where $0 < \zeta_a < 1$, $\varepsilon_{at} \sim N\left(0, \sigma_a^2\right)$ and is serially uncorrelated.

Domestically produced goods, C_{it}^H, are aggregated through a C.E.S. function. This and its associated price index are given by:

$$C_{it}^H = \left[\int_0^1 C_{jt}^{\frac{\theta_t - 1}{\theta_t}} dj\right]^{\frac{\theta_t}{\theta_t - 1}} \quad ; \quad P_t = \left[\int_0^1 p_{jt}^{1-\theta_t} dj\right]^{\frac{1}{1-\theta_t}} \tag{20}$$

where θ_t is the elasticity of substitution between different domestic goods.

Imported goods, C_{it}^F, have a fixed price in terms of foreign currency and the law of one price is assumed to hold.[18] As a result, the price of imports in domestic currency is equal to the nominal exchange rate S_t.

The first-order conditions for the household's intra-temporal problem are:[19]

$$\left(\frac{1-\gamma}{\gamma}\right) \frac{C_t^H}{C_t^F} = \frac{S_t}{P_t} \equiv e_t \tag{21}$$

That is, this condition equates the demand for home versus foreign goods to the real exchange rate. The minimum cost of one unit of aggregate demand is then:

$$Q_t = P_t^\gamma S_t^{1-\gamma} \tag{22}$$

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17 L should be thought as efficiency of labor rather than actual hours worked, H, with $H = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{1}{\nu}} L$. See Obstfeld and Rogoff (1996 and 2000).

18 An important issue in the new open economy macroeconomics literature is departing from the law of one price assumption because evidence seems to reject it on the data. Departing from this assumption would require introducing additional features to the model, which is already very complicated. For instance, Kollman (2001) assumes pricing to market (PTM) to avoid the law of one price assumption.

19 Formally, this is an equilibrium condition derived after imposing symmetry conditions.

Define real wages as $w_{it} = \frac{W_{it}}{Q_t}$, real wage inflation as $\Omega_{it} \equiv \frac{w_{it}}{w_{it-1}}$, overall inflation (c.p.i.) as $\pi_{it} \equiv \frac{Q_t}{Q_{t-1}}$, nominal devaluation as $f_t^s \equiv \frac{S_t}{S_{t-1}}$ and express nominal wage growth as $\frac{W_{it}}{W_{it-1}} = \Omega_{it}\pi_{it}$. This allows us to write the optimal inter-temporal conditions in a more convenient manner. The household's problem yields the standard inter-temporal Euler equations for consumption smoothing and an optimal wage setting equation:

$$\frac{1}{C_{it}} = \beta\left(1+i_t\right)E_t\left(\frac{a_{t+1}}{a_t}\frac{1}{\pi_{t+1}C_{it+1}}\right) \tag{23}$$

$$\frac{1}{C_{it}} = \beta\left(1+i_t^*\right)E_t\left(\frac{a_{t+1}}{a_t}\frac{f_{t+1}^s}{\pi_{t+1}C_{it+1}}\right) \tag{24}$$

$$-\left(\frac{1-\sigma}{\sigma}\right)L_{it}^{\nu-1} = \frac{w_{it}}{C_{it}}\left(1-\frac{1}{e_{it}^L}\right) \tag{25}$$

where e_{it}^L is the labor demand elasticity augmented with adjustment costs:

$$e_{it}^L \equiv \sigma\left[\begin{array}{c} 1-\frac{\psi_w}{L_{it}}\frac{w_t}{w_{it-1}}\pi_t\left(\Omega_{it}\pi_t-\bar{\Omega}\bar{\pi}\right) \\ +\beta\frac{\psi_w}{L_{it}}E_t\left[\frac{a_{t+1}}{a_t}\frac{C_{it}}{C_{it+1}}\frac{w_{it+1}}{w_{it}^2}w_{t+1}\pi_{t+1}\left(\Omega_{it+1}\pi_{t+1}-\bar{\Omega}\bar{\pi}\right)\right]\end{array}\right]^{-1} \tag{26}$$

This term can be thought of as a "wage mark-up" that captures frictions in wage setting. Therefore it distorts the real wage from its competitive equilibrium value $w_{it} = C_{it}L_{it}^{\nu-1}$. Finally, in addition to the above optimality conditions, a non-Ponzi transversality condition for bond holdings is imposed.

1.3 The Entrepreneur's Problem

Entrepreneur's behavior is modeled as in CCV, which in turn is based on Bernanke, Gertler and Gilchrist's (1999) analysis of the role of credit market frictions in business cycle fluctuations in a closed economy.[20] For convenience, it is assumed that entrepreneurs' main activity is to decide how much to invest.[21] The analysis relies on the fact that entrepreneurs borrow from world capital markets to finance investment in excess of net worth. For this purpose they issue dollar-denominated debt contracts, which, due to imperfections in international financial markets, require a risk premium over the risk free international interest rate.

More specifically, assume that an entrepreneur is making the decision of how much to invest.[22] This agent will then finance investment using its own net worth and the

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[20] Bernanke, Gertler and Gilchrist's (1999) analysis is an optimal debt contract problem between a single entrepreneur and foreign lenders. These agents face a joint problem of choosing investment, a dollar loan and a repayment schedule so as to maximize profits. This problem can be transformed into one where the optimal contract maximizes the entrepreneur's utility by choosing the investment-net worth ratio and the optimal cutoff of a random variable required to make the project profitable enough to allow the repayment of the loan. See also Carlstrom and Fuerst (1997).

[21] This assumption differs from Bernanke, Gertler and Gilchrist (1999), who rely on a more general setting that considers the possibility of consumption by these agents. This simplifies matters, as we need not care about their labor supply or the impact of their consumption on the economy.

[22] Details are discussed in appendix A.

remaining portion will be financed through debt. As a result the entrepreneur's budget constraint is determined by:

$$P_t N_t + S_t D_{t+1} = Q_t K_{t+1} \tag{27}$$

where it is assumed that there is full capital depreciation and that the price index for the cost of investment is the same as that for consumption as captured by eq.(22).

Entrepreneurs borrow abroad, paying a risk premium, $1+\eta_t$, above the world risk free interest rate, $1+\rho_t$. It is assumed that the risk premium is an increasing concave function in the ratio of the value of investment to net worth:

$$1+\eta_t = \left(\frac{Q_t K_{t+1}}{P_t N_t}\right)^{\mu} \tag{28}$$

where μ is the elasticity of the risk premium to the ratio of investment to net worth.

Therefore, in equilibrium, the expected yield of capital in foreign currency must equal the cost of borrowing in international capital markets to finance capital investment:

$$\frac{E_t\left(R_{t+1}K_{t+1}/S_{t+1}\right)}{Q_t K_{t+1}/S_t} = \left(1+\rho_t\right)\left(1+\eta_t\right) \tag{29}$$

In addition, it is assumed that the world interest rate follows a first-order autoregressive process:

$$\ln\rho_t - \ln\overline{\rho} = \zeta_\rho\left(\ln\rho_{t-1} - \ln\overline{\rho}\right) + \varepsilon_{\rho t} \tag{30}$$

where $0 < \zeta_\rho < 1$ and $\varepsilon_{\rho t} \sim N\left(0, \sigma_\rho^2\right)$ are serially uncorrelated.

In Bernanke, Gertler and Gilchrist (1999), net worth is defined as the entrepreneurial equity of the firms that remain in business. That is the wealth accumulated from operating firms. Firms that fail in t consume the residual equity, which in our case is only imported goods. Entrepreneurs are assumed here to own domestic firms, so entrepreneurial equity equals gross earnings on holdings of equity from $t-1$ to t less repayment of borrowings. Therefore, net worth is defined to be:

$$P_t N_t = R_t K_t + \Pi_t - S_t D_t = \left[1 - \frac{\psi_p}{2}\left(\frac{P_t}{P_{t-1}} - \bar{f}^p\right)^2\right] P_t Y_t - W_t L_t - S_t D_t \tag{31}$$

1.4 Monetary Policy

The central bank's policy instrument is the short-term nominal interest rate. Therefore, the central bank follows an interest rate rule that targets different macroeconomic variables. In open economy settings the specification of such rules is more controversial than in closed economy ones, where most of the theoretical contributions have been made.[23] The reason is related to the wider set of variables to which monetary policy can react. The specification adopted is such that the interest rate target reacts to deviations of expected c.p.i. inflation, output and the nominal exchange rate from their

[23] See Woodford (2003) and Clarida, Gali and Gertler (1999) for a discussion of interest rate rules in a closed economy setting. For an open economy overview see Clarida, Gali and Gertler (2001) and Benigno and Benigno (2000).

long-run levels (i.e., steady-state levels).[24] Formally, the interest rate target is captured by:

$$\frac{1+\tilde{\imath}_t}{1+\bar{\imath}} = \left(\frac{E_t \pi_{t+1}}{\bar{\pi}}\right)^{\omega_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\omega_y} \left(\frac{S_t}{\overline{S}_t}\right)^{\frac{\omega_s}{1-\omega_s}} \tag{32}$$

where $\overline{S}_t = \frac{\overline{S}\cdot\overline{\chi}}{\chi_t}$, ω_π, ω_y and $\omega_s \in [0,1]$ are the weights on each of the target variables and χ_t is a devaluationary policy shock.[25] Since central banks tend to smooth changes in interest rates, the actual interest rate is allowed to partially adjust to the target as follows:[26]

$$\frac{1+i_t}{1+\bar{\imath}} = \left(\frac{1+i_{t-1}}{1+\bar{\imath}}\right)^{\omega_i} \left(\frac{1+\tilde{\imath}_t}{1+\bar{\imath}}\right)^{1-\omega_i} \tag{33}$$

where the parameter $\omega_i \in [0,1]$ is the interest rate smoothing parameter.

Inflation and output targeting are standard in closed economy models. However, and given the open economy nature of the model, it is assumed that the central bank also targets the nominal exchange rate. Therefore, monetary policy is tightened by increasing the nominal interest rate if the nominal exchange rate exceeds its long-run level. Targeting the exchange rate is justified in the model because firms borrow in foreign currency (dollars), and external shocks may cause significant volatility of the exchange rate.[27]

Given this rule, a devaluation is defined to be an increase of the nominal exchange rate target, $\overline{S}_t$, which leads to a decrease in the interest rate. For this purpose a shock χ_t on this variable is introduced.[28] Its motivation is that during crisis episodes the focus of monetary policy is on stabilizing the exchange rate. Formally, χ_t follows a first-order autoregressive process:[29]

$$\ln \chi_t - \ln \bar{\chi} = \zeta_\chi \left(\ln \chi_{t-1} - \ln \bar{\chi}\right) + \varepsilon_{\chi t} \tag{34}$$

where $0 < \zeta_{\chi t} \leq 1$, $\varepsilon_{\chi t} \sim N\left(0, \sigma_\chi^2\right)$ and is serially uncorrelated.

The specification of the interest rate rule also allows us to approximate the systematic behavior of monetary policy for a continuum of exchange rate regimes depending on the weight ω_s. Hence, for $\omega_s = 0$ the rule approximates a pure floating exchange rate regime while for larger values of ω_s (i.e. $\omega_s \cong 1$) it approximates a managed float regime.

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24 See Monacelli (2004).

25 As will be discussed later, the coefficient on inflation (ω_π) must be greater than one. The coefficient ω_s has been restricted here to be less than 1. This follows the general perception, including on the part of the IMF, that an increasing exchange rate should induce the central bank to raise interest rates. Following the Asian crises there was some argument on whether this should be the case. This controversy is discussed in Cho and West (2003) and Furman and Stiglitz (1998).

26 Clarida, Gali and Gertler (1998 and 2000) adopt this partial adjustment mechanism in their empirical analysis.

27 It could also be argued that in emerging markets with a poor history of monetary stability, the exchange rate may act as a credibility device.

28 See Cho and West (2003) for a similar approach.

29 For operational purposes the shock enters in a multiplicative form in the interest rule. Therefore a devaluation will be captured by a negative shock on $\varepsilon_{\chi t}$.

1.5 Market-Clearing Condition

Provided that a proportion γ of output is spent on consumption and investment of domestic goods, that a fraction of output is used to cover price adjustment costs, and that another fraction of domestic output is exported, then the market-clearing condition may be written as:

$$P_t Y_t = \gamma Q_t \left(K_{t+1} + C_t\right) + \frac{\psi_p}{2}\left(f_t^p - \bar{f}^p\right)^2 P_t Y_t + S_t X_t \tag{35}$$

where the last term stands for the home good value of exports to the rest of the world. For simplicity, export demand is assumed to follow an autoregressive process:

$$\ln X_t - \ln \overline{X} = \zeta_x \left(\ln X_{t-1} - \ln \overline{X}\right) + \varepsilon_{xt} \tag{36}$$

where $0 < \zeta_x < 1$ and $\varepsilon_{xt} \sim N\left(0, \sigma_x^2\right)$ are serially uncorrelated.

To close the model, a firm's stochastic discount factor must be specified. In standard models, where firms are owned by households and where every agent has access to a complete competitive market for contingent claims, it is assumed that firms maximize their market value. Hence, there is a unique discount factor equivalent to the marginal utility to the representative household of an additional unit of profits received each period. However, in the present framework, firms are owned by entrepreneurs. Therefore, for simplicity it is assumed that entrepreneurs discount profits at a rate equivalent to that of the marginal utility of consumption:

$$\frac{\Delta_{t+1}}{\Delta_t} = \beta\left(\frac{a_{t+1}}{a_t}\frac{C_t}{C_{t+1}}\right) \tag{37}$$

2. SOLUTION METHOD AND CALIBRATION

The system of equations describing this economy cannot be solved for analytically. As a result the system is log-linearized around the non-stochastic symmetric steady state and solved with the method of undetermined coefficients described by Uhlig (1997).[30] The solution relies on the fact that the system can be expressed as a linear rational expectations model with 15 endogenous variables:[31] output (y), consumption (c), capital (k), labor (l), real rental rate on capital (r), real wages (w), real exchange rate (e), nominal exchange rate (s), overall domestic inflation (π), nominal devaluation rate (f^s), nominal interest rate on risk free domestic bonds (i), foreign bonds (b^*), net worth (n), foreign debt (d), and the risk premium (η). These endogenous variables are matched by 15 equilibrium conditions. In addition, there are six stochastic equations that capture the role of shocks in the model. These are the technology shock (A), the mark-up shock (θ), the preference shock (a), the interest rate rule shock (χ), the export demand shock (x) and the shock to international interest rates (ρ). Overall there are 21 equations and 21 unknowns.

[30] The symmetric equilibrium, the existence and solution of the steady state and the log-linearized system of equations are discussed in appendices B, C and D. The solution method and its implementation for the model are discussed in appendix F.

[31] Some variables were substituted out: domestically produced goods inflation rate (f^p), interest rate on foreign bonds (i^*), output demand elasticity augmented with adjustment costs $\left(e^Y\right)$, labor demand elasticity augmented with adjustment costs $\left(e^L\right)$ and real wage inflation rate (Ω).

2.1 Parameter Values

The empirical implications of the model are obtained by calibrating it with reasonable parameter values found in the literature. Benchmark values are summarized in Table 1. Parameter values for preferences and technology are quite standard in the literature so no major comments are necessary. An exception is the elasticity of substitution between different varieties of goods, $\theta = 6$, which was chosen following Gali and Monacelli (2002) so that the steady-state mark-up equals 20%. There seems to be less of a consensus regarding the values for price and wage adjustment costs. These are set to $\psi_p = 5$ and $\psi_w = 2$. Intuitively, these values indicate that a 2% deviation from steady-state inflation implies a 0.1% price adjustment cost in terms of domestic output value. The adjustment cost for wages can be analyzed similarly but taking into account that the cost is expressed in terms of the monetary wage value. These parameter values are very sensitive to other parameters of the economy, as is shown from the estimates of Bergin (2004), Dib (2001) or Ireland (2004a) for Australia, Canada, the UK or the US. In the present framework the parameterization is motivated to ensure that the balance sheet mechanism operates in a contractionary manner. The reasoning for this is explained in more detail in the next subsection.

The main balance sheet parameter which captures international capital market imperfections is set to $\mu = 0.5$. This value is higher than in CCV (2004) but in line with Carlstrom and Fuerst's (1997) suggested range of 0.2 to 0.4. This choice was complemented with a ratio of inherited debt to net worth, ψ, equal to 1.25 to ensure a strong balance sheet effect.

Parameter values for the interest rate rule are motivated by Monacelli (2004), Engel and West (2002) and Clarida, Gali and Gertler (1998 and 2000). The partial adjustment weight of the interest rate, ω_i is set to 0.75. The weight on inflation, ω_π, is set equal to 1.75. Known in the literature as the *Taylor Principle*, the optimal policy response to a rise in inflation is to increase interest rates sufficiently to induce an increase in real interest rates. For such purposes, the coefficient on the inflation term should exceed unity.[32] The inflation parameter value implies that, everything else constant, a one percentage point increase in quarterly expected inflation induces a 75 basis point increase in the quarterly real interest rate. On the other hand, ω_y is set to 0.93, implying, ceteris paribus, a 93 basis point increase in the quarterly nominal interest rate. The weight on the nominal exchange rate varies in order to simulate alternative exchange rate regimes.

The technology persistence parameter, $\zeta_A = 0.95$, is as in Chari, Kehoe and McGrattan (2002) and Ireland (2004b). The autocorrelation coefficient for exports and the international risk free interest rate, $\zeta_x = 0.9$ and $\zeta_\rho = 0.9$, follows CCV (2004). Consumer preference and mark-up persistence parameters are set as in Ireland (2004a) at $\zeta_a = 0.95$ and $\zeta_\theta = 0.96$, respectively. Finally, the persistence parameter for the monetary policy shock is set to $\zeta_\chi = 0.7$.[33]

32 See Clarida, Gali and Gertler (1999) and Woodford (2003). In the model a value of $\omega_\pi < 1$ would imply a decline in the real interest rate in response to a rise in anticipated inflation. As a result aggregate demand would increase and inflation would be pushed up further. Hence, the initial expected increase in inflation would be a self-fulfilling prophecy.

33 Simulations were also performed for permanent monetary shocks, i.e. $\zeta_\chi = 1$. Qualitative results are robust in this sense.

3. ON THE MECHANICS OF THE MODEL

Before simulation results are discussed, it is useful to derive some analytical results that highlight the transmission mechanisms involved during a devaluation. In particular, an "IS-BP" system is constructed that captures the essence of the effects of devaluations on output, which resemble those obtained by CCV. In particular, it is shown that eliminating some variables such as net worth (n) and risk premium (η) illustrates better the mechanics of the balance sheet effect.

3.1 The IS Curve

The IS curve captures the equilibrium conditions in the goods market. It is derived by combining the consumption Euler equation with the goods market-clearing condition:[34]

$$\hat{y}_t = E_t\hat{y}_{t+1} - \Lambda_k E_t\hat{k}_{t+2} + \Lambda_k\hat{k}_{t+1} + \Lambda_e E_t\hat{e}_{t+1} + \Lambda_e\hat{e}_t - \Lambda_\tau\left[\hat{\imath}_t - E_t\pi_{t+1}\right] + \Lambda_a\hat{a}_t + \Lambda_x\hat{x}_t \quad (38)$$

All coefficients are defined to be positive. This relationship is captured graphically in Figure 1 as an upward sloping line in (y, k) space. Observe that devaluations in period t and output are positively related holding everything else constant. This is the standard Mundell-Fleming expansionary effect of devaluations. The term in brackets captures the negative relation between output and the real interest rate. The elasticity coefficient Λ_τ captures the intertemporal substitution of consumption, so that expected higher output raises current output because individuals prefer to smooth consumption. Hence, expectations of higher consumption next period lead them to demand more consumption today, which raises current output demand. Finally, ceteris paribus, preference and export demand shocks have a positive effect on output. In terms of Figure 2, these shocks shift the IS curve to the right.

3.2 The BP Curve

The BP relationship captures the equilibrium conditions in international financial markets. Obtained from the entrepreneur's problem, it has a fundamental role as it provides the intuition behind the balance sheet mechanism and why devaluations might be contractionary or expansionary.

Three steps are crucial in building this relationship. First, the connection between the real exchange rate and net worth needs to be established. In CCV's framework there is an inverse relation, but in the present framework this need not be the case. Second, the exchange rate and the risk premium must be linked. Below we will show that the exchange rate has two effects, a positive direct effect, and an indirect effect that operates through firms' net worth. In general, the combined impact is indeterminate. Finally, the relation between exchange rate and investment is determined, that is, the BP curve is derived. Again, we will show that a devaluation has both a direct and an indirect effect. The latter will operate via the risk premium. The final direction of the relationship will depend on the deep parameter values of the economy. This implies that a devaluation can shift the BP curve in any direction when represented in the (y, k) space. Each step is now discussed in detail.

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34 For notational purposes, define $\widehat{z}_t \equiv \frac{z_t - \bar{z}}{\bar{z}} \cong \ln\left(\frac{z_t}{\bar{z}}\right)$ as the percentage deviation from the steady state value, $\bar{Z}$. See appendix E for details and exact definitions of different coefficients used.

3.2.1 Net Worth and Devaluations

The effect of devaluations on net worth is captured by the following equation:[35]

$$\hat{n}_t = (1+\psi)\,\hat{y}_t - \psi\hat{e}_t - \psi\hat{d}_t + (1+\psi)\,(1-\phi)\,\frac{\hat{e}_t^Y}{\bar{\theta}-1} \tag{39}$$

Net worth is related positively to output as captured by the first term, and negatively to the inherited level of external debt as captured by the third term. The second term captures the direct negative relationship between net worth and the real exchange rate. This is the effect identified by CCV. But in the present framework there is an additional indirect effect that operates through the output demand elasticity augmented with adjustment costs. This term is related inversely to real devaluations and positively to the expected real devaluation rate, as captured by:

$$\begin{aligned}\hat{e}_t^Y &= \beta\psi_p\pi^3\,(1-\gamma)\,E_t\hat{e}_{t+1} - \psi_p\pi^2\,(1-\gamma)\,(1+\beta\pi)\,\hat{e}_t + \psi_p\pi^2\,(1-\gamma)\,\hat{e}_{t-1} \\ &\quad -\beta\psi_p\pi^3 E_t\hat{\pi}_{t+1} + \psi_p\pi^2\hat{\pi}_t + \hat{\theta}_t \end{aligned} \tag{40}$$

To understand how CCV's results change with this term, observe that the overall impact of devaluations on net worth is captured by the *negative* value of the following parameter:[36]

$$\Xi = \psi + (1+\psi)\,(1-\phi)\,\frac{\psi_p\pi^2\,(1-\gamma)\,(1+\beta\pi)}{\bar{\theta}-1} \tag{41}$$

Given that $1-\phi < 0$[37] and the remaining terms are positive, devaluations need not worsen firms' balance sheets. Whether it does or not depends on the sign of the second term in Ξ, and this in turn will depend on two things: the expenditure-switching effect (γ) and the degree of price stickiness of the economy (ψ_p). Therefore, an economy with a small share of home goods in consumption will benefit more from a devaluation due to the expenditure-switching effect. This effect will be magnified if there is a higher degree of price stickiness in the economy (ψ_p is large). Hence, this combination will operate to improve entrepreneurs' net worth rather than to reduce it. Overall, a devaluation will always worsen firms' balance sheets if Ξ is positive. This will happen if the economy has a large inherited external debt, i.e. a large ratio of external debt to net worth, ψ. In the benchmark parameterization a devaluation always worsens firm's net worth (See Table 2).

3.2.2 Risk Premium and Devaluations

The effect of devaluations on the risk premium is captured by:

$$\hat{\eta}_t = \mu\left[(1-\gamma+\psi)\,\hat{e}_t + \hat{k}_{t+1} - (1+\psi)\,\hat{y}_t + \psi\hat{d}_t - (1+\psi)\,(1-\phi)\,\frac{\hat{e}_t^Y}{\bar{\theta}-1}\right] \tag{42}$$

Here a devaluation operates in two ways: directly, as captured by the term $1-\gamma$ multiplying the real exchange rate, and indirectly via the effects of devaluations on net worth,

[35] Readers familiar with CCV's framework will note that only the first two terms in this equation appear in their analysis.

[36] Observe that the discussion assumes for simplicity that $\hat{e}_{t-1} = 0$.

[37] Where $\phi \equiv \left[1-(1-\alpha)\left(1-\frac{1}{\bar{\theta}}\right)\right]^{-1}$.

i.e. through Ξ. Hence, if a devaluation lowers entrepreneur's net worth the country's risk premium will rise.

An important result is that in contrast with CCV's framework, the risk premium is not independent of nominal rigidities. In fact, price rigidities affect the output demand elasticity augmented with adjustment costs and therefore, the risk premium. In the absence of price rigidities, a devaluation of the exchange rate affect the risk premium by $\mu(1-\gamma+\psi)$. But when price adjustment costs are present the term last term in Eq.(42) must be considered. In the benchmark parameterization a real exchange rate devaluation increases the risk premium (See Table 2).

3.2.3 Investment and Devaluations: The BP Curve

The BP curve is derived from the entrepreneur's problem and is summarized by:

$$\begin{aligned}\hat{k}_{t+1} &= \Gamma_y \hat{y}_t - \Gamma_\pi \hat{\pi}_t - \Gamma_d \hat{d}_t + \Gamma_\mu E_t \hat{y}_{t+1} + \beta\pi\Gamma_\pi E_t \hat{\pi}_{t+1} + \Gamma_{e1} E_t \hat{e}_{t+1} + \Gamma_e \hat{e}_t \\ &\quad + \Gamma_{e2} \hat{e}_{t-1} - \Gamma_\mu \hat{\rho}_t - \Gamma_\theta \hat{\theta}_t \qquad (43)\end{aligned}$$

All coefficients are positive for the benchmark parameterization except Γ_e, which is negative.[38] Therefore, the BP curve is upward sloping in (y,k) space as represented in Panel A of Figure 1. The degree of international financial imperfections determines the slope of the BP curve given that $\Gamma_y = \frac{\mu(1+\psi)}{1+\mu}$. A more distorted international financial market makes the BP steeper while a perfect one implies a flat BP curve.

The coefficient on the real exchange rate given by:

$$\Gamma_e = \frac{\gamma - \mu\left(1-\gamma+\psi\right)}{1+\mu} - \psi_p \bar{\pi}^2 \left(1+\beta\bar{\pi}\right)\left(1-\gamma\right) \frac{\left[1+\mu\left(1+\psi\right)\left(1-\phi\right)\right]}{\left(1+\mu\right)\left(\bar{\theta}-1\right)} \qquad (44)$$

can be either positive or negative. This term is key as it captures the essence of why devaluations might be contractionary or not. To understand why, note the following. In the first term, $\frac{\gamma-\mu(1-\gamma+\psi)}{1+\mu}$, CCV's framework determines the direction in which the BP shifts following a devaluation. There the exchange rate has a positive effect on investment if the expenditure-switching mechanism (γ) is strong enough so that $\gamma - \mu\left(1-\gamma+\psi\right) > 0$. In this case, a devaluation will be unambiguously expansionary given the "IS curve". On the other hand, if the balance sheet effect is strong enough, i.e. μ and ψ are large, then a devaluation might be contractionary.[39] However, the final effect depends on how the BP and IS curves interact. Several cases are possible depending on whether the IS is steeper or flatter than the BP curve,[40] and on the strength of the balance sheet effect relative to the expenditure-switching effect.

In the present model there is an extra term which may shift the BP in either direction. Therefore the effects of devaluations on output will also depend on whether the second term in Γ_e is positive or negative. This in turn will depend on the sign of

38 Explicit coefficient expression and signs are shown in the appendix.

39 CCV refer to this case as a *financially vulnerable economy*. Conversely, if the expenditure-switching dominates they refer to it as a *financially robust economy*.

40 In the benchmark parameterization of the model the IS curve is always steeper than the BP curve. The same is true when the balance sheet is absent, i.e. $\mu = 0$. Thus attention is restricted to this case in the rest of the paper.

$1+\mu(1+\psi)(1-\phi)$ and on the magnitude of price adjustment costs. Hence, in contrast to CCV's framework, there is more involved in whether a devaluation is contractionary or expansionary once you endogenize price stickiness. For instance, in the absence of international capital market imperfections ($\mu = 0$) the expenditure-switching effect will not be as strong as in CCV's case. It will be determined by $\gamma - \frac{\psi_p \bar{\pi}^2 (1+\beta\pi)(1-\gamma)}{(\bar{\theta}-1)}$. Overall, the strength of the expenditure-switching effect will depend on the intensity of capital market imperfections and on the degree of price stickiness, among other parameters of the economy.

Finally, observe the role of shocks on the BP curve. All else equal, a shock on the international risk free interest rate, ρ, lowers investment. In terms of the BP curve in (y, k) space, this implies a downward shift. Note that a higher degree of capital market imperfections reduces the impact of the shock on investment since $\Gamma_\mu = (1+\mu)^{-1}$. Intuitively, since foreign borrowing is already restricted the impact on capital investment cannot be large if the cost of foreign borrowing raises. On the other hand, a shock on the cost-push factor $\hat{\theta}$, which lowers mark-ups, will have, under the benchmark parameterization, a positive effect on investment so that the BP curve shifts up.

3.3 The IS-BP System

In equilibrium the effect of a devaluation on output will depend on how the IS and BP curves interact. Several cases are illustrated in Figure 2. A devaluation will always be expansionary if Γ_e is positive as in point 1. However, a devaluation can be either expansionary or contractionary if Γ_e is negative, that is, depending on the relative strength of the expenditure-switching and the balance sheet effects. These cases are illustrated by points 2 and 3, respectively.

Table 2 shows the effects of devaluations on the components of the BP curve under two scenarios: the benchmark case and the case where there are no international financial imperfections. It also shows how CCV's components compare to the present framework. The main point is that under the benchmark parameterization a devaluation, ceteris paribus, will always worsen firm's balance sheets, push the risk premium up and lower investment. Finally, a word of caution. This section was intended to clarify some of the mechanics of the model, but it does not disentangle all of its dynamics, in particular given the feedback of different shocks on expectations.

4. AN EXPANSIONARY MONETARY POLICY SHOCK

This section analyzes the implications of monetary policy and nominal rigidities. For this purpose, a particular case is considered in which the nominal exchange rate is completely flexible, i.e. ω_s is set to zero in eq.(32). With this restriction in place, the economy is exposed to a pure expansionary monetary shock (a negative shock on $\varepsilon_{\chi t}$) and its implications are analyzed.[41] The first column in Figure 3 shows the impulse response to this shock for the benchmark case. In the two remaining columns the shock

[41] Formally, the interest rate rule is exactly the same as that captured by eq.(46) except that the term χ_t is not multiplied by $\tilde{\omega}_s$. Thus, it is not possible to think of the shock as a devaluation of the exchange rate target, but rather the shock becomes a pure monetary shock.

is analyzed in the absence of the balance sheet mechanism and of nominal rigidities. In Figure 4 the shock is analyzed focusing on the role of different components of the interest rate rule.

Intuitively, the shock can be analyzed in terms of the graphical analysis developed in Figure 1. Given that the direct impact is to lower the interest rate, the IS curve shifts down. This induces a positive response of output and capital investment. But since the shock has a devaluationary effect, the IS curve shifts further down and so does the BP curve given the parameterization of the model. Overall, the shock has an expansionary effect on output and an ambiguous one on capital investment.

Impulse response functions for the benchmark case of the model reported in Figure 3 indicate that following the shock output expands while capital investment is unresponsive. Contrary to what is expected of this policy, interest rates increase. Although counter-intuitive, this is explained by the feedback effect of output on the interest rate, as visualized by comparing the impulse response of the full model reported in Figure 3 with that in which output is not a policy target, as reported in the third column of Figure 4.

Figure 3 also displays large nominal and real devaluations in the benchmark case. The behavior of the nominal exchange rate is critical because it appears to be the main force behind the observed output expansion. In other words, the expenditure-switching effect associated with the devaluation dominates other forces in the model. To understand the effects of the shock on the nominal exchange rate, combine the interest parity condition with the interest rate rule to obtain:

$$\hat{s}_t = \hat{\eta}_t + E_t\hat{s}_{t+1} + \omega_i\hat{\imath}_{t-1} - \tilde{\omega}_\pi E_t\hat{\pi}_{t+1} - \tilde{\omega}_y\hat{y}_t + \hat{\rho}_t - \hat{\chi}_t \tag{45}$$

A negative shock on $\hat{\chi}_t$ induces a devaluation upon impact. However, the risk premium also rises with the devaluation, pushing the exchange rate further up. This feedback magnifies the impact of the shock on the nominal exchange rate, indicating that the nominal exchange rate overshoots. This explains why, in the absence of balance sheets effects or when prices are completely flexible, the shock has a smaller effect on the nominal exchange rate and therefore on output (see Figure 3). Indeed, under perfect international capital markets the risk premium is mute, thus the overshooting phenomenon disappears. In other words, capital market imperfections amplify the effect of the shock on the nominal and real exchange rate and, therefore, strengthen the expenditure-switching effect on output. Moreover in the absence of price adjustment costs the effects of devaluations on the risk premium are smaller. Therefore, price rigidities determine the strength with which international financial markets amplify the impact of the shock.

Figure 4 displays the impulse response functions of the model under alternative specifications of the interest rate rule. Worth noting here is that the qualitative implications of the interest rate partial adjustment mechanism are minimal, although there are important differences regarding the magnitude in which variables move. In addition, simultaneously targeting output and inflation exacerbates fluctuations of the economy relative to the benchmark case. That is, output behavior is more volatile but less persistent following the shock.

5. A DEVALUATIONARY POLICY SHOCK

This section investigates the effects of devaluations on output in economies with different exchange rate regimes. It also assesses the relative importance of the balance sheet transmission mechanism in each case. Different exchange rate arrangements are considered by changing the weight parameter in the interest rate rule, as in Monacelli (2004). That is, $\omega_s = 0$ in eq. (46) is interpreted as a flexible exchange regime, intermediate values of ω_s as managed floats and, $\omega_s = 1$ as a fixed exchange rate regime. In this section, four cases are considered: a near flexible exchange rate regime, two floating regimes $(\omega_s = 0.2$ and $0.6)$ and a fixed exchange rate regime, $\omega_s \cong 1$. The role of international capital market imperfections is analyzed by comparing the benchmark parameterization to that when international capital markets are perfect (i.e. $\mu = 0$). Impulse response functions for these exercises are reported in Figures 5 and 6.

A devaluation of the exchange rate target is defined as a negative shock on χ_t in eq. (46). Therefore, monetary authorities achieve a devaluation by lowering the interest rate by a magnitude of $\tilde{\omega}_s$. For the sake of clarity, the linearized interest rate rule is:

$$\hat{\imath}_t = \omega_i \hat{\imath}_{t-1} + \tilde{\omega}_\pi E_t \hat{\pi}_{t+1} + \tilde{\omega}_y \hat{y}_t + \tilde{\omega}_s \hat{s}_t + \tilde{\omega}_s \hat{\chi}_t \tag{46}$$

where $\tilde{\omega}_\pi \equiv (1-\omega_i)\,\omega_\pi$, $\tilde{\omega}_y \equiv (1-\omega_i)\,\omega_y$ and $\tilde{\omega}_s \equiv (1-\omega_i)\,\frac{\omega_s}{1-\omega_s}$. Recall that ω_i is the interest rate smoothing parameter and ω_π and ω_y are the weights on expected inflation and on output, respectively.

An intuitive analysis of the shock can be visualized in Figure 2 as a downward shift in both the IS and BP curves with a final intersection in the first, third or fourth quadrant.[42] Therefore, the effect on output and investment is ambiguous.

Before analyzing simulation results, we need to determine the role of the exchange rate arrangement. To see this, combine the interest parity and the interest rate rule and solve for $\hat{s}_t$:

$$\hat{s}_t = \ell E_t \hat{s}_{t+1} - \tilde{\omega}_\pi \ell E_t \hat{\pi}_{t+1} - \omega_i \ell \hat{\imath}_{t-1} - \tilde{\omega}_y \ell \hat{y}_t + \ell \eta_t - (1-\ell)\,\hat{\chi}_t + \ell \rho_t \tag{47}$$

where $\ell = \frac{1}{1+\tilde{\omega}_s}$ and $\tilde{\omega}_s = (1-\omega_i)\left(\frac{\omega_s}{1-\omega_s}\right)$. Figure 7 displays the elasticity of the exchange rate to a shock on the nominal exchange rate target. Observe that the response of the exchange rate is smaller as the exchange regime becomes more flexible (non-existent in the case of a pure flexible regime). In other words, the central bank is able to induce a larger nominal and real exchange rate devaluation under fixed regimes than under flexible ones. This has important implications in terms of output behavior, as shown in Figure 4: devaluations have larger expansionary effects under less flexible exchange rate regimes. Therefore this result suggests that under the parameterization of the model the expansionary expenditure-switching effect dominates.

An important aspect of the model is that the interest rate is quite unresponsive to a devaluation under all exchange regimes. Intuitively, what happens is that the interest rate response to the risk premium cancels the impact of the devaluationary shock. Formally, this can be seen if eq. (47) is substituted back into the interest rate rule:

$$\hat{\imath}_t = (1-\ell)\,E_t \hat{s}_{t+1} + \tilde{\omega}_\pi \ell E_t \hat{\pi}_{t+1} + (1-\ell)\,\hat{\eta}_t + \tilde{\omega}_y \ell \hat{y}_t + \tilde{\omega}_i \ell \hat{\imath}_{t-1} + (1-\ell)\,\hat{\rho}_t + (1-\ell)\,\chi_t \tag{48}$$

42 An equilibrium in the third quadrant is not possible because in the parameterization of the model the IS always responds by a larger magnitude to a devaluation than the BP curve.

Making use of Figure 7, it is possible to realize that under a pure flexible exchange rate regime the interest rate will not adjust. However, there might be a response as the exchange regime moves towards a fixed one. The final impact depends on whether the response of the risk premium is large enough to cancel the negative impact of the devaluation on the interest rate. Figure 5 indicates that the devaluationary impact dominates the risk premium behavior under more rigid exchange rate regimes. Therefore the interest rate rises slightly under more flexible regimes.

Impulse response functions also indicate that the balance sheet mechanism is operating in a contractionary manner. Indeed, for all regimes net worth falls, the risk premium rises and capital investment falls. Figure 6 clarifies the role of international capital market imperfections even better. Upon impact net worth falls less and capital investment increases more than when there are frictions in international financial markets. Intuitively, it is not difficult to understand why investment rises when international capital markets are perfect. On the one hand, the shock shifts the IS down. On the other, the BP is flat and a devaluation shifts it up. Thus, under these circumstances investment and output unambiguously increase. Overall this indicates that the cost of financing investment is lower.

In summary, in the absence of any other shock to the economy an induced devaluation is expansionary, being larger under less flexible exchange rate regimes. Capital investment and consumption fall, and output expands despite the contractionary balance sheet effect. This is only possible if the expenditure-switching effect is the main dominating transmission mechanism, given also that the interest rate channel is found to have no major role. Finally, output expansion is achieved at the cost of high inflation, which can be a critical issue in emerging markets, and at the expense of deteriorating workers' income, as reflected by the collapse of real wages.

6. EXTERNAL SHOCKS AND DEVALUATIONS

This section analyzes the behavior of the economy when hit by an adverse external shock induced by either an increase in the risk free international interest rate (i.e. a shock on $\varepsilon_{\rho t}$) or a decline in export demand (i.e. a shock on ε_{xt}). These shocks are analyzed first in an isolated manner. Once this is done the behavior of the economy is analyzed if the central bank responds to these shocks by devaluing the nominal exchange rate target.

6.1 Adverse Shock on International Interest Rates

Impulse response functions to a positive shock on international interest rates under alternative exchange rate regimes are reported in Figures 8 through 11. Figures 8 and 9 consider the pure shock on international interest rates, while Figures 10 and 11 show the economy's behavior when the central bank actively pursues a devaluationary policy at the time of the shock. Differences within each pair of figures reside on the presence or absence of the balance sheet effect.

Intuition on capital and output behavior can be built from Figure 1. An international interest rate shock shifts the IS curve up due to its impact on domestic interest rates (see eq. 48), and the BP curve down, as the cost of capital rises. The real devaluation induced by the shock pushes both the BP and IS down. The final equilibrium depends on whether the devaluation is able to reverse the initial upward shift in the IS curve. Overall, investment is quite likely to fall under all circumstances, while output's behavior will depend on the magnitude of the real devaluation. This in turn depends on the exchange rate regime in place.

In the absence of any other shock, an increase in international interest rates generates important differences in output's behavior depending on the exchange rate regime (Figure 8). Under flexible exchange regimes the shock induces an expansion, while under less flexible ones a contraction takes place. Following the shock the economy adjusts via a real devaluation. However, since prices are sticky, the only available mechanism to achieve a real devaluation is via the nominal exchange rate. But, if the nominal exchange rate is fixed then the economy is unavailable to induce a real exchange rate devaluation. In this case the adjustment must take place via a severe output and labor contraction. Conversely, if the nominal exchange rate is flexible, the adjustment takes place through a higher nominal exchange rate and output need not fall. Furthermore, if the expenditure-switching mechanism dominates the balance sheet effect then output may expand as captured in Figure 8. The contraction in capital investment is no surprise given that the shock increases the marginal cost of funding capital independently of the exchange rate regime in place.

Eliminating international financial market imperfections has an unexpected effect. In Figure 9 output appears to be unresponsive under any exchange rate regime. However, the reasons differ from one regime to another. Under flexible regimes the overshooting of the nominal exchange rate is smaller and, therefore the effective impact of the expenditure-switching mechanism is smaller. In other words, while the contractionary force associated with the balance sheet is being eliminated, the magnitude of the devaluation is also being diminished, thus underpinning the strength of the expansion associated with the expenditure-switching effect. For fixed exchange rates the story is similar, except that in this case the expenditure-switching mechanism never played a role. Therefore, note that eliminating the balance sheet effect effectively removes the main contractionary force in place but also weakens the expansionary forces in the model.

Simulations indicate that if the exchange rate regime is flexible enough, the response to the shock will be roughly the same irrespective of whether the central bank actively pursues a devaluationary policy or not. Section 5. argued that under these regimes a devaluation had a modest impact on the exchange rate and on the economy. However, important differences arise when the central bank pursues a more active response toward deviations of the exchange rate. These differences are more evident when observing output's behavior under a fixed exchange rate regime. In this case, a devaluation can help avoid a recession (compare Figures 8 and 10). The reason is that a devaluation of the nominal exchange rate target induces a real exchange rate devaluation that would not take place otherwise, due to the presence of price rigidities, which allows the central bank to exploit the benefits of the expenditure-switching.

Results indicate that under rigid exchange rate arrangements the central bank can play a stabilizing role as it is able to induce a large real exchange rate depreciation to adjust to the shock. In addition, the balance sheet effect magnifies the impact of the shock on the nominal exchange rate, and therefore the strength of the expenditure-switching effect. The implication is that removing the distortion associated with international capital markets is not reflected in an evident positive effect on output. In fact, it worsens relative to the case where this distortion is in place.

6.2 Adverse Shock on Export Demand

The response of the economy to an adverse shock on export demand is analyzed in Figures 12 through 15. Figure 12 shows the response when the economy is exclusively hit by the shock and Figure 13 analyzes it in the absence of the balance sheet transmission mechanism. Figures 14 and 15 report the same exercises, but the shock is analyzed jointly with an exogenous explicit policy shock aimed at devaluing the nominal exchange rate target.

The economy's response can be understood using of Figure 1. Intuitively, the shock on export demand induces an upward shift in the IS curve and, ceteris paribus, this induces a collapse in output. The real exchange rate depreciation that follows pushes both the IS and BP curves down. Given that the real exchange rate depreciation is larger for more flexible exchange rate arrangements, this may neutralize the initial upward shift of the IS curve and eventually reverse it. As a result, it is possible to see a small output contraction or even an expansion, while capital investment is most likely to collapse. Under rigid exchange regimes the depreciation is very small, so the initial upward shift in the IS curve is not reversed and the BP curve remains in place. In this case, output and capital investment fall. It is then, given the expansionary effects of a devaluationary policy, that the central bank is able to stabilize output. Intuitively, the induced devaluation would shift the IS and BP curves down.

Figure 12 shows that an adverse shock on exports induces a depreciation of the exchange rate. As argued, the effect on output depends mostly on the stance of the monetary authority towards the exchange rate. Greater flexibility of the exchange rate results in an expansion, while the opposite occurs when the exchange regime is less flexible. The shock lowers the demand for domestically produced goods and therefore output falls. Under flexible regimes the exchange rate rises to compensate for the lower demand, triggering a strong expenditure-switching effect that compensates for the lower export demand, and eventually leads to an output increase. In the case of managed floats or fixed exchange rate regimes, the expenditure-switching mechanism does not operate with the same strength, thus the adjustment takes place in quantities as reflected by output's collapse.

The system's behavior with and without the balance sheet mechanism shows that the initial devaluation associated with the shock is magnified if the balance sheet mechanism is in place under more flexible exchange rate regimes. This is due to the feedback that the risk premium has on the exchange rate. An implication of this is that in the absence of international capital market imperfections the expenditure-switching effect operates with less strength. Thus, as before, even if the contractionary force associated with the balance sheet mechanism is eliminated, in net terms output rises by a smaller magnitude than when the balance sheet mechanism is in place. Under fixed regimes the expenditure-switching mechanism is never strong, so eliminating the distortion in international financial markets has no significant effect in terms of output behavior. However, capital investment falls less once these types of imperfections are removed.

As in the case of a shock on international interest rates, the central bank can play an important stabilizing role by pursuing an active devaluationary policy if the exchange rate is relatively fixed. As shown in Figure 14, for these types of exchange rate regimes such a policy is able to avoid an output collapse in the very short run and is able to mitigate the contraction in the medium run. Obviously, this is done at the expense of generating significant inflation pressures in the short run and also at the expense of workers' income. Real wages deteriorate significantly given the sticky wage characteristics of the model.

7. CONCLUDING REMARKS

The goal of this paper has been to disentangle the relative importance of different transmission mechanisms through which devaluations affect output. For this purpose, the framework developed by Cespedes, Chang and Velasco (2004, 2003) is modified and extended in several directions. As a result, endogenous wage and price rigidities are introduced, and several relevant additional sources of shocks are incorporated. Furthermore, to make the model more realistic, monetary policy is incorporated using an interest rate rule. This rule is specified so that monetary authorities target the nominal exchange rate together with output and expected inflation. These modifications have resulted in a fully dynamic stochastic general equilibrium model that incorporates three main mechanisms through which devaluations can affect output: the traditional expansionary expenditure-switching effect, the more novel (contractionary) balance sheet effect, and a monetary channel associated with the endogenous policy response to deviations of the nominal exchange rate from a target.

In addition to these transmission mechanisms, the effects of devaluations on output are shown to depend critically on the type of exchange rate regime in place and on the degree of nominal rigidities. In contrast with CCV (2003), price rigidities are found to play an important role on the transmission of the balance sheet effect. The relevance of this relies on the fact that a higher degree of price stickiness magnifies the expenditure-switching effect and, therefore, reverses the adverse effect of a devaluation on net worth. The opposite is true in the absence of the balance sheet effect.

Simulations of the model employing reasonable parameters found in the literature, and in the absence of any additional shock to the economy, show that devaluations (defined as an increase in the nominal exchange rate target) are always expansionary. This behavior is more notorious the less flexible the exchange rate regime. Output's response to adverse external shocks is shown to depend crucially on the exchange rate arrangement. Contractions do occur as the exchange rate becomes less flexible. In this context, an explicit devaluationary policy shock can stabilize output. However, this result is not achieved without trade-offs: inflation rises and workers' incomes fall. This potential stabilizing role of a devaluation observed under more rigid exchange rate regimes when the economy faces an adverse international shock suggests that "fear of floating" as argued by Calvo and Reinhart (2002) is not justified. Results also suggest that flexible exchange rate regimes are more desirable than fixed regimes in terms of output behavior.

Overall, three main points must be concluded regarding the relative importance of the different mechanisms through which devaluations affect output. First, under reasonable parameters used in the literature, the balance sheet effect does not appear to be strong enough to overturn the expansionary expenditure-switching effect. In this regard it was shown that, in the presence of an adverse international shock, eliminating the distortion associated with the balance sheet mechanism does not translate into larger output expansions or smaller contractions. In fact, although removing the distortion associated with the balance sheet eliminates its contractionary effects, it weakens, at the same time, the strength of the expansionary expenditure-switching effect. Second, the exchange rate regime is all-important in terms of how the economy absorbs external shocks. It is only under more rigid exchange regimes that monetary authorities can have a stabilizing role. Finally, the role of the balance sheet effect depends on the interaction of several deep parameters of the model, such as the degree of price rigidity. This highlights the importance of structurally estimating the model and disentangling its specific role, a task performed in Tovar (2005).

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APPENDICES

A The Entrepreneur’s Problem

This appendix presents the details of the entrepreneur’s problem. The appendix follows CCV’s (2004) appendix, but extends it to explicitly discuss some details highlighted in Bernanke, Gertler and Gilchrist’s (1999) paper in the context of a closed economy. A very close analysis can be found in Carlstrom and Fuerst (1997).

Suppose at time t an entrepreneur who manages firm j makes a capital investment decision.[43] He decides to purchase an amount of capital K^j_{t+1} given prices and the expected return to capital. The return to capital is sensitive to both aggregate and idiosyncratic risk. The *ex post* gross return on capital for firm j is $\omega^j\left(\frac{R^k_{t+1}}{S_{t+1}}\right)$ dollars, where ω^j is an idiosyncratic disturbance to firm j’s return, which is i.i.d. across time and firms with continuous and differentiable C.D.F. $F(\omega)$ and $E(\omega^j) = 1$. R^k_{t+1} is the *ex post* aggregate return to capital, that is, the gross return averaged across firms.

At the end of period t (going into period $t+1$), entrepreneur j must finance the difference between his expenditures on capital goods, $Q_tK^j_{t+1}$, and his net worth, $P_tN^j_{t+1}$, by borrowing an amount $S_tD^j_{t+1}$. That is:

$$S_tD^j_{t+1} = Q_tK^j_{t+1} - P_tN^j_{t+1} \tag{49}$$

The entrepreneur borrows from a financial intermediary, which in our case is a foreign lender. The foreign lender faces an opportunity cost of funds between t and $t+1$ equal to the international riskless gross rate of return, $(1+\rho_t)$. The international riskless rate is the relevant opportunity cost for the foreign lender because in equilibrium this agent

[43] It is assumed that capital is homogenoeus so that it is irrelevant whether investment is in new or old capital. In addition, it is assumed that entrepreneurs purchase or repurchase their entire capital stock each period. This guarantees that financial constraints apply to the firm as a whole and not only to the marginal investment.

holds a perfectly safe portfolio. To motivate why uncollateralized external finance (to the firm) is more expensive than internal finance without assuming arbitrary restrictions on the contract structure, it is assumed that the financial intermediary faces a "costly state verification" problem. That is, the foreign lender must pay an auditing cost in order to observe an individual borrower's realized return (the borrower observes the return for free). This cost is a fixed proportion μ of the realized gross payoff to the firm's capital, that is:

$$\mu\omega^j\left(\frac{R_{t+1}^k}{S_{t+1}}\right)K_{t+1}^j \tag{50}$$

When there is no aggregate risk, the **contract terms** can be described as follows. Let the aggregate return to capital $\left(\frac{R_{t+1}^k}{S_{t+1}}\right)$ be known in advance, so the only uncertainty is idiosyncratic to the firm. The entrepreneur then chooses the value of capital, $Q_tK_{t+1}^j$, and the level of borrowing, D_{t+1}^j, prior to the realization of the idiosyncratic shock. Given $Q_tK_{t+1}^j$, D_{t+1}^j, and $\left(\frac{R_{t+1}^k}{S_{t+1}}\right)$, the optimal contract may be characterized by:

- a gross non-default loan rate, Z_{t+1}^j, and
- a threshold value of the idiosyncratic shock, $\bar{\omega}^j$.

Let $\overline{\omega}^j$ be defined as the value that allows the entrepreneur to repay the loan at the contractual rate Z_{t+1}^j:

$$\bar{\omega}^j\left(\frac{R_{t+1}^k}{S_{t+1}}\right)K_{t+1} = Z_{t+1}^jD_{t+1}^j \tag{51}$$

Therefore, for $\omega^j \geq \overline{\omega}^j$ the entrepreneur pays the lender the promised amount $Z_{t+1}^jD_{t+1}^j$ and keeps the difference, formally:

$$\omega^j\left(\frac{R_{t+1}^k}{S_{t+1}}\right)K_{t+1} - Z_{t+1}^jD_{t+1}^j \tag{52}$$

However, if $\omega^j < \overline{\omega}^j$ the entrepreneur cannot pay the return and declares default. As a result, the lender pays an auditing cost and gets to keep everything it can find. The lender's net receipts in this case are:

$$(1-\mu)\,\omega^j\left(\frac{R_{t+1}^k}{S_{t+1}}\right)K_{t+1} \tag{53}$$

The values for $\overline{\omega}^j$ and Z_{t+1}^j under the optimal contract are such that they guarantee the financial intermediary an expected return equal to the opportunity cost of its funds. In this case the opportunity cost is determined by the riskless rate ρ_t. Therefore the contract must satisfy:

$$\left[1-F\left(\overline{\omega}^j\right)\right]Z_{t+1}^jD_{t+1}^j + (1-\mu)\int_0^{\overline{\omega}^j}\omega\left(\frac{R_{t+1}^k}{S_{t+1}}\right)K_{t+1}^j dF(\omega) = (1+\rho_t)\,D_{t+1}^j \tag{54}$$

Using equations 49 and 51 allows us to rewrite this condition exclusively in terms of the threshold value $\overline{\omega}^j$:

$$\left\{ \begin{array}{c} \left[1 - F\left(\overline{\omega}^j\right)\right]\overline{\omega}^j + \\ (1-\mu)\int_0^{\overline{\omega}^j} \omega dF(\omega) \end{array} \right\} \left(\frac{R^k_{t+1}}{S_{t+1}}\right) K^j_{t+1} = (1+\rho_t)\frac{\left(Q_t K^j_{t+1} - P_t N^j_t\right)}{S_t} \tag{55}$$

It follows from here that there are two opposite effects of changing $\overline{\omega}^j$ on the expected return:

- A rise in the threshold value increases the non-default payoff; but
- It also raises the default probability, which lowers the expected payoff.

Finally, it is worth pointing out that if the lender's opportunity cost is too high, the borrower may be "rationed" by the market.

Once we have shown the conditions that $\overline{\omega}^j$ and Z^j_{t+1} must satisfy for the foreign lender, the entrepreneur must determine his demand for capital. Given the state-contingent debt form of the optimal contract, the return for the entrepreneur may be expressed as:

$$\left\{ \int_{\overline{\omega}^j}^{\infty} \omega dF(\omega) - \left[1 - F\left(\overline{\omega}^j\right)\right]\overline{\omega}^j \right\} R^k_{t+1} K^j_{t+1} \tag{56}$$

where expectations are set with respect to the random variable, R^k_{t+1}.Observe that $\overline{\omega}^j$can be made contingent on the realization of this variable. Therefore, the entrepreneur's problem is to maximize its expected return by choosing $K^j_{t+1}$and a schedule for $\overline{\omega}^j$ subject to Eq. 55. The problem can be simplified by making the following transformations. Define the risk premium as

$$1 + \eta_t \equiv \frac{S_t R^k_{t+1}}{Q_t S_{t+1}(1+\rho_t)} \tag{57}$$

and the capital-net worth ratio as:

$$\kappa \equiv \frac{Q_t K^j_{t+1}}{P_t N^j_t} \tag{58}$$

so that the problem can be re-written as follows[44]:

$$\underset{\kappa,\overline{\omega}^j}{Max} \left\{ \int_{\overline{\omega}^j}^{\infty} \omega dF(\omega) - \left[1 - F\left(\overline{\omega}^j\right)\right]\overline{\omega}^j \right\} \kappa \tag{59}$$

s.t.

$$\left\{ \left[1 - F\left(\overline{\omega}^j\right)\right]\overline{\omega}^j + (1-\mu)\int_0^{\overline{\omega}^j} \omega dF(\omega) \right\} (1+\eta_t)\, k = \kappa - 1 \tag{60}$$

[44] Notice that there is no change in the solution if the objective function is multiplied or divided by positive variables known at t.

To simplify the problem further, define $\Gamma\left(\overline{\omega}^j\right) \equiv \int_0^{\overline{\omega}^j} \omega dF(\omega) + \overline{\omega}^j \int_{\overline{\omega}^j}^{\infty} dF(\omega)$ which capture the expected gross profits going to the lender, and let $G\left(\overline{\omega}^j\right) \equiv \int_0^{\overline{\omega}^j} \omega F(\omega)$, so that $\mu G\left(\overline{\omega}^j\right)$ captures the auditing cost. Therefore, the problem can be rewritten as:

$$\underset{\kappa,\vec{\omega}^j}{Max}\left[1-\Gamma\left(\overline{\omega}^j\right)\right](1+\eta_t)\,\kappa \tag{61}$$

s.t.

$$\left[\Gamma\left(\overline{\omega}^j\right)-\mu G\left(\overline{\omega}^j\right)\right](1+\eta_t)k = \kappa - 1 \tag{62}$$

Before solving the problem, it is important to highlight two important assumptions made by Bernanke, Gertler and Gilchrist (1999) to ensure the existence of a non-rationing outcome. For completeness, I will reproduce these conditions here but the reader is referred to their paper for a complete discussion of them. The first one establishes that $\Gamma\left(\overline{\omega}^j\right)-\mu G\left(\overline{\omega}^j\right) > 0$ for $\bar{\omega}^j \in (0,\infty)$ and the limit of this expression as $\bar{\omega}^j$ goes to 0 (∞) is 0 $(1-\mu)$ .This implies that $R^k(1-\mu) < R$, otherwise the firm could make unbounded profits. The second assumption is that $\bar{\omega}^j \frac{\Gamma\left(\bar{\omega}^j\right)}{1-F\left(\bar{\omega}^j\right)}$ is increasing in $\bar{\omega}^j$. This assumption ensures that there is a unique global maximum at $\bar{\omega}^*$.

The first-order conditions for this problem for κ, $\overline{\omega}^j$ and λ (the Lagrange multiplier) are, respectively:

$$1+\eta_t = \frac{\lambda}{\left[1-\Gamma\left(\overline{\omega}^j\right)+\lambda\left(\Gamma\left(\overline{\omega}^j\right)-\mu G\left(\overline{\omega}^j\right)\right)\right]} \tag{63}$$

$$\lambda = \frac{\Gamma'\left(\overline{\omega}^j\right)}{\Gamma'\left(\overline{\omega}^j\right)-\mu G'\left(\bar{\omega}^j\right)} \tag{64}$$

$$\left[\Gamma\left(\bar{\omega}^j\right)-\mu G\left(\bar{\omega}^j\right)\right](1+\eta_t)\,\kappa = \kappa - 1 \tag{65}$$

Note that combining the first two F.O.C.'s allows us to write the expected discounted return to capital as:

$$1+\eta_t = s\left(\bar{\omega}^j\right) \tag{66}$$

so that $s\left(\bar{\omega}^j\right)$ is the wedge between the expected rate of return on capital and the safe return demanded by lenders. Inverting this expression allows us to write:

$$\bar{\omega}^j = s^{-1}(1+\eta_t) \tag{67}$$

that is, we have established a relation between default probabilities and the premium on external funds. Bernanke, Gertler and Gilchrist (1999) show that $\bar{\omega}^j(s)' > 0$ for $s \in (1, s^*)$ where $s < s^*$ is required to obtain an interior solution (See their appendix for additional details).

Now, note that combining the first-order condition for λ and κ implies that:

$$\kappa = 1 + \frac{\lambda\left(\Gamma\left(\bar{\omega}^j\right)-\mu G\left(\bar{\omega}^j\right)\right)}{1-\Gamma\left(\bar{\omega}^j\right)} \equiv \Psi\left(\bar{\omega}^j\right) \tag{68}$$

this combined with Eq. 67 implies that we can express the capital-net worth ratio as:

$$\kappa = \widetilde{\psi}\left(1+\eta_t\right) \tag{69}$$

with $\psi'(s) > 0$ for $s \in (1, s^*)$ and $\psi(1) = 1$. Inverting this last expression, we get:

$$1+\eta_{t+1} = \tilde{\psi}^{-1}(\kappa) = \tilde{\psi}^{-1}\left(\frac{Q_t K_{t+1}^j}{P_t N_t^j}\right) = \left(\frac{Q_t K_{t+1}^j}{P_t N_t^j}\right)^{\mu} \tag{70}$$

The third equality is simply motivated by the fact that μ captures the elasticity of the risk premium to the investment-net worth ratio.

To incorporate this firm-level relation into a general equilibrium framework is not always straightforward, since entrepreneurs' demand for capital depends on their financial position and, therefore, on the distribution of wealth across them. However, things are simplified by the fact that there are constant returns to scale in the problem so that there is a proportional relation between net worth and capital demand at the firm level. To see this, rewrite eq. 69 as:

$$Q_t K_{t+1}^j = \tilde{\psi}\left(1+\eta_{t+1}\right) P_t N_t^j \tag{71}$$

Note that this factor of proportionality is independent of firm-specific factors; therefore, aggregation is immediate.

B Symmetric Equilibrium

The equilibrium in this model is given by the optimal behavior of households, firms and entrepreneurs, and by the behavior of the government. In a symmetric equilibrium, all firms make identical decisions, so that $Y_{jt} = Y_t$, $P_{jt} = P_t$, $K_{jt} = K_t$, $L_{jt} = L_t$ and $\Pi_{jt} = \Pi_t$ for all $j \in [0,1]$. Households also make identical decisions, so that $W_{it} = W_t$, $L_{it} = L_t$, $C_{it}^H = C_t^H$, $C_{it}^F = C_t^F$, $C_{it} = C_t$, and $B_{it}^* = B_t^*$ for all $i \in [0,1]$. Also observe that the market-clearing condition for domestic currency bonds requires that the domestic households' (net) stock of bonds of this type is zero, $B_{it} = B_t = 0$ for all $i \in [0,1]$.[45] After imposing these conditions, the symmetric equilibrium can be described as follows.

For the firms' problem, the equilibrium conditions are the production function (Eq. 2), the first-order conditions for factor returns (Eq. 8 and Eq. 9), the elasticity of output demand augmented with adjustment costs (Eq. 11), and the two stochastic shocks, that is, the technology shock (Eq. 6) and the mark-up or cost push shock (Eq. 7). Now, relying on the fact that $\frac{Q_t}{P_t} = e_t^{1-\gamma}$ and defining $f_t^p \equiv \frac{P_{jt}}{P_{jt-1}}$, we can formally express these conditions as:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \tag{72a}$$

$$r_t = \alpha\left[1-\frac{1}{e_t^Y}\right]\frac{Y_t}{K_t}e_t^{\gamma-1} \tag{73}$$

$$w_t = (1-\alpha)\left[1-\frac{1}{e_t^Y}\right]\frac{Y_t}{L_t}e_t^{\gamma-1} \tag{74}$$

45 Implicitly it is being assumed that foreigners do not hold these types of bonds.

$$e_t^Y = \theta_t \left[\begin{array}{c} 1 - \psi_p \left(f_t^p - \bar{f}^p \right) f_t^p \\ + \psi_p E_t \left[\frac{\Delta_{t+1}}{\Delta_t} \left(f_{t+1}^p - \bar{f}^p \right) \left(f_{t+1}^p \right)^2 \right] \end{array} \right]^{-1} \tag{75}$$

In addition, we must include the stochastic process for the productivity and mark-up shocks:

$$\ln A_t - \ln \overline{A} = \zeta_A \left(\ln A_{t-1} - \ln \overline{A} \right) + \varepsilon_{At} \tag{76}$$

$$\ln \theta_t - \ln \overline{\theta} = \zeta_\theta \left(\ln \theta_{t-1} - \ln \overline{\theta} \right) + \varepsilon_{\theta t} \tag{77}$$

The equilibrium conditions derived from the household's problem are the consumer price index (Eq. 22), the intra-temporal first-order condition (Eq. 21), the budget constraint (Eq. 16), the Euler equations (Eq. 23 and Eq. 24), the optimal wage setting equation (Eq. 25), the labor demand elasticity augmented with adjustment costs (Eq. 26), and a preference shock (Eq. 19). For some expressions $\frac{S_t}{Q_t} = e_t^\gamma$ is employed:

$$Q_t = P_t^\gamma S_t^{1-\gamma} \tag{78}$$

$$\left(\frac{1-\gamma}{\gamma} \right) \frac{C_t^H}{C_t^F} = \frac{S_t}{P_t} = e_t \tag{79}$$

$$C_t = e_t^\gamma i_{t-1}^* B_{t-1}^* - e_t^\gamma \left(B_t^* - B_{t-1}^* \right) + w_t L_t - \frac{\psi_w}{2} \left(\Omega_t \pi_t - \bar{\Omega} \bar{\pi} \right)^2 w_t \tag{80}$$

$$\frac{1}{(1+i_t)} = \beta E_t \left(\frac{a_{t+1}}{a_t} \frac{C_t}{C_{t+1}} \frac{1}{\pi_{t+1}} \right) \tag{81}$$

$$\frac{1}{(1+i_t^*)} = \beta E_t \left(\frac{a_{t+1}}{a_t} \frac{C_t}{C_{t+1}} \frac{f_{t+1}^s}{\pi_{t+1}} \right) \tag{82}$$

$$\left(1 - \frac{1}{\sigma} \right) L_t^{\nu - 1} = \frac{w_t}{C_t} \left(1 - \frac{1}{e_t^L} \right) \tag{83}$$

$$e_t^L = \sigma \left[\begin{array}{c} 1 - \frac{\psi_w}{L_t} \Omega_t \pi_t \left(\Omega_t \pi_t - \bar{\Omega} \bar{\pi} \right) \\ + \beta \frac{\psi_w}{L_t} E_t \left[\frac{a_{t+1}}{a_t} \frac{C_t}{C_{t+1}} \Omega_{t+1}^2 \pi_{t+1} \left(\Omega_{t+1} \pi_{t+1} - \bar{\Omega} \bar{\pi} \right) \right] \end{array} \right]^{-1} \tag{84}$$

$$\ln a_t = \zeta_a \ln a_{t-1} + \varepsilon_{at} \tag{85}$$

The equilibrium conditions for the entrepreneur's problem are its budget constraint (Eq. 27), the risk premium (Eq. 28), the interest parity condition (Eq. 29), the world interest rate shock (Eq. 30) and the net worth equation (Eq. 31). The entrepreneur's problem is rewritten in terms of the real exchange rate.

$$e_t^{\gamma-1} N_t + e_t^\gamma D_{t+1} = K_{t+1} \tag{86}$$

$$1 + \eta_{t+1} = \left(e_t^{1-\gamma} \frac{K_{t+1}}{N_t} \right)^\mu \tag{87}$$

$$E_t \left(r_{t+1} \frac{\pi_{t+1}}{f_{t+1}^s} \right) = (1+\rho_t)(1+\eta_t) \tag{88}$$

$$e_t^{\gamma-1} N_t = \left[1 - \frac{\psi_p}{2} \left(f_t^p - \bar{f}^p \right)^2 \right] e_t^{\gamma-1} Y_t - w_t L_t - e_t^\gamma D_t \tag{89}$$

And the stochastic dynamics for the international risk free interest rate are given by:

$$\ln \rho_t - \ln \overline{\rho} = \zeta_\rho \left(\ln \rho_{t-1} - \ln \overline{\rho}\right) + \varepsilon_{\rho t} \tag{90}$$

Finally, the market-clearing condition, Eq. (35) can be written in terms of the real exchange rate as:

$$e_t^{\gamma-1} Y_t = \gamma \left(K_{t+1} + C_t\right) + \frac{\psi_p}{2} \left(f_t^p - \bar{f}^p\right)^2 e_t^{\gamma-1} Y_t + e_t^\gamma X_t \tag{91}$$

C Non-Stochastic Steady-State

This appendix describes the initial non-stochastic steady-state for this economy, in which the net foreign asset position is zero, i.e. $B_t^* = \bar{B}^* = 0$. In the absence of shocks the economy converges to a steady state in which $C_t = \bar{C}$, $Y_t = \bar{Y}$, $K_t = \bar{K}$, $L_t = \bar{L}$, , $N_t = \bar{N}$, $D_t = \bar{D}$, $i_t = \bar{\imath}$, $\bar{\imath}_t^* = \bar{\imath}^*$, $\eta_t = \bar{\eta}$, $w_t = \bar{w}$, $r_t = \bar{r}$, $e_t = \bar{e}$, $\pi_t = \bar{\pi}$, $f_t^s = \bar{f}^s$. Steady-state values $\bar{A}$, $\bar{\theta}$, $\bar{a}$, $\bar{\chi}$, $\bar{\rho}$, and $\bar{X}$ are determined from Eqs. (6), (7), (19), (145), (30) and (36).

Using the fact that $e^Y = \bar{\theta}$ and $e^L = \sigma$, observing that the stationarity of real wages implies that $\bar{\Omega} = 1$ and imposing steady state values, it is possible to summarize the non-stochastic steady-state conditions corresponding to the symmetric equilibrium described by equations (72a), (73), (74), (78), (79), (81), (82), (83), (80), (86), (87), (88), (89), (91). In addition, consider the definitional condition implied by Eq. (134):

$$\left(1 + \bar{\imath}^*\right) = \left(1 + \bar{\rho}\right)\left(1 + \bar{\eta}\right) \tag{92}$$

To solve for the non-stochastic steady-state assume that steady state,inflation is exogenously determined. Next, combine Eqs. (78) and (79) to obtain $\pi_t = \frac{Q_t}{Q_{t-1}} = \frac{e_t^{1-\gamma}}{e_{t-1}^{1-\gamma}} \frac{P_t}{P_{t-1}} = \frac{e_t^{1-\gamma}}{e_{t-1}^{1-\gamma}} f_t^p$. Given the steady state stationary behavior of the real exchange rate, it follows that $\bar{f}^p = \bar{\pi}$. Furthermore, following the same argument it is possible to show that $\bar{f}^s = \bar{\pi}$. That is, steady state overall domestic inflation equals the steady state inflation rate of domestically produced goods and also the steady state nominal devaluation rate.

So far it is possible to summarize the steady state equilibrium conditions as:

$$\bar{Y} = \bar{A}\bar{K}^\alpha \bar{L}^{1-\alpha} \tag{93}$$

$$\bar{r} = \alpha \left(1 - \frac{1}{\bar{\theta}}\right) \frac{\bar{e}^{\gamma-1}\bar{Y}}{\bar{K}} \tag{94}$$

$$\bar{w} = (1-\alpha)\left(1 - \frac{1}{\bar{\theta}}\right) \frac{\bar{e}^{\gamma-1}\bar{Y}}{\bar{K}} \tag{95}$$

$$\bar{f}^s = \bar{\pi} \tag{96}$$

$$\bar{C} = \bar{w}\bar{L} \tag{97}$$

$$1 + \bar{\imath} = \frac{\bar{\pi}}{\beta} \tag{98}$$

$$1+\bar{\imath}^{*}=\frac{\bar{\pi}}{\beta\bar{f}^{s}} \tag{99}$$

$$\bar{L}^{\nu-1}=\frac{\bar{w}}{\bar{C}} \tag{100}$$

$$\bar{e}^{\gamma-1}\bar{N}+\bar{e}^{\gamma}\bar{D}=\bar{K} \tag{101}$$

$$1+\bar{\eta}=\left(\frac{\bar{K}}{\bar{e}^{\gamma-1}\bar{N}}\right)^{\mu} \tag{102}$$

$$\frac{\bar{r}\bar{\pi}}{\bar{f}^{s}}=(1+\bar{\rho})(1+\bar{\eta}) \tag{103}$$

$$\bar{e}^{\gamma-1}\bar{N}=\bar{e}^{\gamma-1}\bar{Y}-\bar{w}\bar{L}-\bar{e}^{\gamma}\bar{D} \tag{104}$$

$$\bar{e}^{\gamma-1}\bar{Y}=\gamma\bar{K}+\gamma\bar{C}+\bar{e}^{\gamma}\bar{X} \tag{105}$$

Plus Eq. (92). Thus the system contains 13 equations and 13 unknowns: $\bar{Y}$, $\bar{K}$, $\bar{L}, \bar{C}$, $\bar{r}$, $\bar{e}$, $\bar{w}$, $\bar{f}^{s}$, $\bar{\imath}$, $\bar{\imath}^{*}$, $\bar{N}$, $\bar{D}$ and $\bar{\eta}$.

The system is solved as follows. First, note that the steady-state interest rate on domestic bonds is determined by Eq. (98). Next, use Eq. (96) to eliminate $\bar{f}^{s}$. In particular, Eqs. (96) and (99) imply that:

$$1+\bar{\imath}^{*}=\frac{1}{\beta} \tag{106}$$

Combining Eqs. (98) and (99) results in a steady-state uncovered interest parity condition:

$$(1+\bar{\imath})=(1+\bar{\imath}^{*})\,\bar{\pi} \tag{107}$$

Now, use Eq. (103) together with the definitional Eq. (92) and Eq. (106) to obtain:

$$\bar{r}=\frac{1}{\beta} \tag{108}$$

That is, in steady state the real return to capital equals the gross interest rate on international denominated bonds. Notice also that Eq. (108) together with Eq. (98) can be used to establish a steady-state Fisher relationship between the real return on capital and the nominal interest rate for domestic bonds. That is:

$$\bar{r}=\frac{1+\bar{\imath}}{\bar{\pi}} \tag{109}$$

Eqs. (92) and (108) imply that:

$$1+\bar{\eta}=\frac{1}{\beta(1+\bar{\rho})} \tag{110}$$

Next, combine Eq. (94) and (95) and use Eq. (108) to obtain:

$$\bar{w}=\frac{1-\alpha}{\alpha\beta} \tag{111}$$

To continue, combine Eqs. (97) and (100) to obtain the steady-state labor supply, i.e.

$$\bar{L}=1 \tag{112}$$

this result implies that $\bar{C} = \bar{w}$, as can be seen from Eq. (97).

Use the previous results to substitute $\bar{D}$ out of the system by combining Eqs. (101) and (104), so that we can write:

$$\bar{K} = \bar{e}^{\gamma-1}\bar{Y} - \frac{1-\alpha}{\alpha\beta} \tag{113}$$

Combine this result with Eq. (105) once $\bar{w}\bar{L}$ has been substituted out:

$$\bar{Y} = \frac{\bar{X}\bar{e}}{1-\gamma} \tag{114}$$

that is, a positive linear relation between output and the real exchange rate is obtained. This is important because the strategy to solve the remaining portion of the system relies on expressing everything in terms of these two variables.

Note now that Eq. (94) and Eq. (108) imply that:

$$\bar{K} = \Lambda\bar{e}^{\gamma-1}\bar{Y} \tag{115}$$

where $\Lambda = \alpha\beta\left(1 - \frac{1}{\theta}\right)$. Now replace $\bar{K}$ in the production function and rearrange terms so that:

$$\bar{Y} = \left[\bar{A}^{\frac{1}{\alpha}}\Lambda\bar{e}^{\gamma-1}\right]^{\frac{\alpha}{1-\alpha}} \tag{116}$$

This is a second equation linking output and the real exchange rate. Therefore, we can use it to solve for $\bar{e}$ and $\bar{Y}$.

Now, combine Eq. (114) with (116) so that:

$$\bar{e} = \left[\bar{A}\Lambda^{\alpha}\left(\frac{\bar{X}}{1-\gamma}\right)^{\alpha-1}\right]^{\frac{1}{1-\alpha\gamma}} \tag{117}$$

and

$$\bar{Y} = \left[\bar{A}\Lambda^{\alpha}\left(\frac{\bar{X}}{1-\gamma}\right)^{\alpha(1-\gamma)}\right]^{\frac{1}{1-\alpha\gamma}} \tag{118}$$

Now, it is a simple matter to use these two equations for the steady-state values of $\bar{e}$ and $\bar{Y}$ to work backwards and obtain the steady-state values for all the remaining variables in the system. Using these results with Eq. (93) determines the steady-state level of capital:

$$\bar{K} = \left[\bar{A}^{\gamma}\Lambda\left(\frac{\bar{X}}{1-\gamma}\right)^{1-\gamma}\right]^{\frac{1}{1-\alpha\gamma}} \tag{119}$$

The steady-state value of net worth is obtained using Eq. (102):

$$\bar{N} = \{\beta(1+\bar{\rho})\}^{\frac{1}{\mu}}\left[\bar{A}\Lambda^{1+\alpha(1-\gamma)}\left(\frac{\bar{X}}{1-\gamma}\right)^{\alpha(1-\gamma)}\right]^{\frac{1}{1-\alpha\gamma}} \tag{120}$$

The steady-state level of debt is obtained using Eq. (101). In particular, :

$$\bar{D}=\left[1-\{\beta\left(1+\bar{\rho}\right)\}^{\frac{1}{\mu}}\right]\left(\frac{\Lambda\bar{X}}{1-\gamma}\right) \tag{121}$$

Overall the 13 steady-state variables are determined by the following equations: (96), (98), (106), (108), (110), (112), (117), (118), (119), (120), (121). Observe that the level of consumption and real wages are given by (111).

D LOG-LINEARIZING AROUND THE STEADY-STATE

The system of equations describing this economy cannot be solved for analytically. As a result, the system is log-linearized around the non-stochastic symmetric steady state. The symmetric equilibrium, the existence and solution of the steady sate are discussed in appendices B and C. The equations describing the log-linearized system (i.e. first-order conditions and the resource constraints) are given below. For notational purposes, define $\widehat{z}_t \equiv \frac{z_t-\bar{z}}{\bar{z}} \cong \ln\left(\frac{z_t}{\bar{z}}\right)$ as the percentage deviation from the steady state value, $\bar{Z}$.

D1 Firms' Behavior

The firm's problem yields the following log-linear expressions:

The linearized production function implies:

$$\hat{y}_t=\hat{A}_t+\alpha\hat{k}_t+\left(1-\alpha\right)\hat{l}_t \tag{122}$$

The first-order condition for capital return implies:

$$\hat{r}_t=\frac{\hat{e}_t^Y}{\bar{\theta}-1}+\hat{y}_t-\hat{k}_t+\left(\gamma-1\right)\hat{e}_t \tag{123}$$

while the first-order condition for labor demand implies:

$$\hat{w}_t=\frac{\hat{e}_t^Y}{\bar{\theta}-1}+\hat{y}_t-\hat{l}_t+\left(\gamma-1\right)\hat{e}_t \tag{124}$$

The output demand elasticity augmented with adjustment cost is:

$$\hat{e}_t^Y=\psi_p\left(\bar{f}^p\right)^2\hat{f}_t^p-\beta\psi_p\left(\bar{f}^p\right)^3E_t\hat{f}_{t+1}^p+\hat{\theta}_t \tag{125}$$

The technology shock yields that:

$$\hat{A}_t=\zeta_A\hat{A}_{t-1}+\varepsilon_{At} \tag{126}$$

and the mark-up shock of price over marginal cost that:

$$\hat{\theta}_t=\zeta_\theta\hat{\theta}_{t-1}+\varepsilon_{\theta t} \tag{127}$$

D2 The Household's Problem

The following equations are derived from the household's problem.

As shown before, the overall domestic consumer price index implies that:

$$\hat{\pi}_t = \gamma \hat{f}_t^p + (1-\gamma)\,\hat{f}_t^s \tag{128}$$

and the definition of the real exchange rate:

$$\hat{e}_t - \hat{e}_{t-1} = \hat{f}_t^s - \hat{f}_t^p \tag{129}$$

The consumers' budget constraint results in:

$$\hat{c}_t = \hat{w}_t + \hat{l}_t - \left(\frac{\bar{e}^\gamma}{\bar{C}}\right)\left[dB_t^* - \frac{1}{\beta}dB_{t-1}^*\right] \tag{130}$$

The Euler equations for consumption can be expressed as:

$$\hat{c}_t = E_t\hat{c}_{t+1} - E_t\hat{a}_{t+1} - (\hat{\imath}_t - E_t\hat{\pi}_{t+1}) + \hat{a}_t \tag{131}$$

$$\hat{c}_t = E_t\hat{c}_{t+1} - E_t\hat{a}_{t+1} - \left(\hat{\imath}_t^* + E_t\hat{f}_{t+1}^s - E_t\hat{\pi}_{t+1}\right) + \hat{a}_t \tag{132}$$

where $\hat{\imath}_t \equiv \ln(1+i_t) - \ln(1+\bar{\imath})$ and $\hat{\imath}_t^* \equiv \ln(1+i_t^*) - \ln(1+\bar{\imath}^*)$. The domestic Euler equation simply states that consumption depends inversely on the ex-ante real interest rate and via expectations on future short real rates. Combining both (131) and (132) implies that up to linearization the uncovered interest parity holds:

$$\hat{\imath}_t = \hat{\imath}_t^* + E_t\hat{f}_{t+1}^s \tag{133}$$

At this point, it is worth introducing a definitional condition relating international bond interest rates and the risk premium which is required to close the model. This is formally done by setting:

$$\hat{\imath}_t^* = \hat{\rho}_t + \hat{\eta}_t \tag{134}$$

where $\hat{\eta}_t \equiv \ln(1+\eta_t) - \ln(1+\bar{\eta})$ and $\hat{\rho}_t \equiv \ln(1+\rho_t) - \ln(1+\bar{\rho})$.

The optimal condition for labor supply results in:

$$(\nu - 1)\,\hat{l}_t = \hat{w}_t - \hat{c}_t + \left(\frac{1}{\sigma - 1}\right)\hat{e}_t^L \tag{135}$$

where the labor demand elasticity is given by:

$$\hat{e}_t^L = \psi_w\bar{\pi}^2\left(\hat{\Omega}_t + \hat{\pi}_t\right) - \beta\psi_w\bar{\pi}^2 E_t\left(\hat{\Omega}_{t+1} + \hat{\pi}_{t+1}\right) \tag{136}$$

and

$$\hat{\Omega}_t = \hat{w}_t - \hat{w}_{t-1} \tag{137}$$

The preference shock yields:

$$\hat{a}_t = \zeta_a\hat{a}_{t-1} + \varepsilon_{at} \tag{138}$$

D3 The Entrepreneur's Problem

The entrepreneur's problem determines the following set of equations:

From the budget constraint :

$$\hat{k}_{t+1} = \left(\frac{1}{1+\psi}\right)\hat{n}_t + \left(\frac{\psi}{1+\psi}\right)\hat{d}_{t+1} + \left(\gamma - \frac{1}{1+\psi}\right)\hat{e}_t \tag{139}$$

where $\psi \equiv \frac{\bar{e}\bar{D}}{\bar{N}}$, that is, the steady-state ratio of foreign debt to net worth.

The risk premium in turn implies:

$$\hat{\eta}_t = \mu\left[(1-\gamma)\hat{e}_t + \hat{k}_{t+1} - \hat{n}_t\right] \tag{140}$$

The arbitrage condition between the cost of capital and its marginal return yields the condition as follows:

$$\hat{\rho}_t + \hat{\eta}_t = E_t\hat{r}_{t+1} + E_t\hat{\pi}_{t+1} - E_t\hat{f}^s_{t+1} \tag{141}$$

This linearized condition together with Eqs. 133 and 134 is key as it provides the link between the nominal interest rate and the ex-ante real return on capital; in other words, we obtain a Fisher Equation.

The shock on international interest rates implies that:

$$\hat{\rho}_t = \zeta_\rho\hat{\rho}_{t-1} + \varepsilon_{\rho t} \tag{142}$$

The entrepreneur's net worth equation yields:

$$\begin{aligned}(\gamma-1)\hat{e}_t + \hat{n}_t &= \phi(1+\psi)\left[(\gamma-1)\hat{e}_t + \hat{y}_t\right] \\ &\quad + (1-\phi)(1+\psi)\left(\hat{w}_t + \hat{l}_t\right) - \psi\left(\gamma\hat{e}_t + \hat{d}_t\right)\end{aligned} \tag{143}$$

recall $\phi \equiv \left[1-(1-\alpha)\left(1-\frac{1}{\theta}\right)\right]^{-1}$.

D4 Monetary Policy

The central bank's interest rate target, Eq. (32), together with partial adjustment mechanism of the interest rate, Eq. (33), yields the following interest rule:

$$\hat{\imath}_t = \omega_i\hat{\imath}_{t-1} + \tilde{\omega}_\pi E_t\hat{\pi}_{t+1} + \tilde{\omega}_y\hat{y}_t + \tilde{\omega}_s\hat{s}_t + \tilde{\omega}_s\hat{\chi}_t \tag{144}$$

where $\tilde{\omega}_\pi \equiv (1-\omega_i)\,\omega_\pi$, $\tilde{\omega}_y \equiv (1-\omega_i)\,\omega_y$ and $\tilde{\omega}_s \equiv (1-\omega_i)\frac{\omega_s}{1-\omega_s}$. Observe that a shock to the interest rule has been included. More precisely, the shock is incorporated directly on $\bar{s}$ in Eq. (32). Its motivation is that during crisis episodes the focus of monetary policy is on stabilizing the exchange rate. The shock is assumed to follow a first-order autoregressive process so that:

$$\hat{\chi}_t = \zeta_\chi\hat{\chi}_{t-1} + \varepsilon_{\chi t} \tag{145}$$

where $0 < \zeta_\chi \leq 1$, $\varepsilon_{\chi t} \sim N\left(0, \sigma^2_\chi\right)$ and is serially uncorrelated. It plays a crucial role in the model as it explicitly allows us to consider the effects of a devaluation induced by the central bank. More precisely, the shock captures a devaluation of the central bank's nominal exchange rate target.[46]

The shock could also capture all other variables that affect monetary policy or it could be associated with some other variables not captured in the model. However, for the purpose of this paper, it is reasonable to focus on the exchange rate as the main determinant of interest rate policy. This is particularly true of an economy in a crisis. The key, then, is that a devaluation in the model is captured by a negative shock on $\varepsilon_{\chi t}$ that induces an exogenous decline in the interest rate.

It is worth discussing an important issue that arises from these exercises. It is well known that interest rate rules are a commitment device. However, the shock on the exchange rate target introduces discretionary behavior on the part of the monetary authority. Although this might be a point of controversy, I do not enlarge on it and simply assume that any monetary policy in the model is credible.[47]

D5 Market Clearing

The log-linearized market-clearing condition for home goods can be written as:

$$\tau\left(\gamma-1\right)\hat{e}_t+\tau\hat{y}_t=\lambda\tau\hat{k}_{t+1}+\left(1-\lambda\tau\right)\left(\hat{e}_t+\hat{x}_t\right)+\left(\tau-1\right)\hat{c}_t \tag{146}$$

where $\tau\equiv\left[1-\gamma\left(1-\alpha\right)\left(1-\frac{1}{\theta}\right)\right]^{-1}$ and $\lambda\equiv\frac{\gamma\bar{K}}{\bar{e}^{\gamma-1}\bar{Y}}=\gamma\alpha\beta\left(1-\frac{1}{\theta}\right)$ where the last equality follows from the steady-state solution (Eq. 115 in appendix C). The export demand shock is expressed as:

$$\hat{x}_t=\zeta_x\hat{x}_{t-1}+\varepsilon_{xt} \tag{147}$$

E Reducing the log-linearized system of equations

This appendix describes how to obtain the system used in the calibration exercise. It also shows how to obtain some important relationships.

E1 Obtaining the System Employed for Simulation

First, combine Eqs. (128) and (129) so that the inflation of domestically produced goods can be expressed as:

$$\hat{f}_t^p=\hat{\pi}_t-\left(1-\gamma\right)\hat{e}_t+\left(1-\gamma\right)\hat{e}_{t-1} \tag{148}$$

This result allows us to eliminate $\hat{f}_t^p$ from the system. In particular, the nominal devaluation rate can then be expressed as:

[46] See Cho and West (2003) for a similar approach.

[47] It is well known that targets for different variables change over time and they need not affect the credibility of the interest rate rule. Fraga, Goldfajn and Minella (2003) present evidence on the evolution of inflation targets for both developed and emerging markets. They find that while the former countries have a constant inflation target over time, the targets are decreasing for emerging markets.

$$\hat{f}_t^s = \hat{\pi}_t + \gamma\hat{e}_t - \gamma\hat{e}_{t-1} \tag{149}$$

Using this result it is possible to express the output demand elasticity augmented with adjustment cost, $\hat{e}_t^Y$, in terms of the CPI inflation rate and the real exchange rate only:

$$\begin{aligned}\hat{e}_t^Y &= \beta\psi_p\bar{\pi}^3(1-\gamma)E_t\hat{e}_{t+1} - \beta\psi_p\bar{\pi}^3E_t\hat{\pi}_{t+1} - \psi_p\bar{\pi}^2(1-\gamma)(1+\beta\bar{\pi})\hat{e}_t \\ &\quad +\psi_p\bar{\pi}^2(1-\gamma)\hat{e}_{t-1} + \psi_p\bar{\pi}^2\hat{\pi}_t + \hat{\theta}_t\end{aligned} \tag{150}$$

The next step is to combine Eqs. (123) and (124) to obtain the capital-labor trade-off equation:

$$\hat{w}_t + \hat{l}_t = \hat{r}_t + \hat{k}_t \tag{151}$$

Observe that this equation replaces Eq. (124) in the system.

To further simplify, insert Eqs. (150) and (136) into Eqs. (123) and (135), respectively. Finally, eliminate $\hat{\Omega}_t$ from the system using Eq. (137).

So far, we have described the algebraic manipulation to obtain the reduced system used in the calibration exercise. However, as mentioned before, the system can be further reduced. This is helpful for two reasons. First, because it is possible to obtain well known behavioral equations. This helps us gain some insight into the dynamics of the model. Second, to be able to take the model to the data we need to get rid of some variables not easily available in the data. This is particularly true of net worth and the risk premium. In what follows, I discuss how to simplify the system further. All the derivations start from where the system is left up to here.

E2 Behavioral Equations

E2.1 The IS Curve

Start by solving for $\hat{c}_t$ from the market-clearing condition (Eq. 146) to obtain:

$$\hat{c}_t = \left(\frac{\tau}{\tau-1}\right)\hat{y}_t + \left[\frac{(\gamma+\lambda-1)\tau-1}{\tau-1}\right]\hat{e}_t - \lambda\left(\frac{\tau}{\tau-1}\right)\hat{k}_{t+1} - \left(\frac{1-\lambda\tau}{\tau-1}\right)\hat{x}_t \tag{152}$$

Next, combine this equation with the Euler Eq. (131) and rearrange terms. This yields:[48]

$$\begin{aligned}\hat{y}_t &= E_t\hat{y}_{t+1} - \lambda E_t\hat{k}_{t+2} + \left[\gamma+\lambda-1-\frac{1}{\tau}\right]E_t\hat{e}_{t+1} + \lambda\hat{k}_{t+1} - \left[\gamma+\lambda-1-\frac{1}{\tau}\right]\hat{e}_t \\ &\quad - \left(\frac{\tau-1}{\tau}\right)(\hat{\imath}_t - E_t\hat{\pi}_{t+1}) - \left(\frac{\tau-1}{\tau}\right)E_t\hat{a}_{t+1} - \left(\frac{1-\lambda\tau}{\tau}\right)E_t\hat{x}_{t+1} \\ &\quad + \left(\frac{\tau-1}{\tau}\right)\hat{a}_t + \left(\frac{1-\lambda\tau}{\tau}\right)\hat{x}_t\end{aligned} \tag{153}$$

48 A simplified version of this equation is given in the next appendix.

this equation resembles an IS curve. Here we find that, all else equal, a devaluation in period t will have a positive effect on output. This can be seen by looking at the term in brackets multiplying the real exchange rate, which is negative for reasonable parameter values.[49] This positive effect is the standard Mundell-Fleming expansionary impact of devaluations.

Note also that $\hat{\imath}_t - E_t\pi_{t+1}$ is simply the real interest rate, $E_t\hat{r}_{t+1}$, indicating that there is an inverse relationship between output and the real exchange rate. This is a result that follows from combining Eqs. (133), (134) and (141), that is, a Fisher relationship.

In compact notation the "IS curve" can be written as:

$$\hat{y}_t = E_t\hat{y}_{t+1} - \Lambda_k E_t\hat{k}_{t+2} + \Lambda_e E_t\hat{e}_{t+1} + \Lambda_k\hat{k}_{t+1} + \Lambda_e\hat{e}_t - \Lambda_\tau\left(\hat{\imath}_t - E_t\pi_{t+1}\right) + \Lambda_a\hat{a}_t + \Lambda_x\hat{x}_t \quad (154)$$

where:

$\Lambda_k = \lambda \equiv \frac{\gamma\bar{K}}{\bar{e}^{\gamma-1}\bar{Y}} = \gamma\alpha\beta\left(1 - \frac{1}{\bar{\theta}}\right) > 0$

$\Lambda_e = -\left[\gamma + \lambda - 1 - \frac{1}{\tau}\right] > 0$

$\Lambda_\tau = \frac{\tau-1}{\tau} = \gamma\left(1-\alpha\right)\left(\frac{\bar{\theta}-1}{\bar{\theta}}\right) > 0$

$\Lambda_a = \left(1-\zeta_a\right)\frac{\tau-1}{\tau} > 0$

$\Lambda_x = \left(1-\zeta_x\right)\frac{1-\lambda\tau}{\tau} > 0$

Recall $\tau \equiv \left[1 - \gamma\left(1-\alpha\right)\left(1-\frac{1}{\bar{\theta}}\right)\right]^{-1}$.

E2.2 The BP Curve: Simplifying the Entrepreneur's Problem by Eliminating $\hat{\eta}_t$ and $\hat{n}_t$

To simplify the entrepreneur's problem, observe that net worth equation (143) can be rewritten as follows. Solve for $\hat{n}_t$ and eliminate $\hat{w}_t + \hat{l}_t$ using the capital-labor trade-off equation. Now replace, $\hat{r}_t + \hat{k}_t$ using the first-order condition for capital by firms (Eq. 123) so that:

$$\hat{n}_t = \left(1+\psi\right)\hat{y}_t - \psi\hat{e}_t + \left(1+\psi\right)\left(1-\phi\right)\frac{\hat{e}_t^Y}{\bar{\theta}-1} - \psi\hat{d}_t \quad (155)$$

Second, using this equation in the risk premium equation (Eq. 140) and grouping terms, obtain:

$$\hat{\eta}_t = \mu\left[\begin{array}{c}\left(1-\gamma+\psi\right)\hat{e}_t + \hat{k}_{t+1} - \left(1+\psi\right)\hat{y}_t - \\ \left(1+\psi\right)\left(1-\phi\right)\frac{\hat{e}_t^Y}{\bar{\theta}-1} + \psi\hat{d}_t\end{array}\right] \quad (156)$$

These two equations can be used to eliminate $\hat{n}_t$ and $\hat{\eta}_t$ from the system. They also provide the key intuition of how the balance sheet mechanism works. In particular, the entrepreneur's net worth is negatively related to the real exchange rate. That is, a devaluation deteriorates entrepreneurs' balance sheets. In addition, the risk premium

49 Notice that: $\gamma + \lambda - 1 - \tau^{-1} = \gamma + \gamma - \gamma\left(1-\alpha\right)\left(1-\frac{1}{\bar{\theta}}\right) - 1 + \gamma\left(1-\alpha\right)\left(1-\frac{1}{\bar{\theta}}\right) = 2\gamma - 1$. That is, as long as the share of domestically produced goods exceeds one-half, this term will be positive.

directly increases with a devaluation, as captured by the term $1-\gamma$, and *indirectly* increases via the effects of devaluations on net worth. This is captured by the term ψ i.e. the ratio of external debt to net worth. The analysis developed in this paper introduces an additional mechanism through which devaluations affect net worth and therefore the risk premium. This effect operates through the output elasticity augmented with adjustment costs, as captured by Eq. (150). A real exchange rate devaluation decreases the elasticity of output demand due to the adjustment costs on prices.

Now use Eq. (123) to replace $E_t\hat{r}_{t+1}$ into Eq. (141). After some manipulation, we reach the following investment demand equation:

$$\hat{k}_{t+1} = E_t\hat{y}_{t+1} - E_t\hat{e}_{t+1} + \gamma\hat{e}_t - \hat{\eta}_t + \frac{E_t\hat{e}^Y_{t+1}}{\bar{\theta}-1} - \hat{\rho}_t \tag{157}$$

Using Eq. (42) to substitute out $\hat{\eta}_t$, replacing the elasticity of output augmented with adjustment costs, e^Y_t, and rearranging terms gives the BP curve equation[50]:

$$\begin{aligned}
\hat{k}_{t+1} \quad = \quad & \frac{\mu(1+\psi)}{1+\mu}\hat{y}_t - \psi_p\pi^2\frac{[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)(\theta-1)}\hat{\pi}_t - \frac{\mu\psi}{1+\mu}\hat{d}_t + \frac{1}{1+\mu}E_t\hat{y}_{t+1} \\
& +\beta\pi\psi_p\pi^2\frac{[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)\left(\bar{\theta}-1\right)}E_t\hat{\pi}_{t+1} + \frac{1-\theta+\beta\psi_p\pi^2(1-\gamma)}{(1+\mu)(\theta-1)}E_t\hat{e}_{t+1} \\
& +\left[\frac{\gamma-\mu(1-\gamma+\psi)}{1+\mu} - (1+\beta\pi)\psi_p\pi^2\frac{(1-\gamma)[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)(\theta-1)}\right]\hat{e}_t \\
& +\psi_p\pi^2\frac{(1-\gamma)[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)(\theta-1)}\hat{e}_{t-1} - \left(\frac{1}{1+\mu}\right)\hat{\rho}_t \\
& -\frac{1+\mu(1+\psi)(1-\phi)}{(1+\mu)(\theta-1)}\hat{\theta}_t
\end{aligned} \tag{158}$$

It is important to highlight that a devaluation can have either an expansionary or a contractionary effect on investment and therefore on output. The reason for this is that it is not possible to sign the expression multiplying the exchange rate. Notice, in particular, that the first term in the brackets multiplying the exchange rate highlights the effects of capital market imperfections as captured by the parameter $\mu,$ i.e. the elasticity of the risk premium to the capital-net worth ratio. Those familiar with CCV's framework will identify this key term, which in their setting completely determines the expansionary or contractionary nature of a devaluation. However, in the present setting the quadratic cost of price adjustment introduces an extra term that makes devaluations more contractionary.

In compact notation the BP curve can be expressed as:

$$\begin{aligned}
\hat{k}_{t+1} \quad = \quad & \Gamma_y\hat{y}_t - \Gamma_\pi\hat{\pi}_t - \Gamma_d\hat{d}_t + \Gamma_\mu E_t\hat{y}_{t+1} + \beta\pi\Gamma_\pi E_t\hat{\pi}_{t+1} + \Gamma_{e1}E_t\hat{e}_{t+1} + \Gamma_e\hat{e}_t \\
& +\Gamma_{e2}\hat{e}_{t-1} - \Gamma_\mu\hat{\rho}_t - \Gamma_\theta\hat{\theta}_t
\end{aligned} \tag{159}$$

where:

$\Gamma_y = \frac{\mu(1+\psi)}{1+\mu} > 0$

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50 See next appendix for a simplified version of this equation and its coefficient signs.

$\Gamma_\pi = \psi_p \pi^2 \frac{[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)(\theta-1)}$ unsigned.

$\Gamma_d = \frac{\mu\psi}{1+\mu} > 0$

$\Gamma_\mu = \frac{1}{1+\mu} > 0$

$\Gamma_{e1} = \frac{1-\theta+\beta\psi_p\pi^2(1-\gamma)}{(1+\mu)(\theta-1)}$ unsigned.

$\Gamma_e = -\left[\frac{\gamma-\mu(1-\gamma+\psi)}{1+\mu} - (1+\beta\pi)\,\psi_p\pi^2 \frac{(1-\gamma)[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)(\theta-1)}\right]$ unsigned.

$\Gamma_{e2} = (1-\gamma)\,\psi_p\pi^2 \frac{[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)(\theta-1)}$ unsigned.

$\Gamma_\theta = \frac{1+\mu(1+\psi)(1-\phi)}{(1+\mu)(\theta-1)}$ unsigned.

Recall:

$\psi \equiv \frac{\bar{e}\bar{D}}{\bar{N}} > 0$

$\phi \equiv \left[1-(1-\alpha)\left(1-\frac{1}{\bar{\theta}}\right)\right]^{-1} = \frac{\bar{\theta}}{1+\alpha\left(\bar{\theta}-1\right)} > 0$

To sign several of the expressions above it is necessary to sign Γ_θ. This term can be positive or negative depending on the magnitude of the coefficients. In particular, it will depend on the magnitude on the degree of capital market imperfections, μ, on the steady-state ratio of external debt to net worth, ψ, and on the magnitude of:

$1-\phi = \frac{(1-\alpha)\left(1-\bar{\theta}\right)}{1+\alpha\left(\bar{\theta}-1\right)} < 0$

Under the benchmark parameterization of the model all unsigned coefficients turn out to be positive except Γ_e, which is negative.

A key term to understand the effects of devaluation on output is $\frac{\gamma-\mu(1-\gamma+\psi)}{1+\mu}$. This term by itself cannot be signed either. In CCV's framework it determines completely the direction in which the BP curve shifts after a devaluation. That is, if the expenditure-switching mechanism is strong enough (γ) then a devaluation will be expansionary. However, if the balance sheet mechanism, as captured by $\mu\,(1-\gamma+\psi)$, is strong enough to make the numerator negative, then a devaluation is contractionary. In our framework, Γ_e depends not only on this term but also on an additional component whose sign depends on Γ_θ. That is, devaluations can be expansionary or contractionary depending on how all these terms interact. However, under the benchmark case, the exchange rate has an adverse effect on investment.

Finally, insert the net worth equation obtained above into the entrepreneurs budget constraint. After some manipulation we obtain an equation that determines the dynamics of debt accumulation:

$$\frac{\psi}{1+\psi}\left(\hat{d}_{t+1} - \hat{d}_t\right) = \hat{k}_{t+1} - \hat{y}_t - (\gamma-1)\,\hat{e}_t - (1-\phi)\,\frac{e_t^Y}{\theta-1} \qquad (160)$$

F SOLUTION METHOD

The recursive stochastic linear system is solved using the undetermined coefficients method described by Uhlig (1997). The method states that if there is an endogenous state vector $\tilde{x}_t$ of size $(m \times 1)$, a list of other endogenous variables $\tilde{y}_t$ of size $(n \times 1)$ and a list of exogenous stochastic processes $\tilde{z}_t$ of size $(k \times 1)$, then the equilibrium relationships between these variables are:

$$0 = \Gamma_A \tilde{x}_t + \Gamma_B \tilde{x}_{t-1} + \Gamma_C \tilde{y}_t + \Gamma_D \tilde{z}_t \tag{161}$$

$$0 = E_t[\Gamma_F \tilde{x}_{t+1} + \Gamma_G \tilde{x}_t + \Gamma_H \tilde{x}_{t-1} + \Gamma_J \tilde{y}_{t+1} + \Gamma_K \tilde{y}_t + \Gamma_L \tilde{z}_{t+1} + \Gamma_M \tilde{z}_t] \tag{162}$$

$$\tilde{z}_{t+1} = \Gamma_N \tilde{z}_t + \tilde{\varepsilon}_{t+1} \tag{163}$$

$$E_t\left[\tilde{\varepsilon}_{t+1}\right] = 0 \tag{164}$$

where Γ_C is of size $(l \times n)$, $l \geq n$ and of rank n, Γ_F is of size $((m+n-l) \times n)$ and Γ_N has only stable eigenvalues. In the model $\tilde{x} = (\hat{k}, \hat{e}, \hat{w}, \hat{d}, dB^*, \hat{\imath}, \hat{\pi}, \hat{s})$, $\tilde{y} = (\hat{y}, \hat{l}, \hat{r}, \hat{c}, \hat{\eta}, \hat{n}, \hat{f}^s)$, and $\tilde{z} = \left(\hat{\rho}, \hat{x}, \hat{A}, \hat{\theta}, \hat{\chi}, \hat{a}\right)$.[51] The solution expresses all variables as linear functions of a vector of endogenous variables $\tilde{x}_{t-1}$ and exogenous variables $\tilde{z}_t$ given at date t, which are usually state or predetermined variables, so that the recursive equilibrium law of motion becomes:

$$\tilde{x}_t = \Gamma_P \tilde{x}_{t-1} + \Gamma_Q \tilde{z}_t \tag{165}$$

$$\tilde{y}_t = \Gamma_R \tilde{x}_{t-1} + \Gamma_S \tilde{z}_t \tag{166}$$

Formally, the idea is to obtain matrices $\Gamma_P, \Gamma_Q, \Gamma_R$ and Γ_S so that the equilibrium is stable.[52]

[51] For notational purposes in the remainder of the paper, define $\widehat{z}_t \equiv \frac{z_t - \bar{z}}{\bar{z}} \cong \ln\left(\frac{z_t}{\bar{z}}\right)$ as the percentage deviation from the steady state value, $\bar{Z}$.

[52] Details for the conditions under which this can be achieved are discussed in Uhlig (1997). The method is equivalent to Blanchard and Kahn (1980) and easily adaptable to incorporate Sims (2000) QZ decomposition, which is numerically more stable.

Preferences	-Discount factor, $\beta = 0.99$ -Elasticity of labor supply, $\nu = 2$ -Consumption share of home goods, $\gamma = 0.65$ -Elasticity of substitution between different varieties, $\theta = 6$
Technology	-Capital share, $\alpha = 0.4$ -Elasticity of labor demand, $\sigma = 2$
Adjustment costs	-Price adjustment cost, $\psi_p = 5$ -Wage adjustment cost, $\psi_w = 2$
Capital market imperfections	- Elasticity of risk premium to capital-net worth ratio, $\mu = 0.5$
Inherited dollar debt	- Ratio of dollar debt to net worth, $\psi = 1.25$
Interest rate rule	- Lagged interest rate, $\omega_i = 0.75$ - Inflation, $\omega_\pi = 1.75$ - Output, $\omega_y = 0.93$
Persistent parameters for shocks	-Export, $\zeta_x = 0.9$ -International free interest rate, $\zeta_\rho = 0.9$ -Technology, $\zeta_A = 0.95$ -Interest rate rule, $\zeta_\chi = 0.7$ -Mark-up, $\zeta_\theta = 0.96$ -Preference, $\zeta_a = 0.95$

Table 1: **Benchmark Parameter Values**

Benchmark parameterization			
	CCV	New	Total
$\hat{n}_t$	$-\psi = -1.2$	$-(1+\psi)(1-\phi)\frac{\psi_p \pi^2 (1-\gamma)(1+\beta\pi)}{\bar{\theta}-1} = 0.9$	-0.30
$\hat{\eta}_t$	$\mu(1-\gamma+\psi) = 0.8$	$-\mu(1+\psi)(1-\phi)\frac{\psi_p \pi^2 (1-\gamma)(1+\beta\pi)}{\bar{\theta}-1} = 0.4$	1.27
$\hat{k}_{t+1}$	$\frac{\gamma-\mu(1-\gamma+\psi)}{1+\mu} = -0.1$	$-\psi_p \bar{\pi}^2 (1+\beta\bar{\pi})(1-\gamma)\frac{[1+\mu(1+\psi)(1-\phi)]}{(1+\mu)\left(\bar{\theta}-1\right)} = 0.08$	-0.02
Perfect international capital markets ($\mu = 0$)			
	CCV	New	Total
$\hat{n}_t$	$-\psi = -1.2$	$-(1+\psi)(1-\phi)\frac{\psi_p \pi^2 (1-\gamma)(1+\beta\pi)}{\bar{\theta}-1} = 0.9$	-0.3
$\hat{\eta}_t$	$\mu(1-\gamma+\psi) = 0.0$	$-\mu(1+\psi)(1-\phi)\frac{\psi_p \pi^2 (1-\gamma)(1+\beta\pi)}{\bar{\theta}-1} = 0.0$	0.0
$\hat{k}_{t+1}$	$\gamma = 0.6$	$-\psi_p \bar{\pi}^2 (1+\beta\bar{\pi})(1-\gamma)\frac{1}{\left(\bar{\theta}-1\right)} = -0.34$	0.3

Table 2: **Effects of Devaluations on the Different Components of the BP Curve.**

FIGURE 1

IS AND BP CURVES

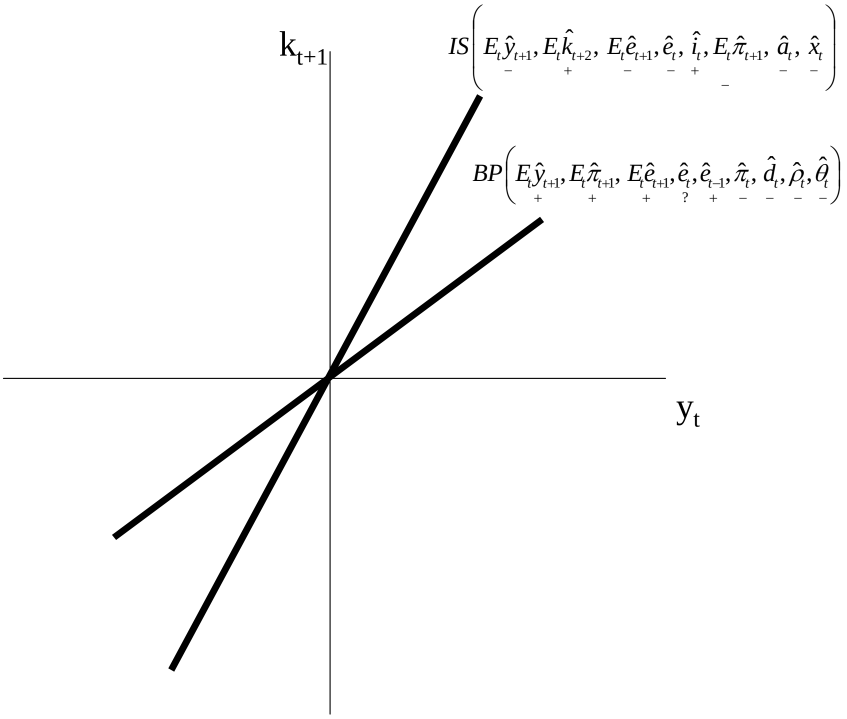

FIGURE 2

EQUILIBRIUM EFFECT OF A DEVALUATION

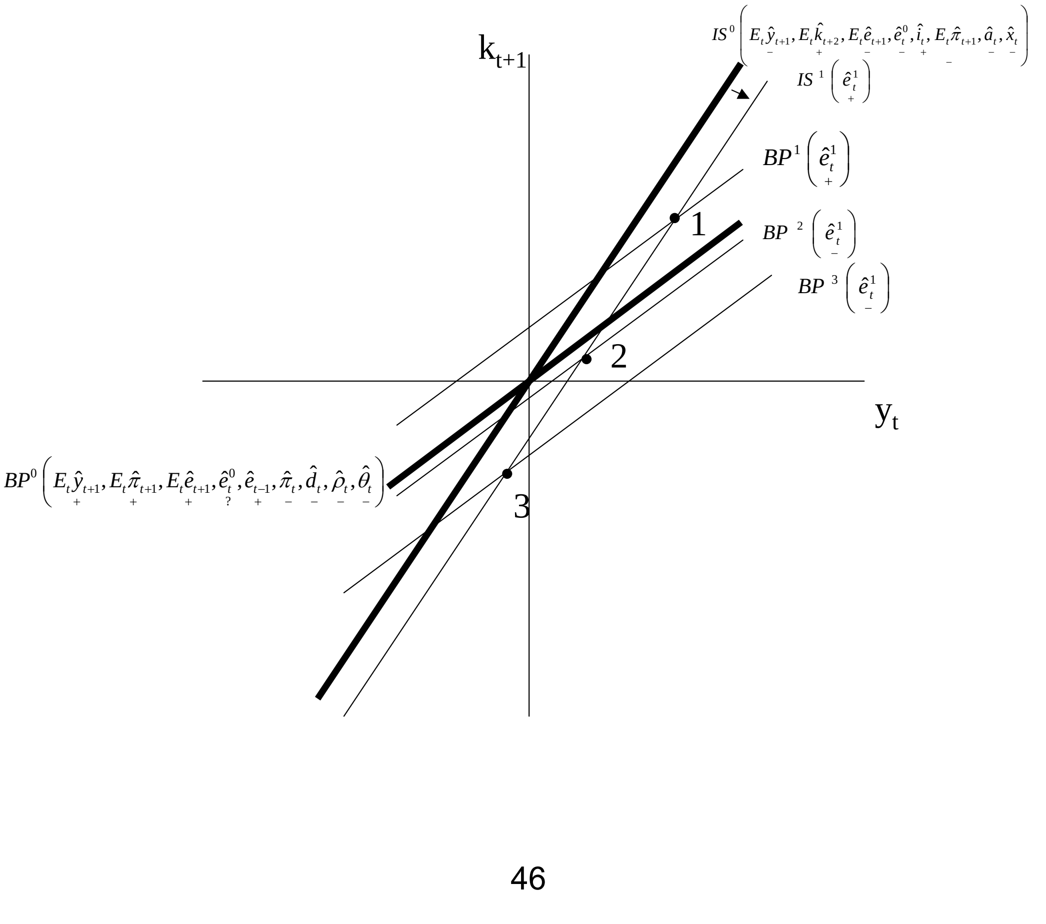

FIGURE 3

EFFECT OF AN EXPANSIONARY MONETARY SHOCK (ω_S=0)

Benchmark

No Balance Sheets

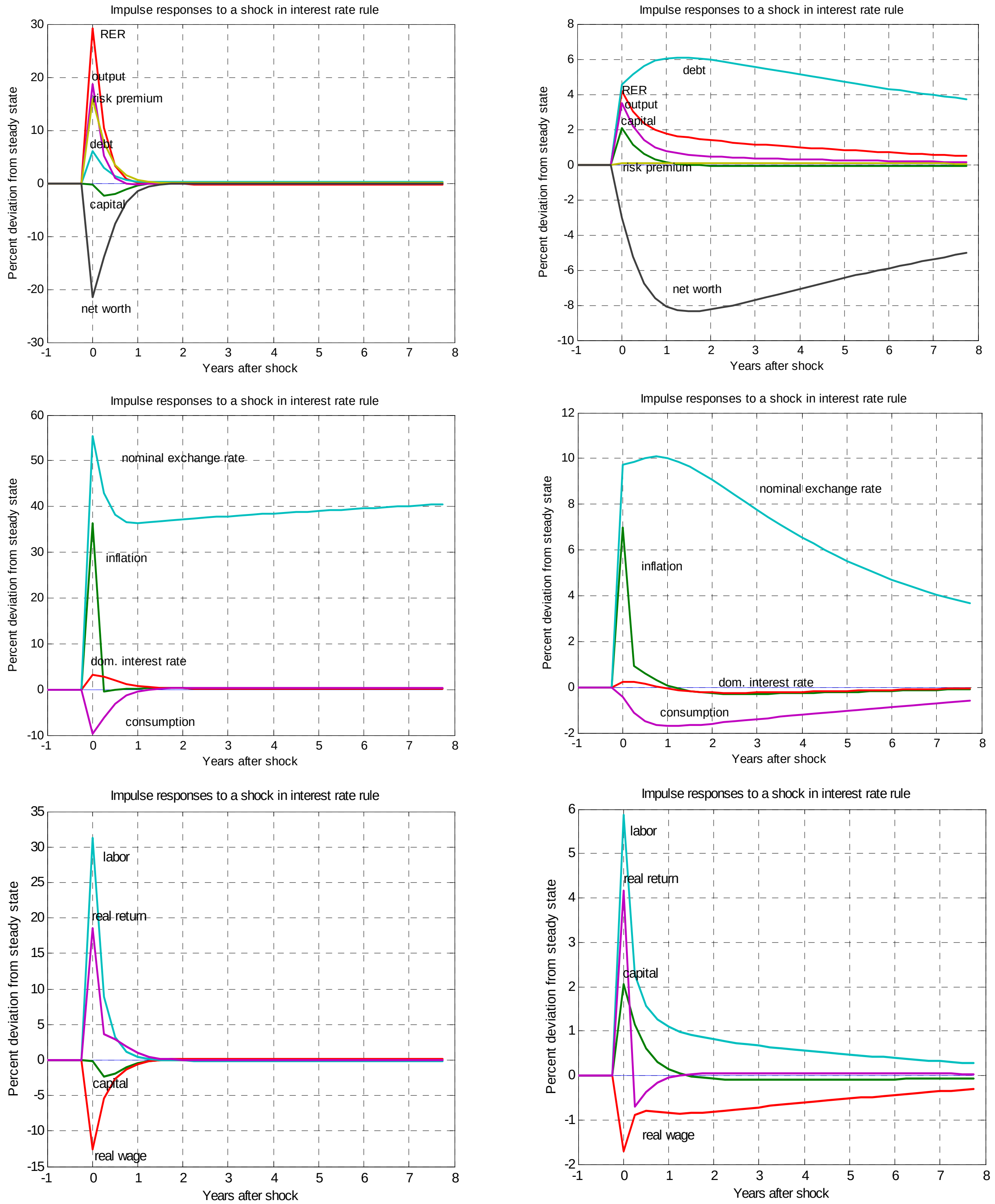

FIGURE 3
(continued)
EFFECT OF AN EXPANSIONARY MONETARY SHOCK (ω_S=0)

Flexible Prices | Flexible Wages

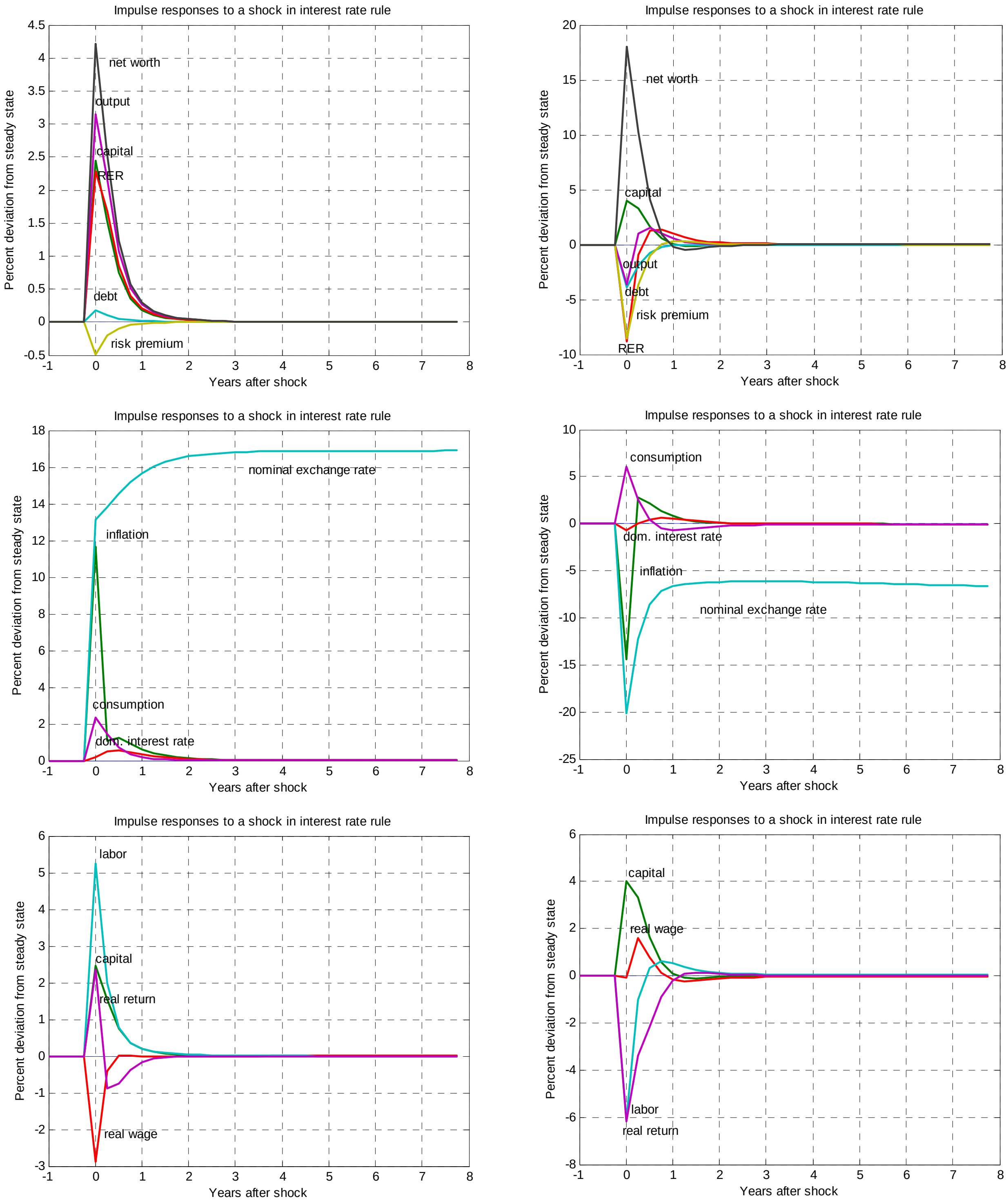

FIGURE 4
EFFECTS OF AN EXPANSIONARY MONETARY SHOCK (ω_S=0)
UNDER ALTERNATIVE INTEREST RATE RULE SPECIFICATIONS

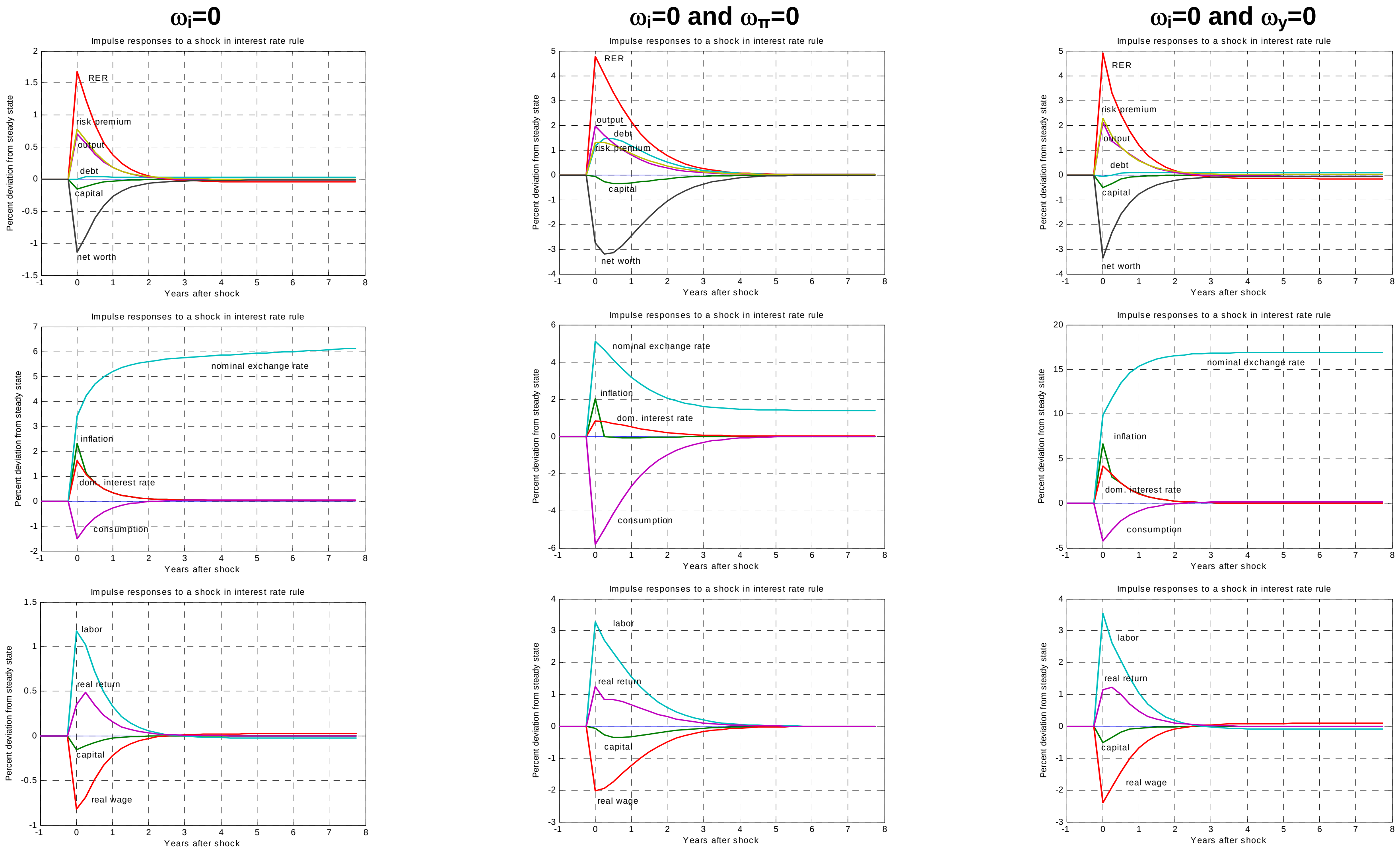

FIGURE 5

EFFECTS OF A DEVALUATIONARY POLICY SHOCK WHEN BALANCE SHEET EFFECTS ARE PRESENT

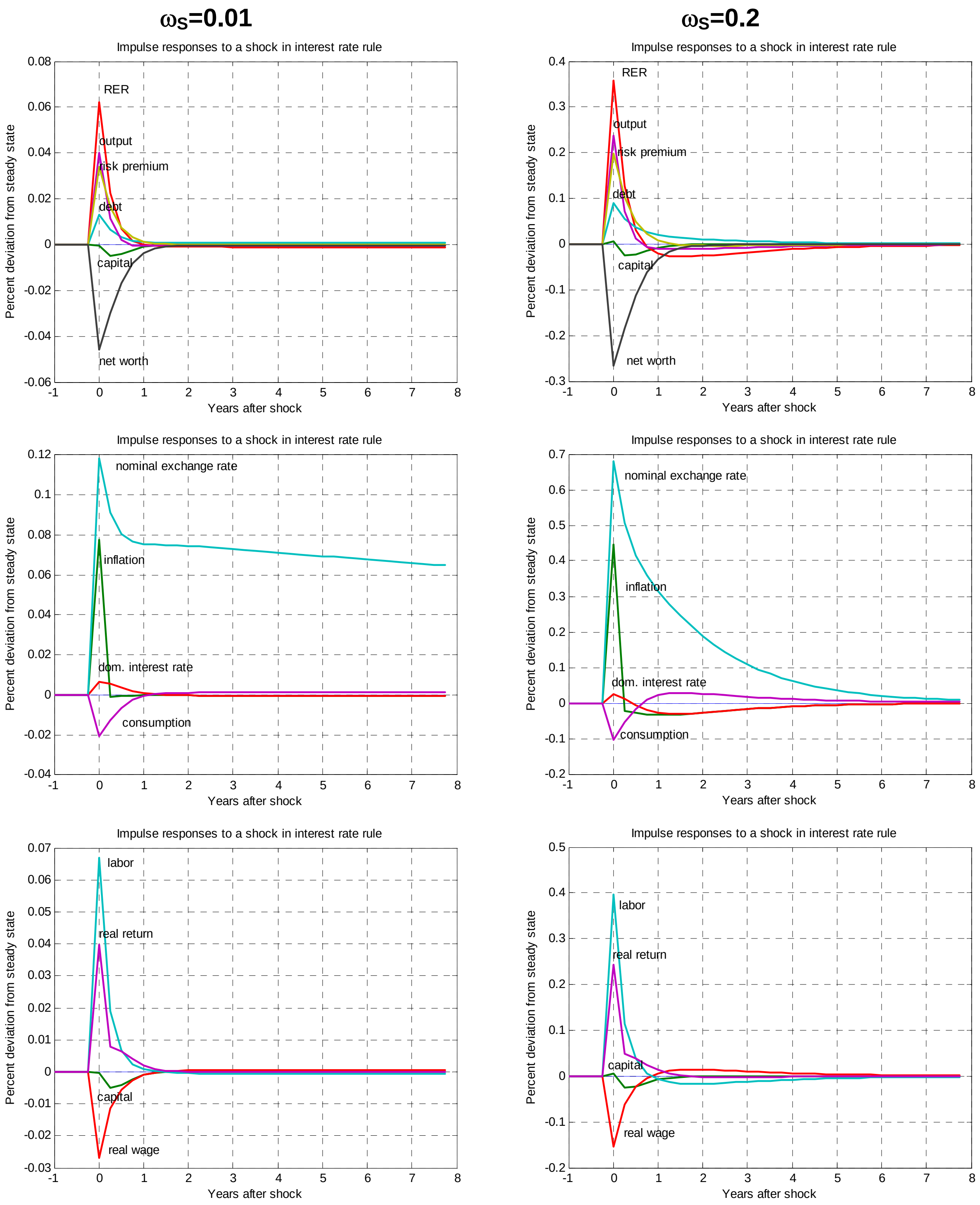

FIGURE 5
(continued)
EFFECTS OF A DEVALUATIONARY POLICY SHOCK WHEN BALANCE SHEET EFFECTS ARE PRESENT

ω_S=0.6 **ω_S=0.99**

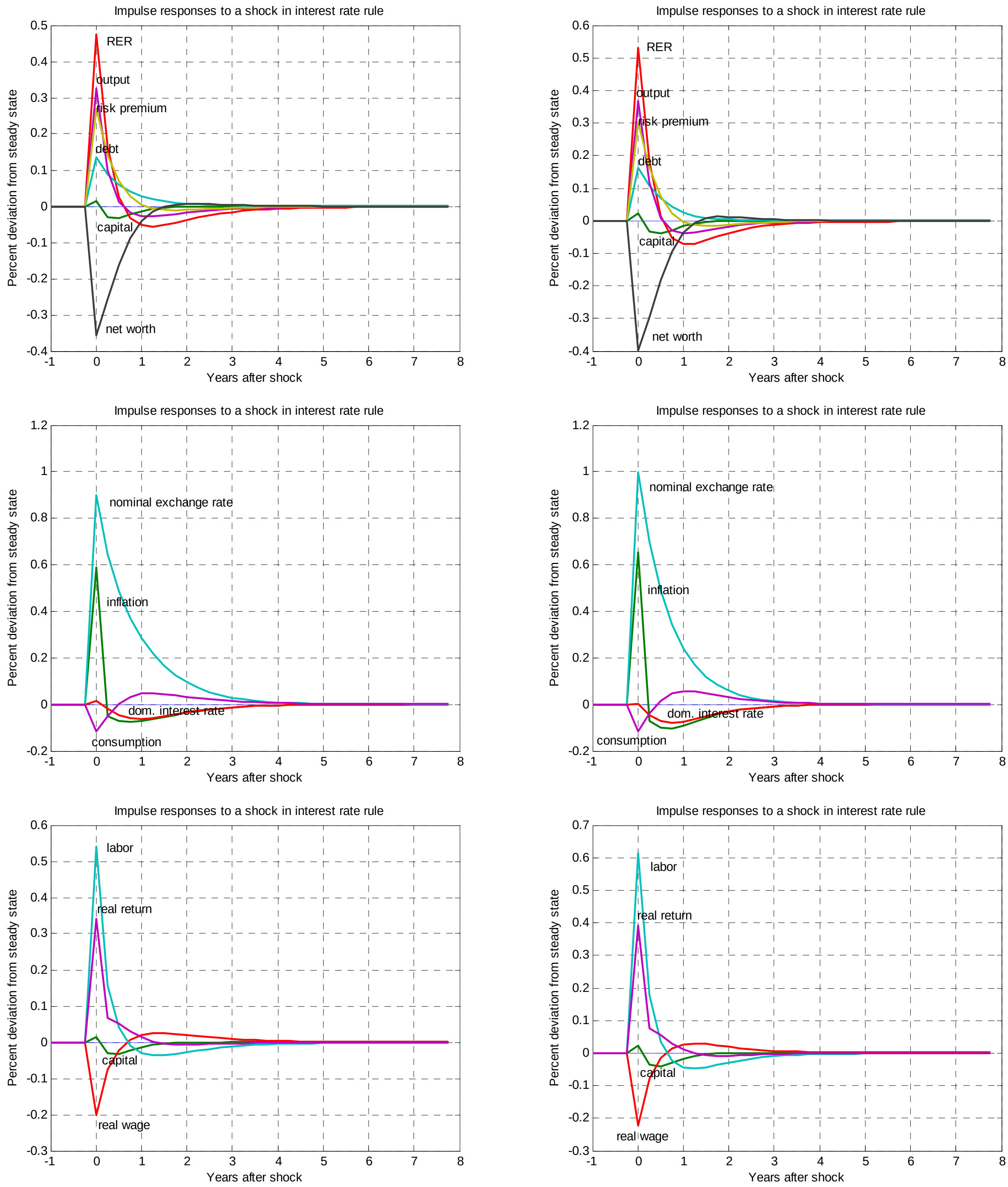

FIGURE 6

EFFECTS OF A DEVALUATIONARY POLICY SHOCK IN THE ABSENCE OF BALANCE SHEET EFFECTS

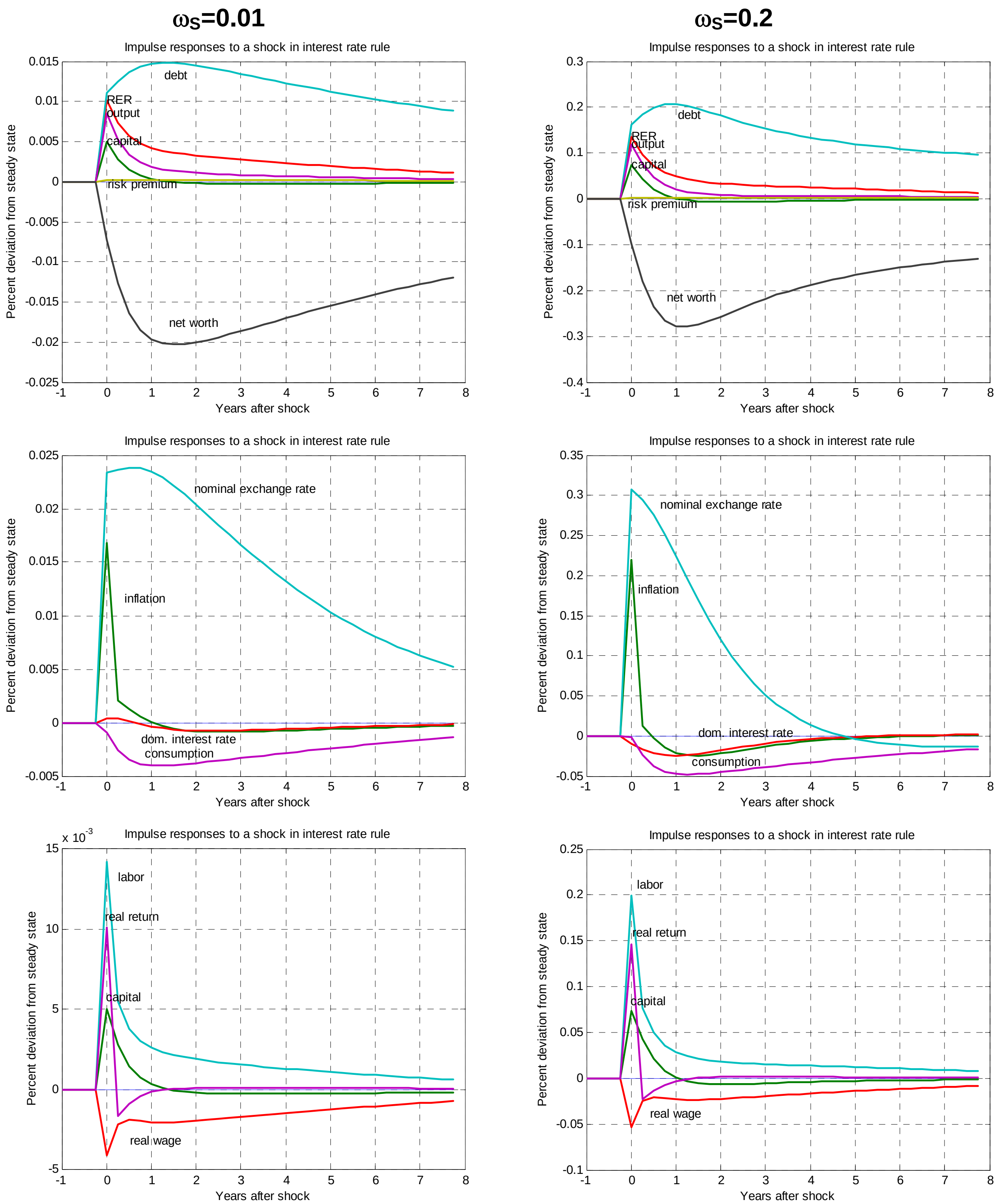

FIGURE 6
(Continued)
EFFECTS OF A DEVALUATIONARY POLICY SHOCK IN THE ABSENCE OF BALANCE SHEET EFFECTS

ω_S=0.6 ω_S=0.99

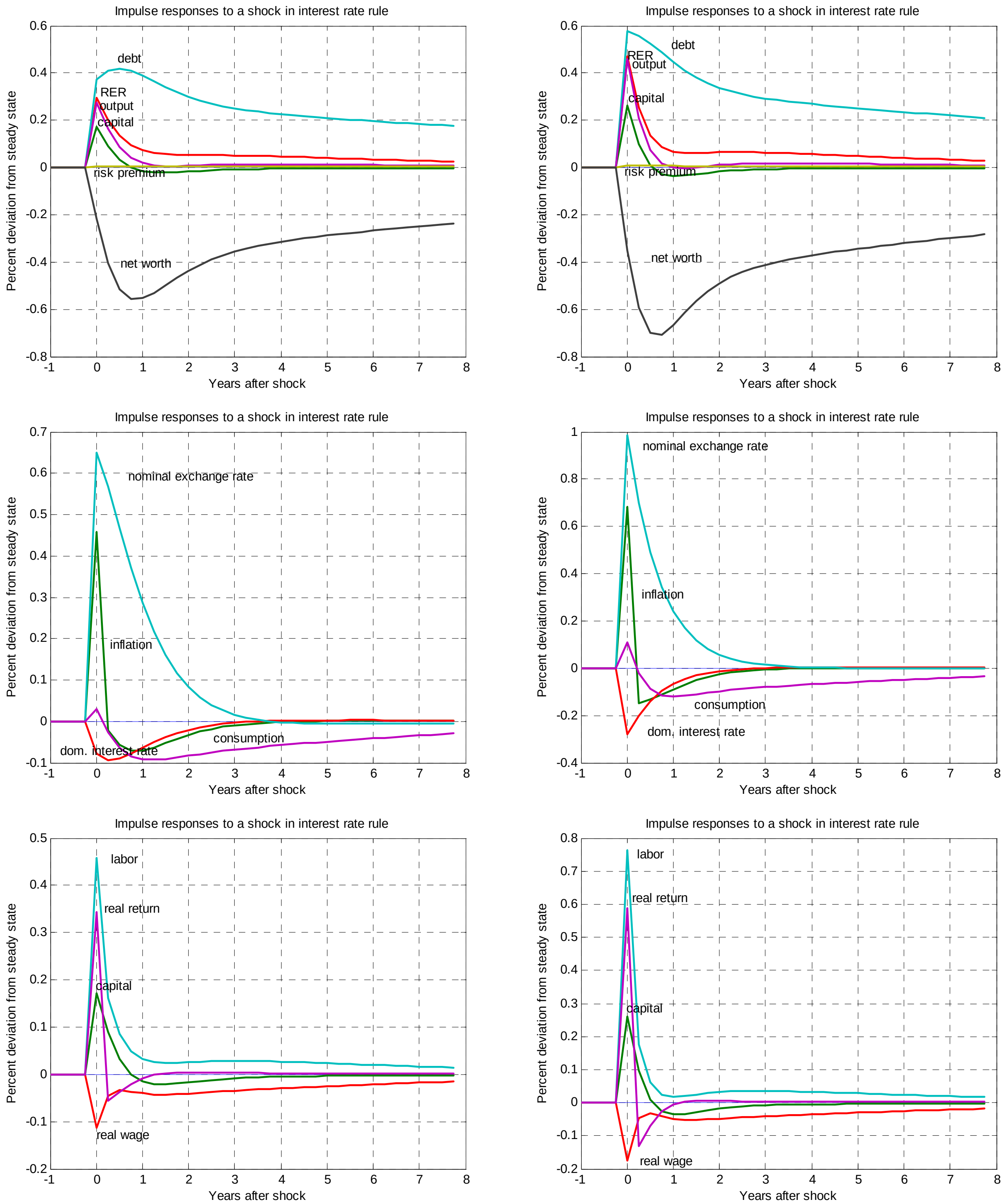

FIGURE 7

INTEREST RATE ELASTICITY TO A DEVALUATIONARY SHOCK UNDER ALTERNATIVE WEIGHT VALUES FOR THE EXCHANGE RATE IN THE INTEREST RATE RULE

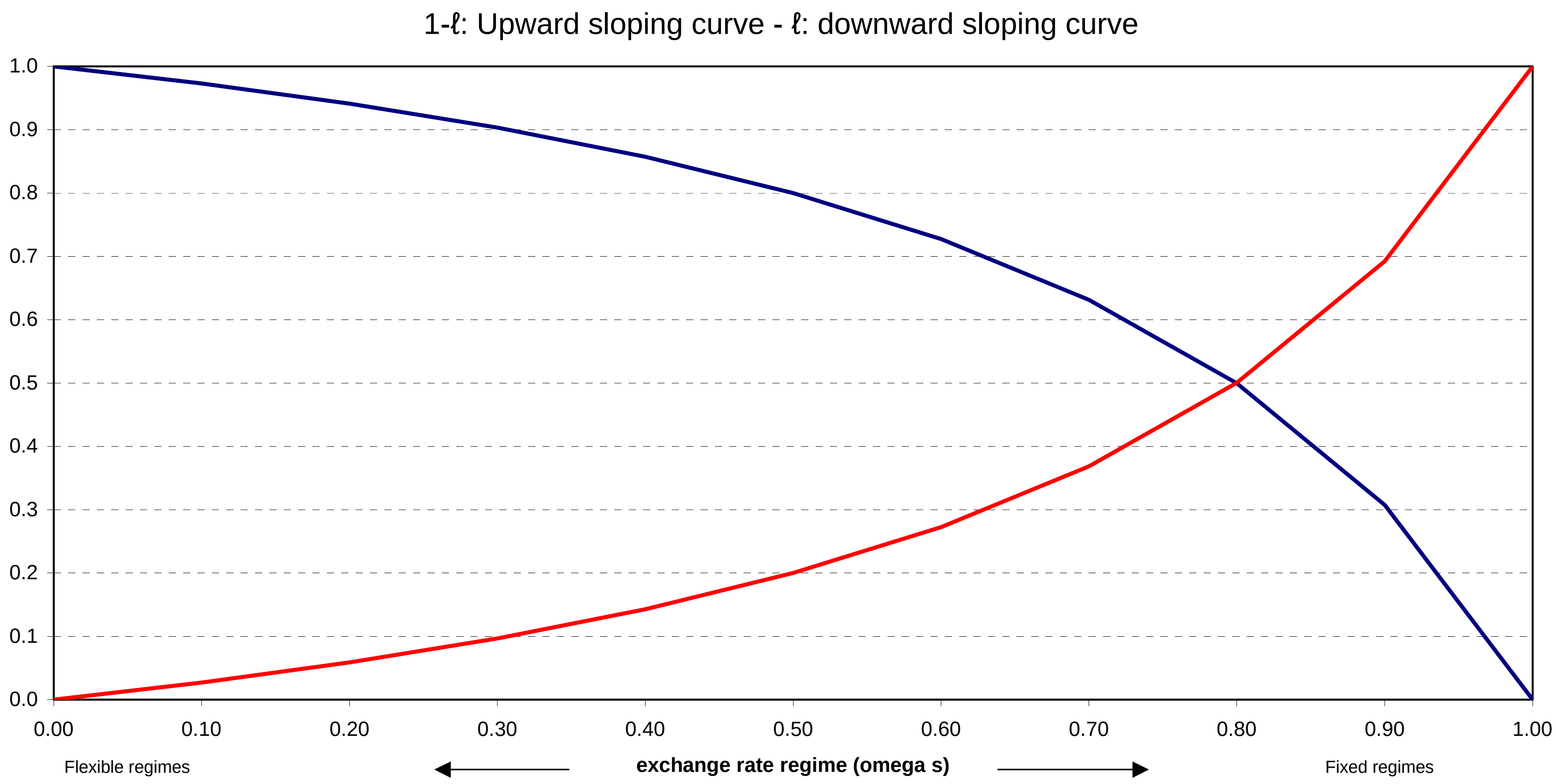

FIGURE 8

EFFECTS OF A SHOCK ON THE INTERNATIONAL INTEREST RATE IN THE PRESENCE OF BALANCE SHEET EFFECTS

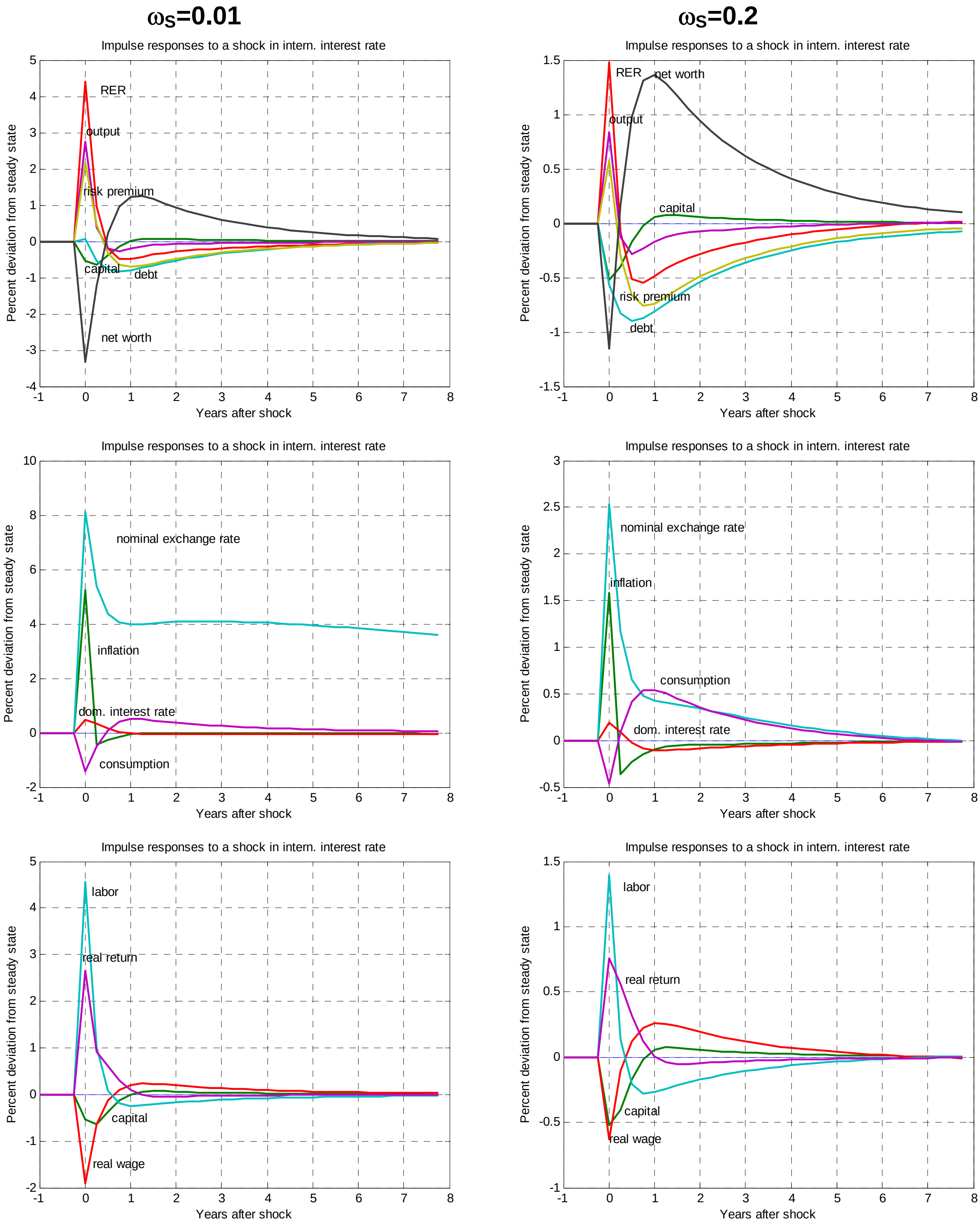

FIGURE 8

(Continued)

EFFECTS OF A SHOCK ON THE INTERNATIONAL INTEREST RATE IN THE PRESENCE OF BALANCE SHEET EFFECTS

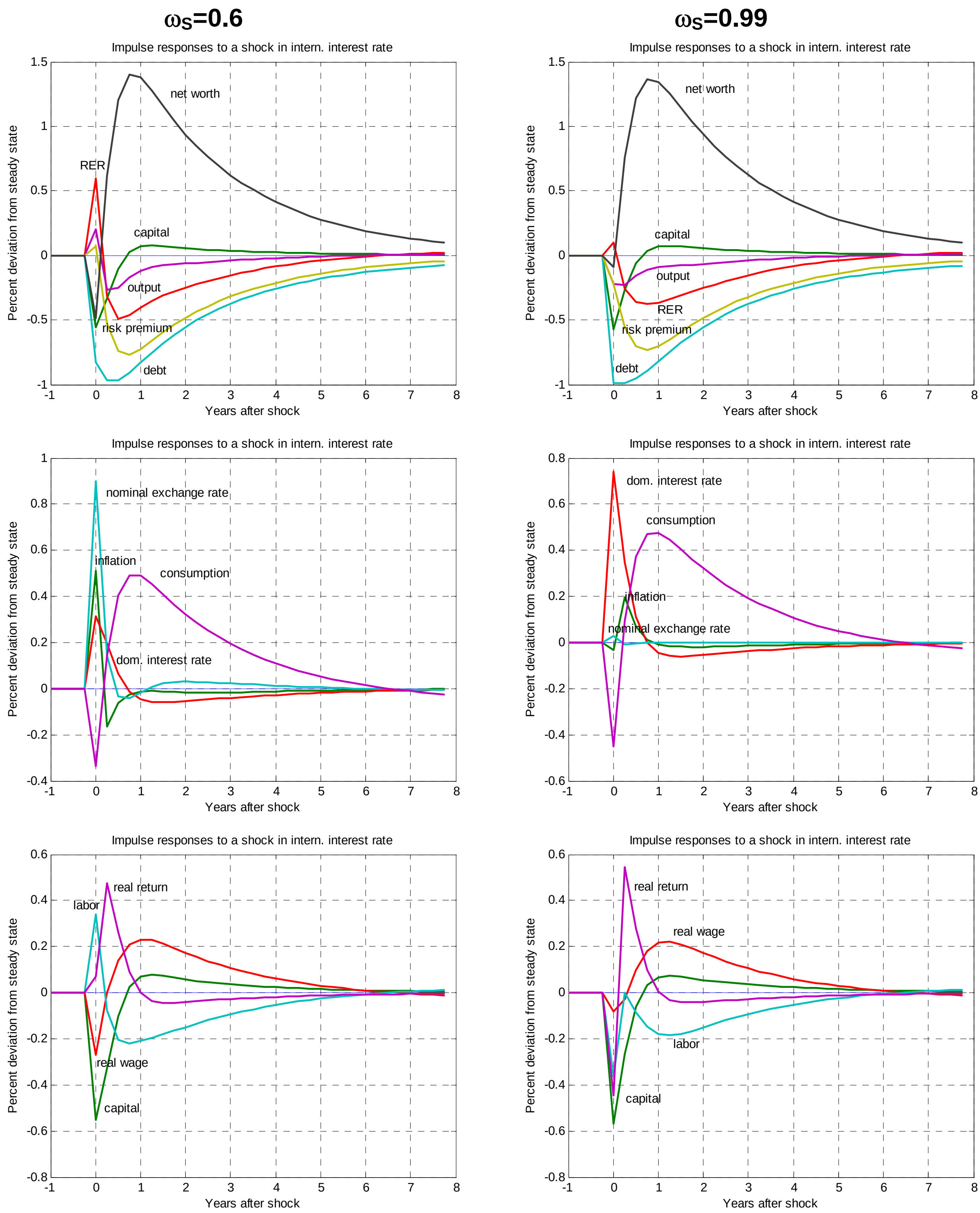

FIGURE 9

EFFECTS OF A SHOCK ON THE INTERNATIONAL INTEREST RATE IN THE ABSENCE OF BALANCE SHEETS

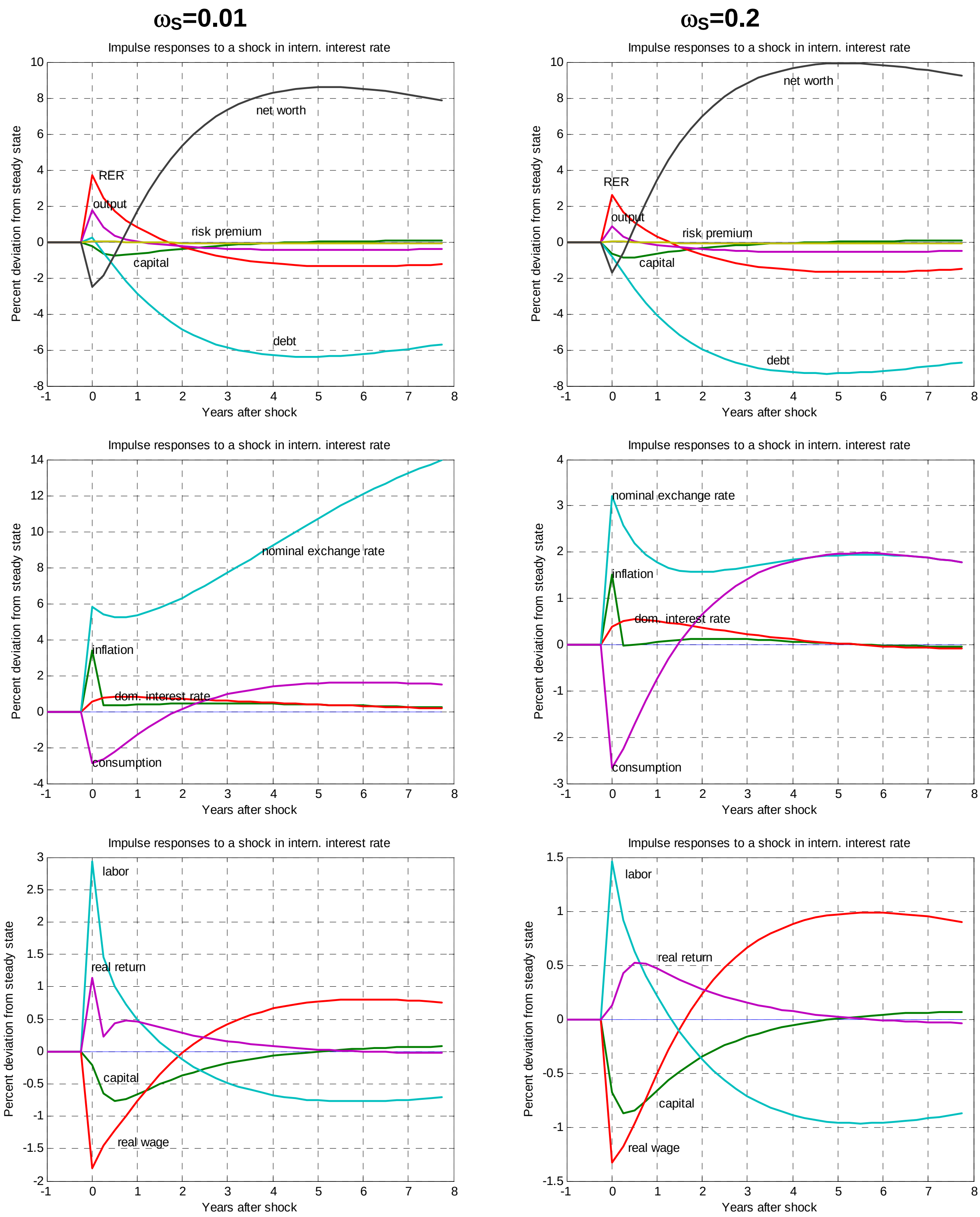

FIGURE 9
(Continued)
EFFECTS OF A SHOCK ON THE INTERNATIONAL INTEREST RATE IN THE ABSENCE OF BALANCE SHEETS

ω_S=0.6 | ω_S=0.99

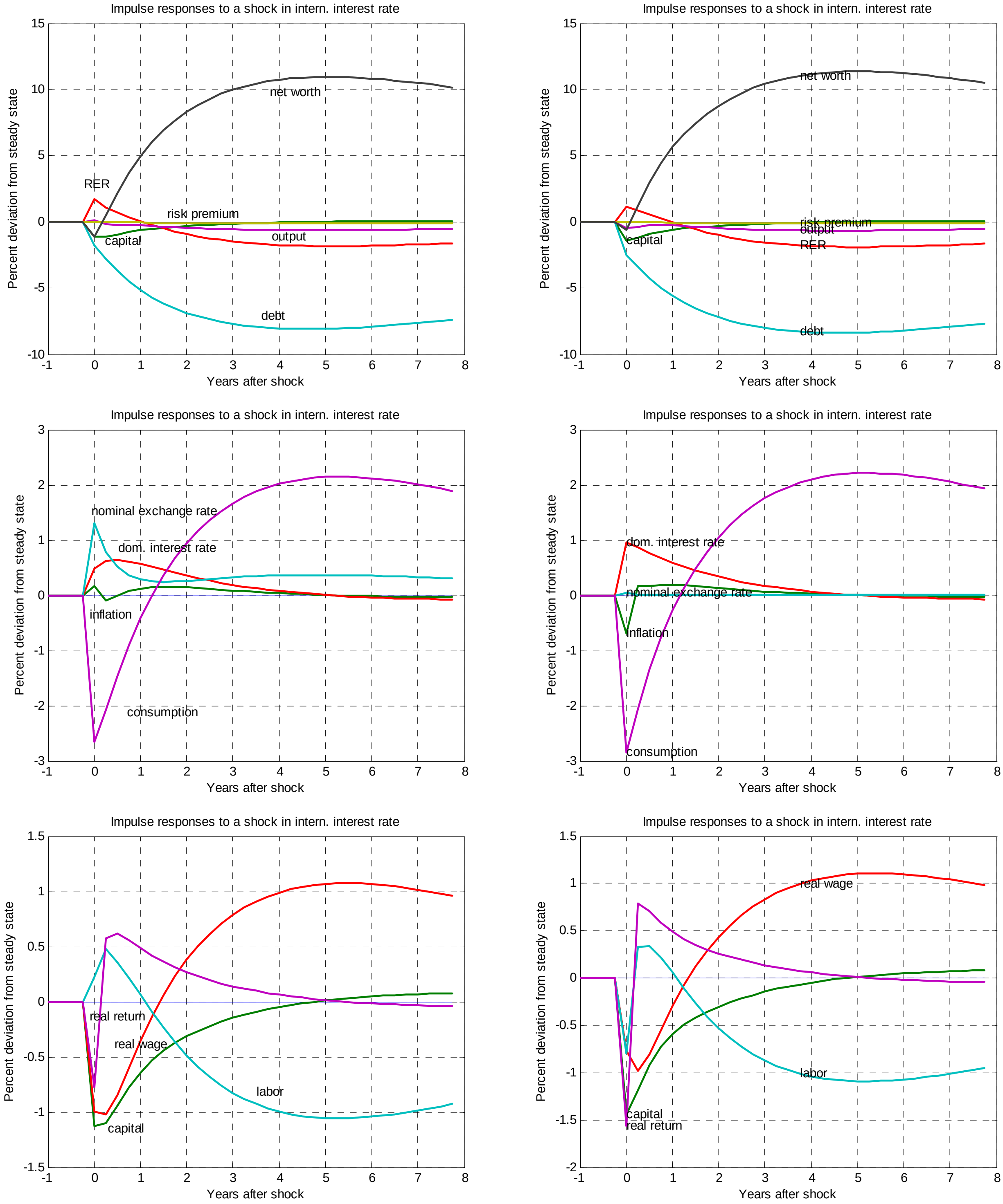

FIGURE 10

EFFECTS OF A SHOCK ON THE INTERNATIONAL INTEREST RATE JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE PRESENCE OF BALANCE SHEET EFFECTS

ω_S=0.01 | **ω_S=0.2**

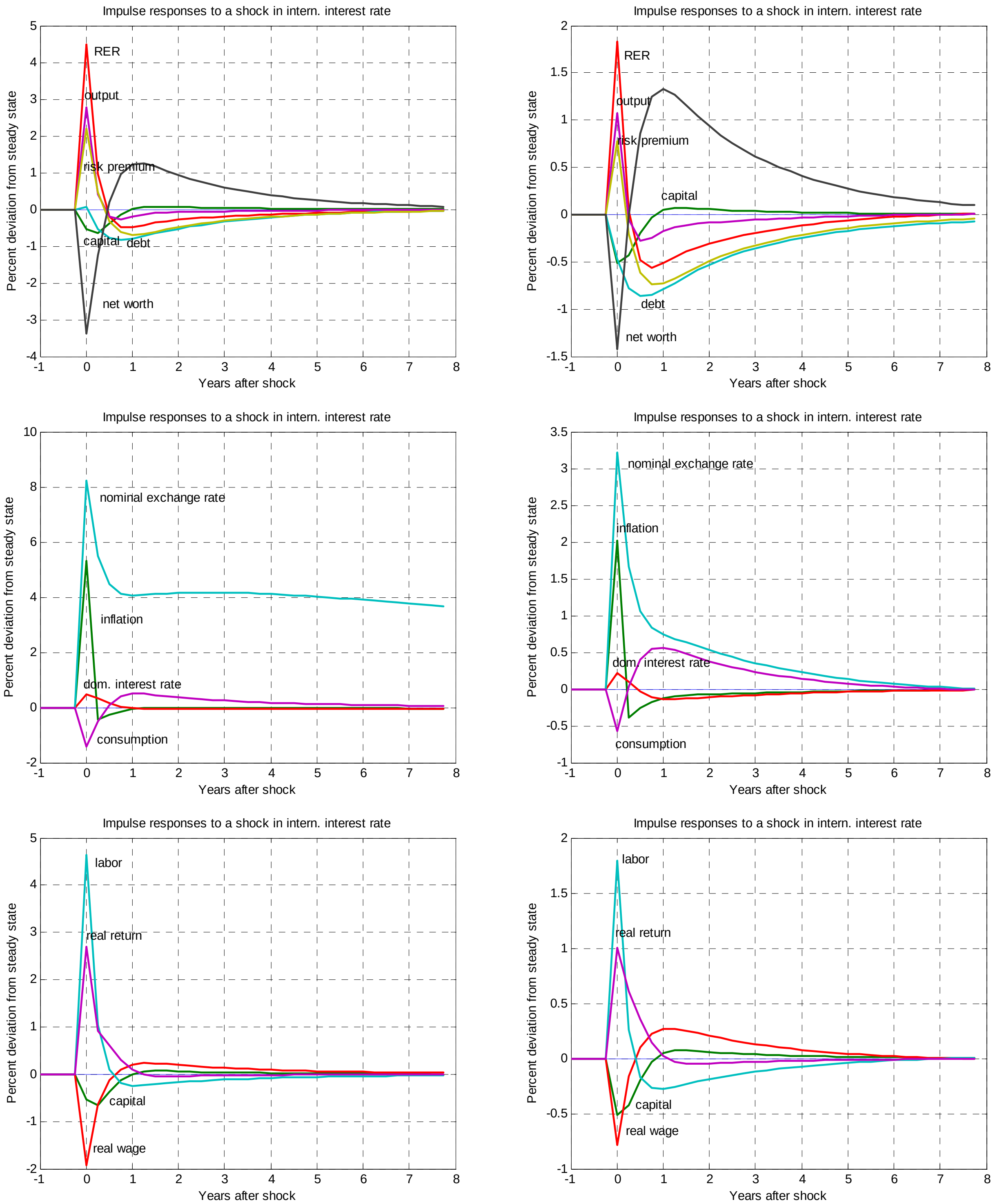

FIGURE 10
(Continued)
EFFECTS OF A SHOCK ON THE INTERNATIONAL INTEREST RATE JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE PRESENCE OF BALANCE SHEET EFFECTS

ω_S=0.6 | **ω_S=0.99**

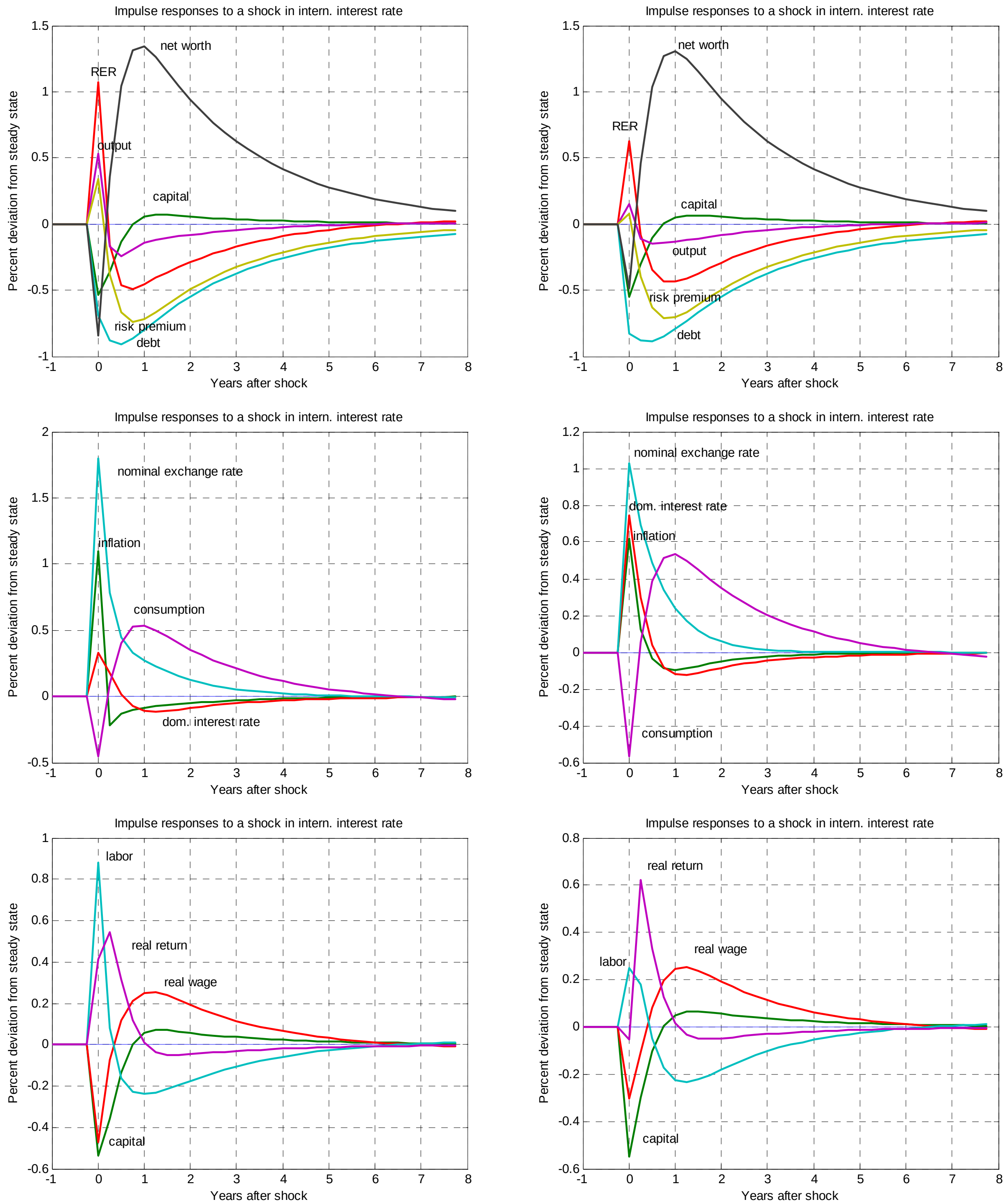

FIGURE 11

EFFECTS OF A SHOCK ON THE INTERNATIONAL RATE JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE ABSENCE OF BALANCE SHEET EFFECTS

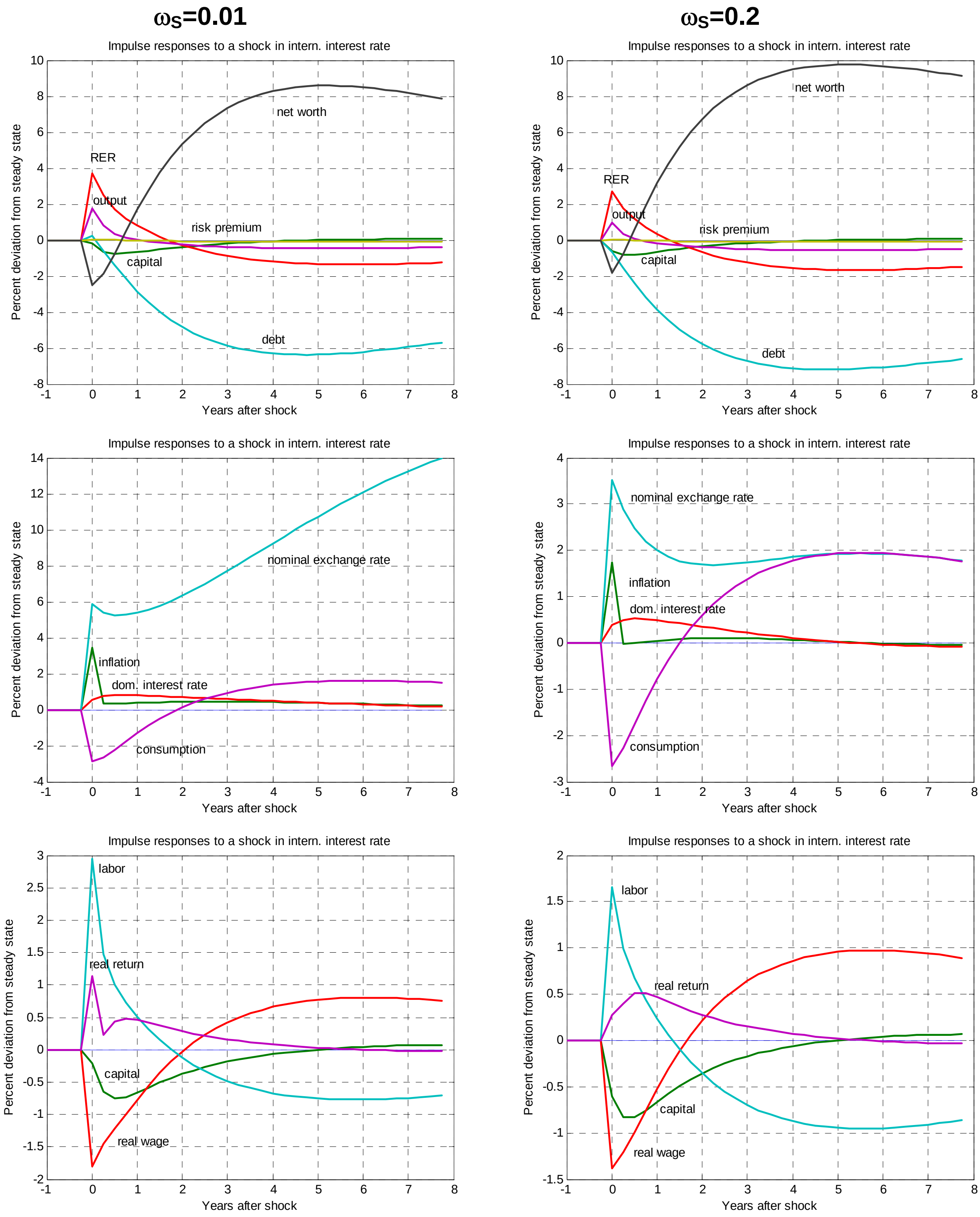

FIGURE 11
(continued)
EFFECTS OF A SHOCK ON THE INTERNATIONAL RATE JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE ABSENCE OF BALANCE SHEET EFFECTS

ω_S=0.6 | **ω_S=0.99**

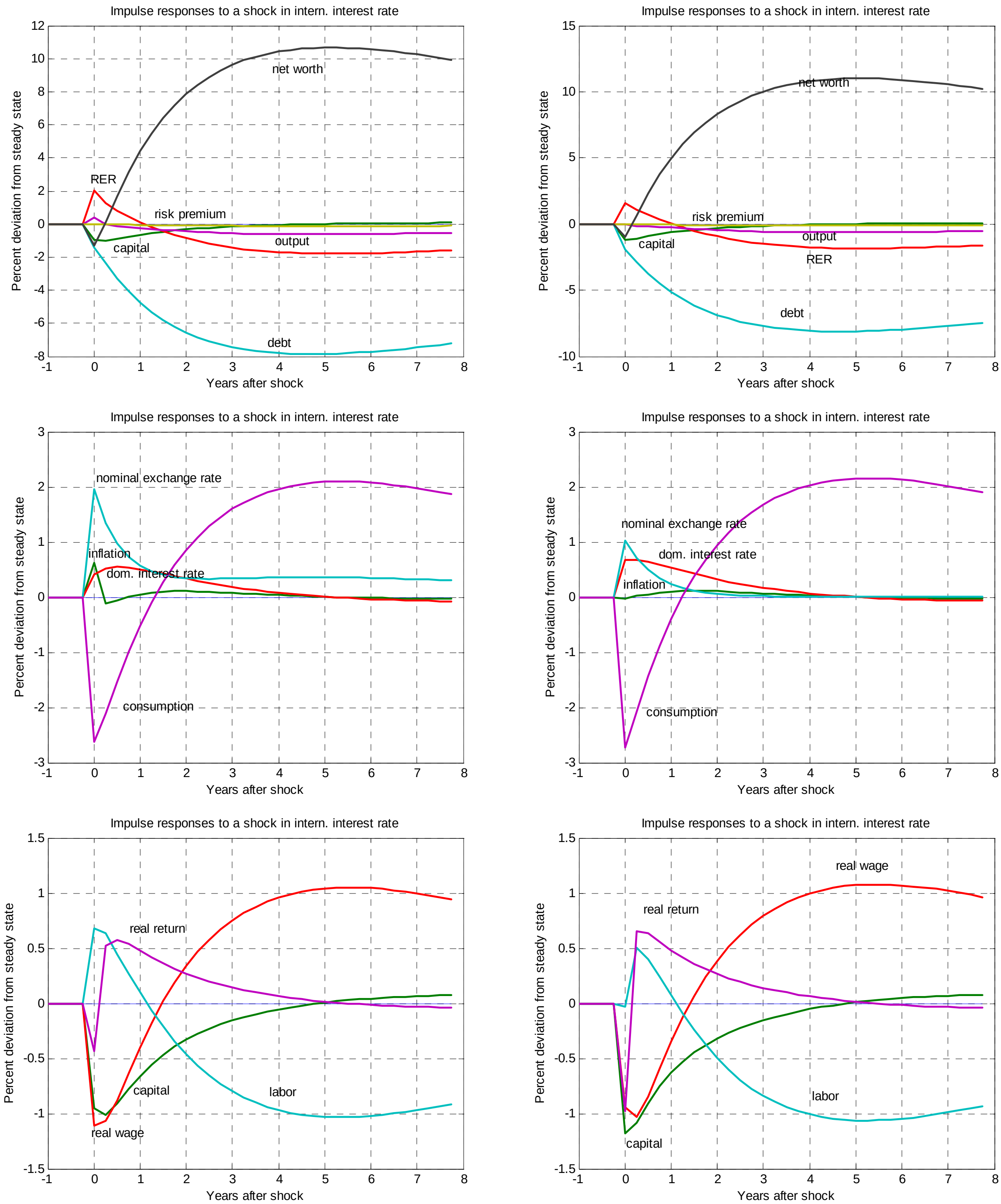

FIGURE 12

EFFECTS OF A SHOCK ON EXPORT DEMAND IN THE PRESENCE OF BALANCE SHEET EFFECTS

ω_S=0.01 | ω_S=0.2

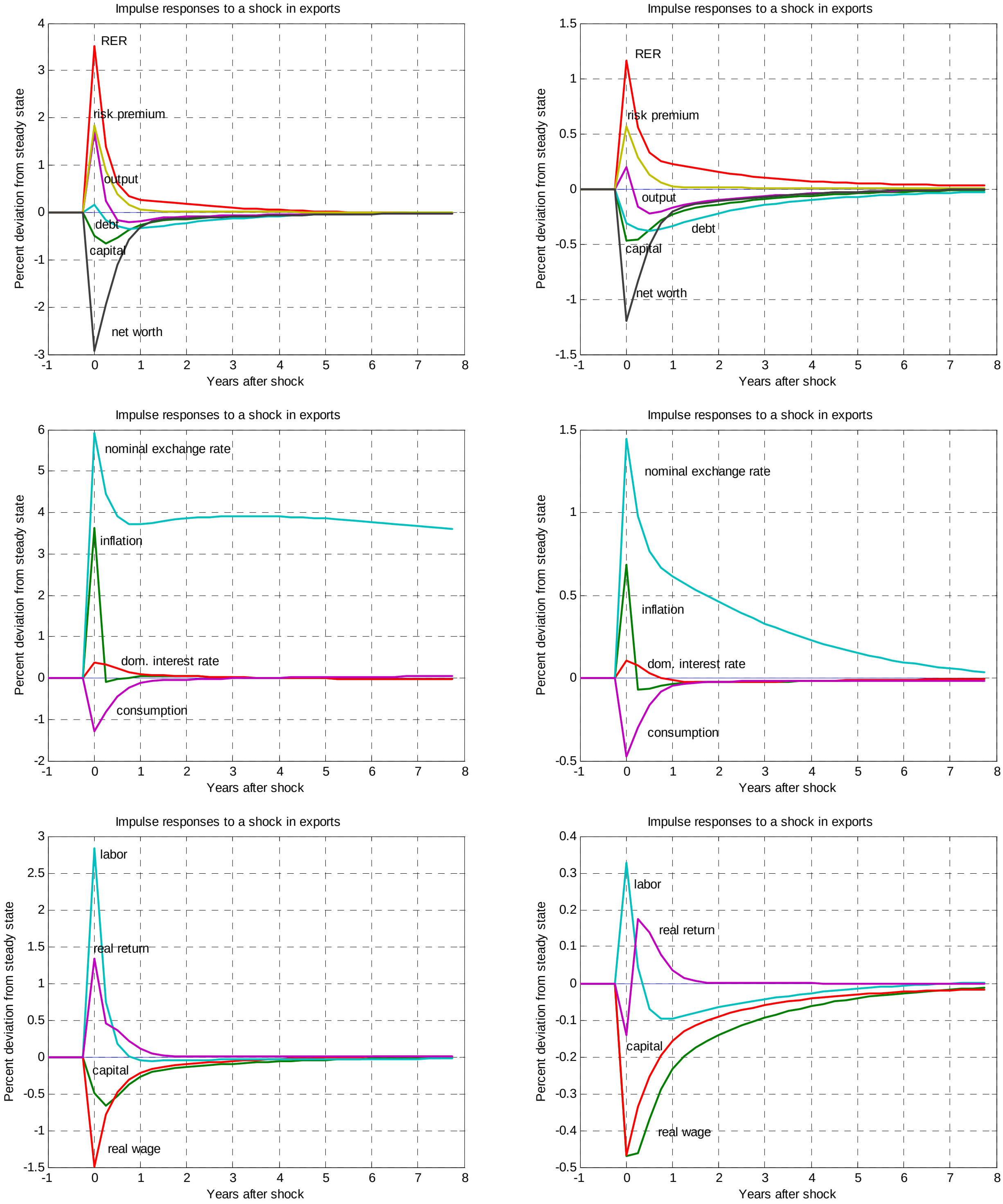

FIGURE 12
(Continued)
EFFECTS OF A SHOCK ON EXPORT DEMAND IN THE PRESENCE OF BALANCE SHEET EFFECTS

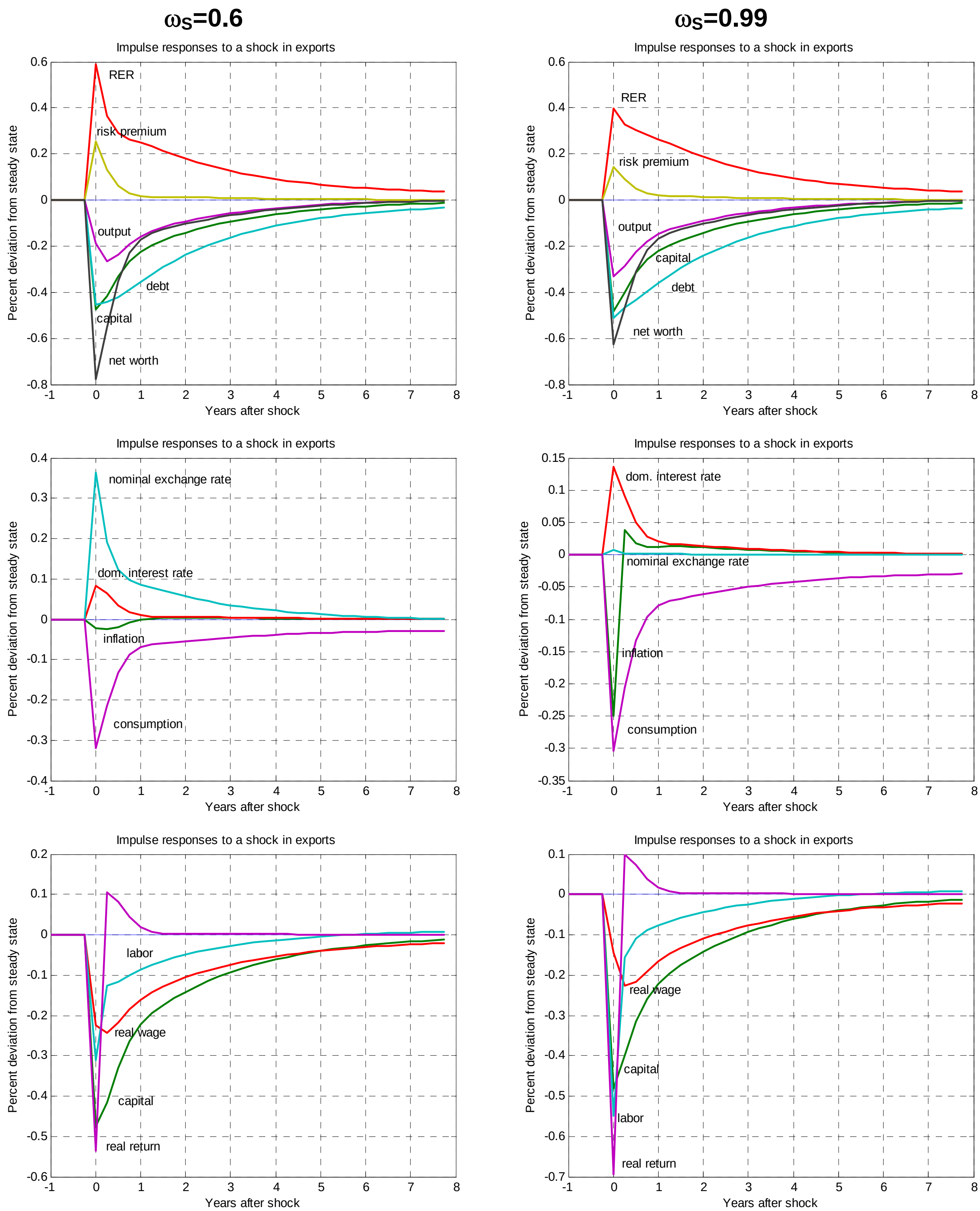

FIGURE 13

EFFECTS OF SHOCK ON EXPORT DEMAND IN THE ABSENCE OF BALANCE SHEET EFFECTS

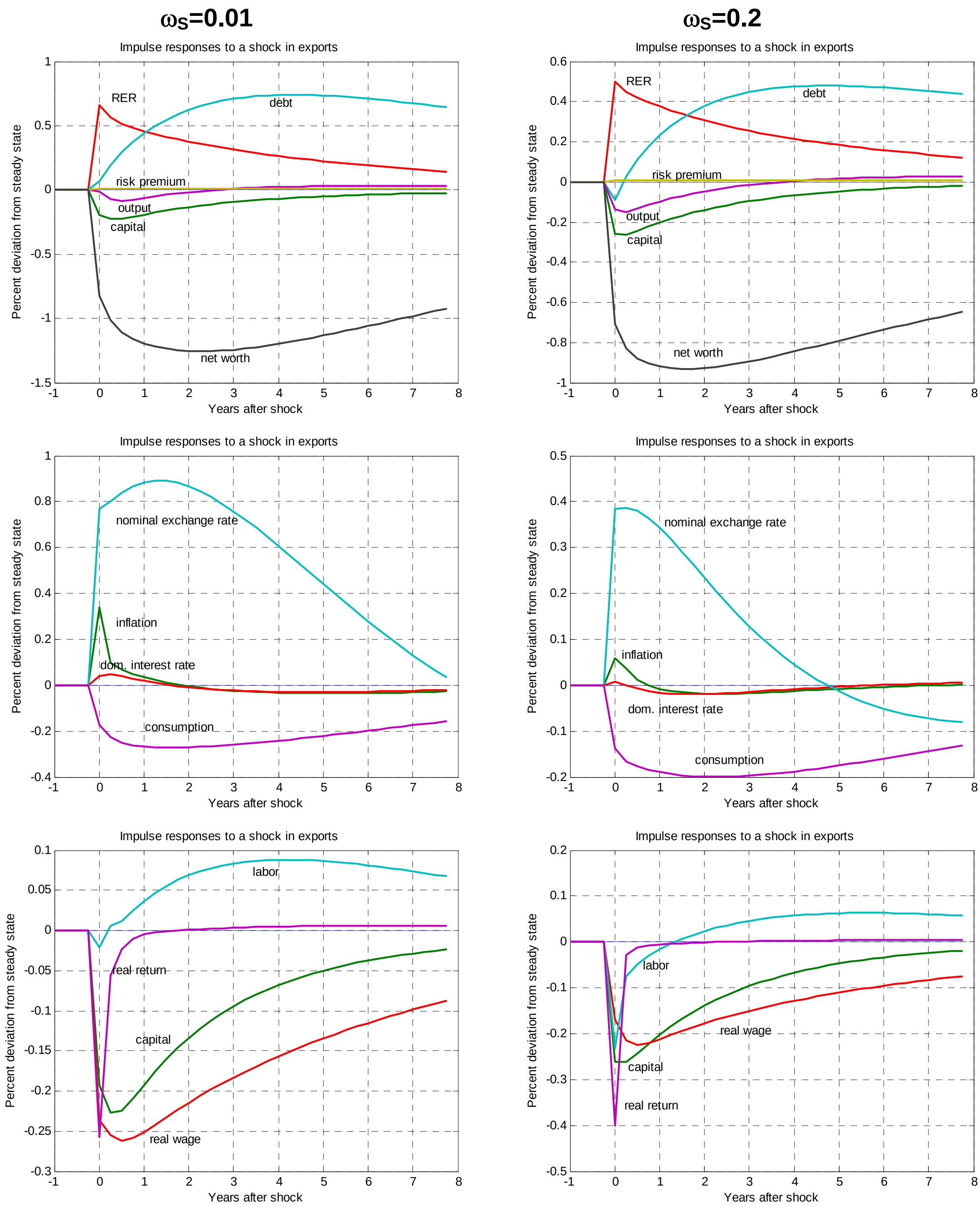

FIGURE 13
(Continued)
EFFECTS OF SHOCK ON EXPORT DEMAND IN THE ABSENCE OF BALANCE SHEET EFFECTS

ω_S=0.6 | ω_S=0.99

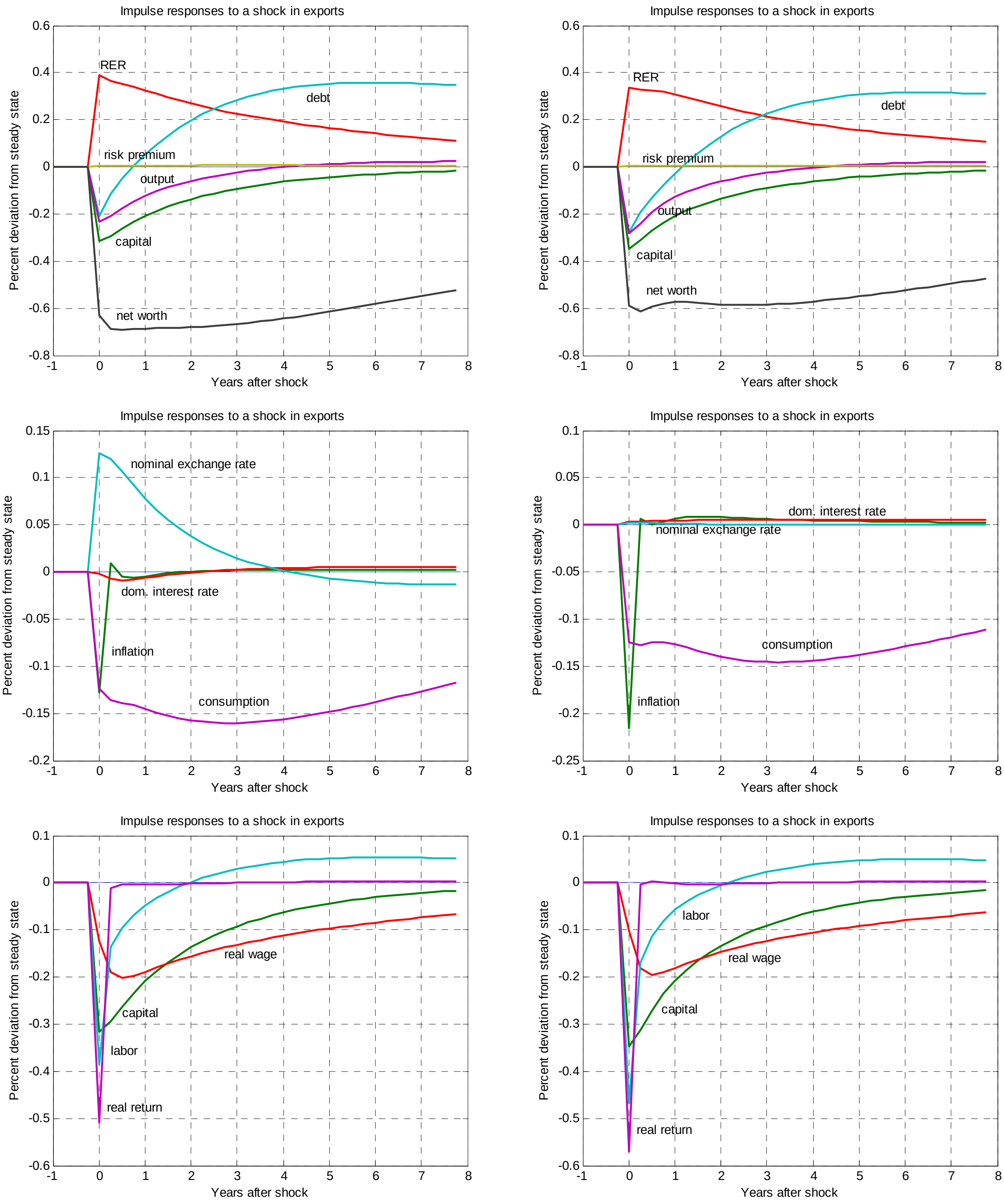

FIGURE 14

EFFECTS OF A SHOCK ON EXPORT DEMAND JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE PRESENCE OF BALANCE SHEET EFFECTS

ω_S=0.01 ω_S=0.2

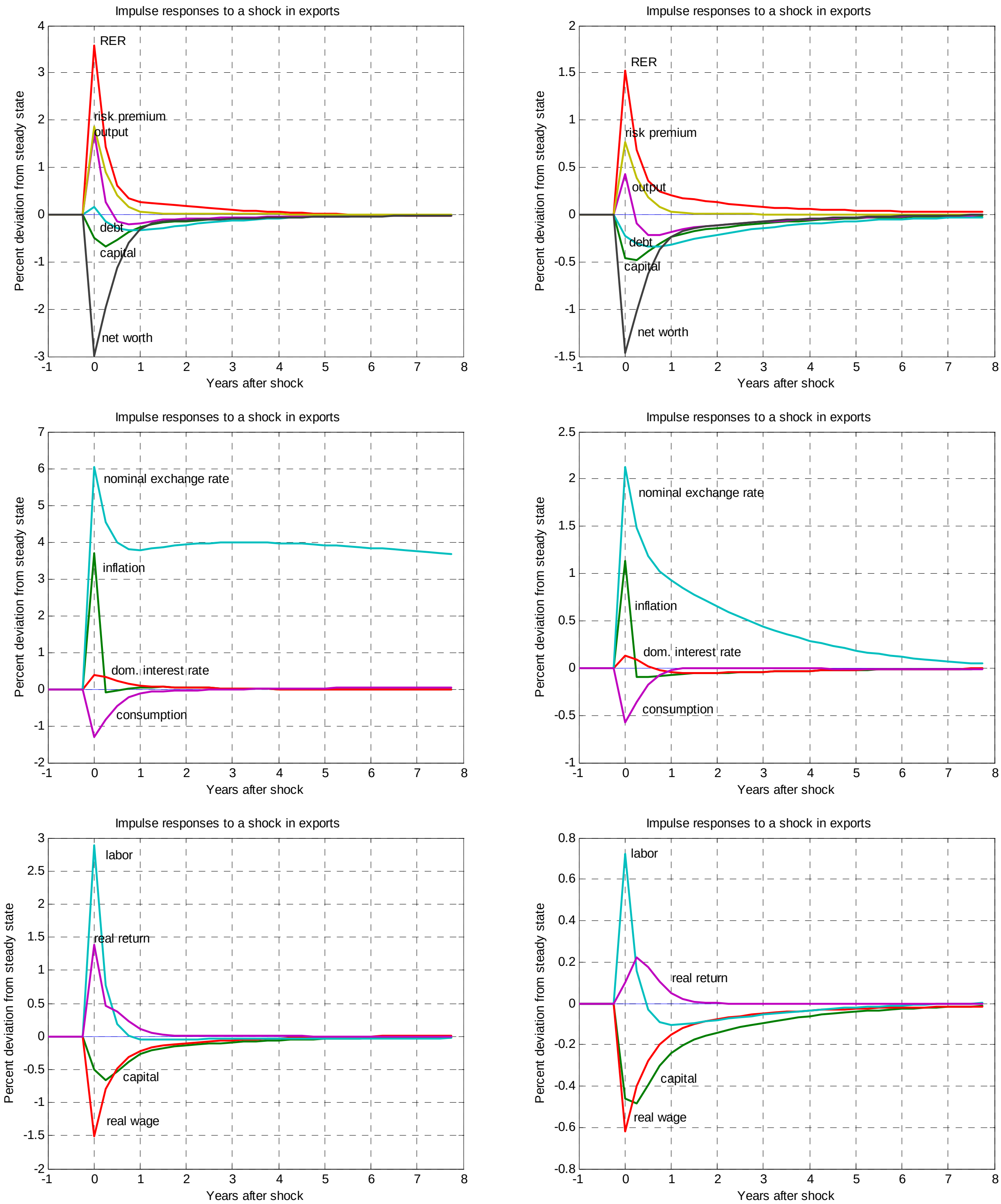

FIGURE 14
(Continued)
EFFECTS OF A SHOCK ON EXPORT DEMAND JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE PRESENCE OF BALANCE SHEET EFFECTS

ω_S=0.6 | **ω_S=0.99**

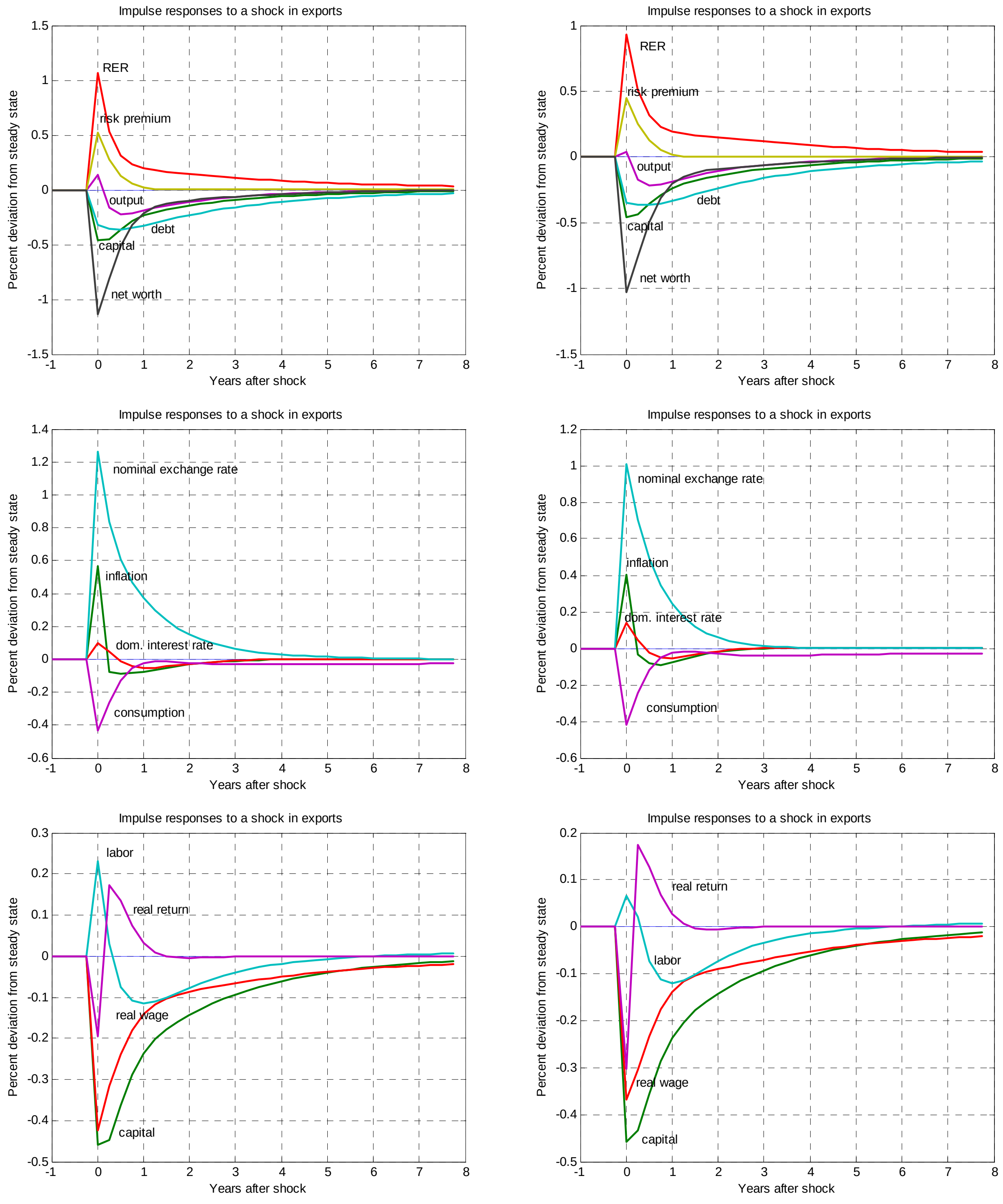

FIGURE 15

EFFECT OF A SHOCK ON EXPORT DEMAND JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE ABSENCE OF BALANCE SHEET EFFECTS

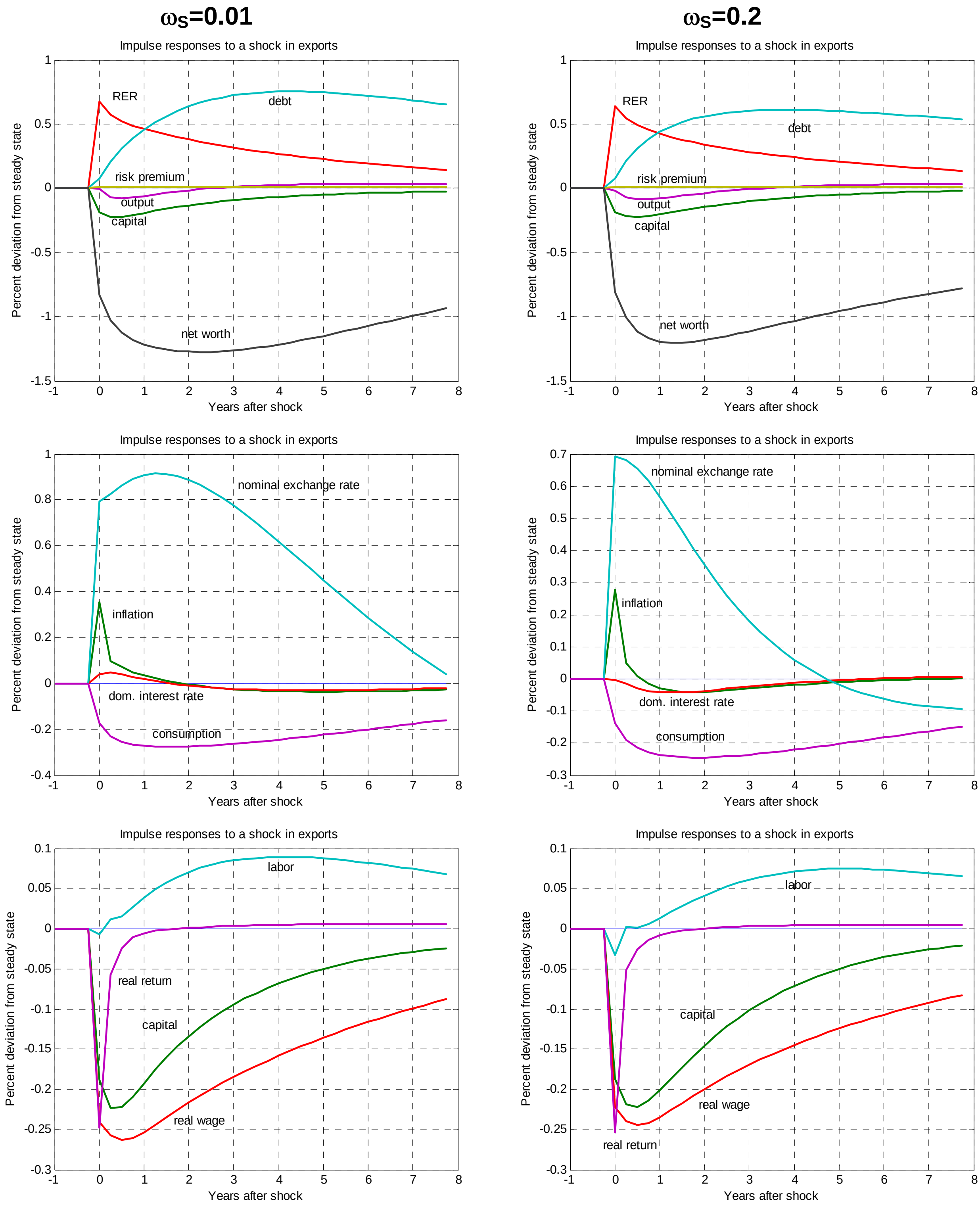

FIGURE 15

(Continued)

EFFECT OF A SHOCK ON EXPORT DEMAND JOINTLY WITH A DEVALUATIONARY POLICY SHOCK IN THE ABSENCE OF BALANCE SHEET EFFECTS