BANK FOR INTERNATIONAL SETTLEMENTS

# BIS Working Papers

No 215

# Devaluations, output and the balance sheet effect: a structural econometric analysis

by Camilo E Tovar

Monetary and Economic Department

September 2006

Copies of publications are available from:

Bank for International Settlements
Press & Communications
CH-4002 Basel, Switzerland

E-mail: publications@bis.org

Fax: +41 61 280 9100 and +41 61 280 8100

This publication is available on the BIS website (www.bis.org).



ISSN 1020-0959 (print)

ISSN 1682-7678 (online

# Contents

**Devaluations, output and the balance sheet effect:**
**a structural econometric analysis**
(by Camilo E Tovar)

# Devaluations, Output, and the Balance Sheet Effect: A Structural Econometric Analysis

Camilo E. Tovar*

Bank for International Settlements

First version May 2004 - This version February 2006

**Abstract**

This paper estimates a new open economy macroeconomic model for South Korea to determine the output effect of currency devaluations. Three transmission mechanisms are considered: the expenditure-switching, the balance sheet, and a monetary channel associated to a nominal exchange rate target. Devaluations are defined as an increase in this target. This allows to isolate the effects of an explicit exogenous devaluationary policy shock. Ceteris paribus, a devaluation is found to be expansionary. Output contractions in South Korea should then be associated with a different shock such as an adverse shock on the international interest rate or on export demand.

**JEL classification: F31, F41**

**Keywords**:Devaluations, balance sheet effect, financial accelerator, interest rate rule, exchange rate target, new open economy macroeconomics, structural estimation, DSGE.

---

*Tel.: +52 55 9138 0290; fax: +52 55 9138 0299. *E-mail address:* camilo.tovar@bis.org (C.E. Tovar). The views expressed are those of the author and do not necessarilly reflect those of the Bank for International Settlements.
This paper is a revised chapter of my dissertation at the Department of Economics of the University of Wisconsin - Madison. I wish to thank Charles Engel for his advise, comments and support. I acknowledge helpful discussions with Bruce Hansen, Ken West, Akito Matsumoto, Steven Durlauf, Claudio Borio, Dudley Cooke, Andrew Filardo, Gabriele Galati, Juan Pablo Medina, Igal Magendzo, Enrique Mendoza, Ramón Moreno, Marco del Negro, Juan F. Rubio-Ramirez, Claudio Soto, Marco Vega, Agustin Villar, Goetz Von Peter, and Feng Zhu. Finally, I thank seminar participants at LACEA 2004, Econometric Society World Congress 2005, the Bank for International Settlements, Bank of Mexico, Banco de la República, IMF's Research Department, CEMLA's research network, FRB of Atlanta, the World Central Bank Macroeconomic Modelling Network, and the South African Reserve Bank. All remaining errors are my own.

# 1. INTRODUCTION

What are the effects of a currency devaluation on output? This is an old and controversial question in macroeconomics. The devaluations and sharp output collapses observed in Asia in the late 1990s have brought the question back to the forefront of the debate among policy makers and academics. These sharp output contractions have questioned once again the relevance of the Mundell-Fleming framework and, in particular, the expenditure-switching effect.[1] According to this framework, a devaluation is expansionary because it increases the relative cost of foreign produced goods vis-à-vis domestically produced ones. This induces domestic agents to consume more of the latter and, hence, induces an output expansion.

More recently, contractionary devaluations have been rationalized by Krugman (1999). He argues that the deterioration of firms' balance sheets resulting from a currency devaluation was the main cause behind the sharp output collapse observed in Asia. His main point is that when firms' revenues are denominated in domestic currency while their debts are dollar-denominated, unexpected changes in the nominal exchange rate deteriorate firms' balance sheets and affect their capacity to borrow and invest. This adverse impact can be magnified if the cost of foreign borrowing increases. This mechanism, now called in the literature the "balance sheet" or "financial accelerator" effect, has been formalized in fully micro-founded open economy settings known as new open economy macroeconomic models - NOEM (see Cespedes, Chang and Velasco (2003, 2004); Gertler, Gilchrist, and Natalucci (2003); Cook (2004) and Tovar (2005)).

Despite important advances at the theoretical level, the debate on the output effects of devaluations and, in particular, the relevance of the different transmission channels involved has not been settled at an empirical level. Several empirical analyses have studied the issue and reached inconclusive results. Gupta, Mishra and Sahay (2003) and Tovar (2004) have shown that nearly half of the large devaluationary episodes in developing countries between 1970 and 2000 where expansionary in terms of output while the remaining half were contractionary. However, their econometric cross-section analyses fail to identify the factors behind this behavior. Magenzo (2002) employs more sophisticated econometric techniques and concludes that the link between the nominal exchange rate change and output completely disappears once selection bias is controlled for. This is possibly, he argues, because different transmission channels cancel each other out.

An important issue that arises in empirical studies is how to identify and isolate the effect of a devaluation from any other shock to the economy. Cook (2004) and Tovar (2005) are exceptions in a literature that is not designed to specifically answer these questions. Simulation exercises by Tovar (2005) show the im-

[1] There is an extensive literature written during the 1970s and 1980s. A good survey is Agénor and Montiel,1999. Here I focus on modern explanations for contractionary devaluations based on wealth effects, rather than on income effects as emphasized by the older literature.

portance of this. In his setting he considers three transmission mechanisms through which devaluations can affect output: the expenditure-switching, the balance sheet, and a monetary channel. He shows that for reasonable parameter values found in the literature, a pure devaluationary policy shock, understood as an exogenous increase in the nominal exchange rate target, is expansionary. Furthermore, these output expansions are larger as the exchange rate regime becomes less flexible. Certainly, most studies would find these results surprising given the general presumption that devaluations are contractionary when the balance sheet effect is present.

In this paper I determine empirically whether a currency devaluation is expansionary or contractionary in terms of output. For this purpose, the model developed by Tovar (2005) is estimated for the South Korean economy using maximum likelihood econometric methods. The aim is to make several contributions to the literature. First, I employ a new structural model to study empirically an old question in macroeconomics. Second, I estimate, for the first time in the literature, a dynamic stochastic general equilibrium model (DSGE) which incorporates the balance sheet or financial accelerator effect.[2] Therefore, I provide a consistent estimate of the parameters that determine the relevance of the balance sheet mechanism. Furthermore, these parameter estimates are likely to be useful for other studies that calibrate similar models in an open economy setting. Third, the impact of a pure and exogenous devaluationary policy shock is isolated from any other shock to the economy. Given that such shock is associated with an explicit exogenous policy decision, important policy implications are derived. Finally, it is an unresolved issue in the literature whether monetary policy should react to nominal exchange rate fluctuations. By incorporating a nominal exchange rate target in the specification of the interest rule, the paper also contributes to this debate.

Empirical results indicate that devaluations are expansionary despite the balance sheet effect. This is true even though the estimated parameter for the balance sheet effect is in the upper bound of what is considered reasonable in the literature. The expenditure-switching effect is found to be the dominating transmission channel. Many could think that this result contradicts the evidence, in particular, the output decline observed in South Korea. However, it is shown that the main features associated to the crises can be rationalized by the model if other shocks affect the economy, for instance, adverse international shocks such as an increase of international interest rates or a contraction for domestic exports. In particular, I show that output collapses can occur while observing an equilibrium increase in the exchange rate not associated to an explicit devaluationary policy shock. The empirical implication is that it would be misleading to conclude that devaluations, understood as an explicit exogenous policy decision, are contractionary from the simple observation of a negative cross-correlation between the exchange rate change and output growth. This framework allows me to conclude that the sharp output collapse ob-

[2] I became aware of two other studies that estimate DSGE models that incorporate the balance sheet effect after the first draft of this paper was written. Christensen and Dib (2004) estimate a closed econonomy DSGE model for the US. Elekdag, Justiniano and Tchakarov (2005) estimate a similar version of the model at hand using Bayesian methods.

served in South Korea was not due to the devaluation per se, but rather to other shocks that had an adverse impact.

The paper is organized as follows. The model is presented in Section 2. The econometric estimation framework is then discussed in Section 3. This is followed by a section presenting the data used for estimation and its sources. Econometric results and the analysis of impulse response functions and variance decompositions are discussed in Section 5. The paper ends with some concluding remarks.

## 2. A DSGE MODEL

The model employed expands the one used by Cespedes, Chang, and Velasco (2004 and 2003) by introducing several extensions aimed at making the model more realistic to fit the data. The model consists of four types of agents: firms, households, entrepreneurs, and a monetary authority. A continuum of monopolistically competitive firms 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. As a result of the monopolistic competition assumption, both firms and households operate setting prices and wages, respectively. This introduces the possibility of nominal rigidities, which take the form of price and wage adjustment costs.[3] Entrepreneurs, which introduce the balance sheet effect, rent capital to firms and borrow from abroad to finance new capital. The economy as a whole faces no trade barriers and capital flows are allowed. However, imperfections in international capital markets associated with informational asymmetries give rise to a risk premium that must be paid in addition to the international risk free interest rate to borrow money from abroad.

The economy is subject to six types of shocks. Firms face technology and cost-push or mark-up shocks and households face a preference shock that enters the Euler equation linking consumption with the real interest rate. In addition, there are shocks on export demand, the international risk free interest rate and the nominal exchange rate target. This last shock is key in the analysis as it is meant to capture a devaluation of the nominal exchange rate.

### 2.1 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

[3] In contrast with Cespedes, Chang, and Velasco (2004 and 2003), these rigidities are endogenously determined.

capital demands, given the demand function for its own goods, 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.[4] 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, $\psi_p$, and increases with the size of the price change and overall level of economic activity.[5] 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:[6]

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

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

The labor input captured by equation (3) is a C.E.S. aggregate of heterogenous labor services. Hence,

---

4 An alternative approach to model price rigidities is Calvo's (1983) staggered price setting. 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). Empirical papers such as Kim (2000), Bergin (2004 and 2003) and Ireland (2004 a,b and 2001) all use this quadratic adjustment approach.

5 Why are prices and not quantities the ones that incur in adjustment costs? The explanation is one of information costs. Price changes must be made known to consumers, but this need not be the case for quantities changes (see Kim, 2000).

6 The present formulation implies a dynamic profit maximization problem associated to the presence of price stickiness rather than the static profit maximization problem in Cespedes, Chang and Velasco (2004 and 2003).

$\sigma$ is the elasticity of demand for worker $i$'s services. In addition, firms face a demand for their products 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, $\theta_t$. Known also as a mark-up or cost-push shock, it follows a first-order autoregressive process:

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

where $0 < \zeta_\theta < 1$ and $\varepsilon_{\theta t} \sim N\left(0, \sigma_\theta^2\right)$ is serially uncorrelated. Its relevance is that it provides an additional source of output and inflation fluctuations different from that of a technology shock alone. Following Galí (2003) it can be rationalized as the consequence of a firm's periodic attempts to correct the misalignment between actual and desired mark-ups.[7]

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 with respect to capital and labor, respectively:

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

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

where the minimum cost of a unit of aggregate labor $L_{jt}$ and aggregate labor cost are given respectively by $W_{jt} = \left[ \int_0^1 W_{ijt}^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}$, $W_{jt} L_{jt} = \int_0^1 W_{ijt} L_{ijt} di$, and $e_{jt}^Y$ is the output demand elasticity augmented with adjustment costs. Formally,

$$e_{jt}^Y \equiv \theta_t \left[ \begin{array}{c} 1 - \psi_p \left( \frac{P_{jt}}{P_{jt-1}} - \bar{f}^p \right) \frac{P_t}{P_{jt-1}} \frac{Y_t}{Y_{jt}} \\ + \psi_p E_t \left[ \frac{\Delta_{t+1}}{\Delta_t} \left( \frac{P_{jt+1}}{P_{jt}} - \bar{f}^p \right) \frac{P_{jt+1}}{P_{jt}^2} \frac{P_{t+1}}{Y_{jt}} Y_t \right] \end{array} \right]^{-1} \tag{10}$$

Both equations (8) and (9) are the standard conditions equating the marginal cost of capital and labor to its marginal revenue after considering the mark-up wedge between them, i.e. $\frac{e_{jt}^Y}{e_{jt}^Y - 1}$.[8] They imply an

---

[7] Clarida, Galí and Gertler (1999) refer to cost-push shocks as anything other than 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-up of price over marginal cost. This is the interpretation followed here. He has found these shocks to be more relevant than technology ones in explaining output, inflation and interest rates.

[8] In the absence of adjustment costs, the elasticity of output demand equals the elasticity of substitution between different varieties of domestic output. In such a case, a 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.

optimal trade-off between capital and labor inputs that depend on the relative cost of each:

$$w_t L_{jt} = \left( \frac{1-\alpha}{\alpha} \right) r_t K_{jt} \tag{11}$$

### 2.2 Households' Problem

There is a continuum of heterogenous households indexed by $i \in [0,1]$, who supply labor in a monopolistically competitive manner. Preferences are additively separable over consumption, $C_{it}$ and labor supply, $L_{it}$, in each period and subject to a shock, $a_t$. Future utility is discounted at a rate of time preference $\beta$. Households derive income by selling labor at a nominal wage rate, $W_{it}$ and hold two types 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 its labor type, as captured by equation (16), 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 equation (17), which depends on the parameter $\psi_w$.[9] 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 introduces the possibility of wage rigidities.

The optimization problem faced by each household is expressed as follows:[10]

$$\underset{C_{it}, L_{it}, B_{it}, B^*_{it}}{Max} E_o \sum_{t=0}^{\infty} \beta^t a_t \left( lnC_{it} - \left( \frac{\sigma - 1}{\sigma} \right) \frac{1}{\nu} L^{\nu}_{it} \right) \tag{12}$$

s.t.

$$C_{it} = \kappa \left( C^H_{it} \right)^{\gamma} \left( C^F_{it} \right)^{1-\gamma} \tag{13}$$

$$P_t C^H_{it} + S_t C^F_{it} = Q_t C_{it} \tag{14}$$

$$B_{it} - B_{it-1} + S_t \left( B^*_{it} - B^*_{it-1} \right) = i_{t-1} B_{it-1} + S_t i^*_{t-1} B^*_{t-1} + W_{it} L_{it} - AC^w_t - Q_t C_{it} \tag{15}$$

$$W_{it} = \left( \frac{L_{it}}{L_t} \right)^{-\frac{1}{\sigma}} W_t \tag{16}$$

$$AC^w_t = \frac{\psi_w}{2} \left[ \frac{W_{it}}{W_{it-1}} - \bar{\Omega} \bar{\pi} \right]^2 W_t \tag{17}$$

where $\beta \in (0,1)$ is the inter-temporal discount factor, $\gamma \in [0,1]$ is the share of home produced goods in

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

10 The standard utility function used in the literature is adopted (see Obstfeld and Rogoff, 2000). Money does not appear in the utility function or the budget constraint and monetary policy is specified in terms of an interest rate rule. Following Galí and Monacelli (2002), it is possible to think of money as playing only the role of a unit of account.

total consumption, and $\bar{\Omega}$ and $\bar{\pi}$ are the steady-state real wage inflation and consumer's 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 $\nu > 1$, and $\frac{\sigma-1}{\sigma}$ determines the marginal disutility of labor.[11] The preference shock $a_t$ follows an autoregressive process:

$$\ln a_t = \zeta_a \ln a_{t-1} + \varepsilon_{at} \tag{18}$$

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

$$C_{it}^H = \left[\int_0^1 C_{jt}^{\frac{\theta_t - 1}{\theta_t}} dj\right]^{\frac{\theta_t}{\theta_t - 1}} \quad ; \quad P_t = \left[\int_0^1 p_{jt}^{1-\theta_t} dj\right]^{\frac{1}{1-\theta_t}} \tag{19}$$

where $\theta_t$ 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.[12] 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:[13]

$$\left(\frac{1-\gamma}{\gamma}\right)\frac{C_t^H}{C_t^F} = \frac{S_t}{P_t} \equiv e_t \tag{20}$$

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:

$$Q_t = P_t^{\gamma} S_t^{1-\gamma} \tag{21}$$

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 (CPI) 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 the 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 households' problem yields the standard inter-temporal Euler equations for consumption smoothing and an optimal wage-setting equation:

$$\frac{1}{C_{it}} = \beta(1+i_t) E_t\left(\frac{a_{t+1}}{a_t}\frac{1}{\pi_{t+1}C_{it+1}}\right) \tag{22}$$

11 $L$ should be thought of as efficiency 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).

12 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. Kollman (2001) assumes pricing to market to avoid the law of one price assumption. For simplicity, this is not pursued in this paper.

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

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

$$-\left(\frac{1-\sigma}{\sigma}\right) L_{it}^{\nu-1} = \frac{w_{it}}{C_{it}}\left(1-\frac{1}{e_{it}^L}\right) \tag{24}$$

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

$$e_{it}^L \equiv \sigma \left[\begin{array}{c} 1-\frac{\psi_w}{L_{it}}\frac{w_t}{w_{it-1}}\pi_t\left(\Omega_{it}\pi_t-\bar{\Omega}\bar{\pi}\right) \\ \\ +\beta\frac{\psi_w}{L_{it}}E_t\left[\frac{a_{t+1}}{a_t}\frac{C_{it}}{C_{it+1}}\frac{w_{it+1}}{w_{it}^2}w_{t+1}\pi_{t+1}\left(\Omega_{it+1}\pi_{t+1}-\bar{\Omega}\bar{\pi}\right)\right]\end{array}\right]^{-1} \tag{25}$$

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 bonds holdings is imposed.

### 2.3 Entrepreneurs' Problem

Entrepreneurs' behavior is modeled as in Cespedes, Chang and Velasco (2004 and 2003), 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.[14] For convenience, it is assumed that entrepreneurs' main activity is to decide how much to invest.[15] 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 (see Cespedes, Chang, and Velasco, 2004 and 2003; and Tovar 2005).

More specifically, assume that an entrepreneur is making the decision of how much to invest. This agent will then finance investment employing its own net worth and the remaining porting will be financed through debt. As a result the entrepreneurs' budget constraint is determined by:

$$P_tN_t + S_tD_{t+1} = Q_tK_{t+1} \tag{26}$$

where it is assumed full capital depreciation and that the price index for the cost of investment is the same as that for consumption as captured by equation (21).

---

14 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 to 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 Calstrom and Fuerst (1997).

15 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.

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:

$$1+\eta_t = \left(\frac{Q_t K_{t+1}}{P_t N_t}\right)^{\mu} \tag{27}$$

where $\mu$ 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:

$$\frac{E_t\left(R_{t+1}K_{t+1}/S_{t+1}\right)}{Q_t K_{t+1}/S_t} = \left(1+\rho_t\right)\left(1+\eta_t\right) \tag{28}$$

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

$$\ln \rho_t - \ln \overline{\rho} = \zeta_\rho \left(\ln \rho_{t-1} - \ln \overline{\rho}\right) + \varepsilon_{\rho t} \tag{29}$$

where $0<\zeta_\rho<1$ and $\varepsilon_{\rho t} \sim N\left(0,\sigma_\rho^2\right)$ is 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 this 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 as:

$$P_t N_t = R_t K_t + \Pi_t - S_t D_t = \left[1 - \frac{\psi_p}{2}\left(\frac{P_t}{P_{t-1}} - \bar{f}^p\right)^2\right] P_t Y_t - W_t L_t - S_t D_t \tag{30}$$

### 2.4 Monetary Policy

The central bank follows an interest rate rule that targets different macroeconomic variables. In open economies, setting the specification of such rules is more controversial than in closed economies, where most of the theoretical contributions have been made.[16] The reason for this is the wider set of variables to which monetary policy can react. The specification adopted here is such that the monetary policy responds to deviations of expected CPI inflation, output, and the nominal exchange rate from their long-

16 See Woodford (2003) and Clarida, Galí and Gertler (1999) for a discussion of interest rate rules in a closed economy setting. For an open economy overview, see Clarida, Galí, and Gertler (2001), Beningno (2004) and Benigno and Benigno (2000).

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

$$\frac{1+\tilde{\imath}_t}{1+\bar{\imath}} = \left(\frac{E_t\pi_{t+1}}{\bar{\pi}}\right)^{\omega_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\omega_y} \left(\frac{S_t}{\bar{S}_t}\right)^{\frac{\omega_s}{1-\omega_s}} \tag{31}$$

where $\bar{S}_t = \frac{\bar{S}\cdot\bar{\chi}}{\chi_t}$. $\omega_s \in [0,1)$, $\omega_\pi$, and $\omega_y$ are the weights on each of the target variables, and $\chi_t$ is a devaluationary policy shock.[17] Since central banks tend to smooth changes in interest rates, the actual interest rate is allowed to partially adjust to the target as follows:[18]

$$\frac{1+i_t}{1+\bar{\imath}} = \left(\frac{1+i_{t-1}}{1+\bar{\imath}}\right)^{\omega_i} \left(\frac{1+\tilde{\imath}_t}{1+\bar{\imath}}\right)^{1-\omega_i} \tag{32}$$

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, it is assumed that the central bank also targets the nominal exchange rate given the open economy nature of the model and that the model is estimated for South Korea, a country where the exchange rate level was an essential element of their export-led growth strategy. Therefore, monetary policy is tightened by increasing the nominal interest rate if the nominal exchange rate exceeds its long-run level. As mentioned, it is an unresolved matter whether monetary policy should react to exchange rate fluctuations. Taylor (2001) has argued that if monetary policy is determined by expected inflation, the central bank should not react to exchange rate fluctuations. However, in small open economies, particularly emerging markets, the exchange rate could be used to stabilize exchange rate disequilibriums (Calvo and Reinhart, 2002) or as a credibility device in economies with a poor history of inflation. In this context, it would make sense to set the nominal exchange rate equilibrium as a target as it is done here. Furthermore, targeting the nominal exchange rate can be also justified in the model because firms borrow in foreign currency (dollars) and external shocks may cause significant volatility of the exchange rate.

Given this rule, a devaluation is defined as an increase of the nominal exchange rate target, $\bar{S}_t$. Such policy induces a decrease in the interest rate. For this purpose, a shock $\chi_t$ on this variable is introduced (See Cho and West, 2003 for a similar approach). Its motivation is that during crisis episodes the focus of monetary policy is on stabilizing the exchange rate. Formally, $\chi_t$ follows a first-order autoregressive process:[19]

$$\ln\chi_t - \ln\bar{\chi} = \zeta_\chi\left(\ln\chi_{t-1} - \ln\bar{\chi}\right) + \varepsilon_{\chi t} \tag{33}$$

---

17 The coefficient $\omega_s$ is restricted to be less than 1, following the general perception, shared by the IMF, that an increasing exchange rate should induce the central bank to raise interest rates. This has been subject of controversy following the Asian crises. See Cho and West (2003) on the issue.

18 Clarida, Galí and Gertler (1998 and 2000) adopt this partial adjustment mechanism in their empirical analysis. Benigno (2004) shows that interest rate smoothing together with price rigidities can introduce additional inertia into the economy as this makes the real exchange rate more persistent.

19 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 $\varepsilon_{\chi t}$.

where $0 < \zeta_{\chi t} \leq 1$ and $\varepsilon_{\chi t} \sim N\left(0, \sigma_{\chi}^{2}\right)$ is serially uncorrelated. 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 involved in a crisis situation. Ultimately, the key 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 well known that interest rate rules are a commitment device. However, the shock on the exchange rate target introduces a discretionary behavior on the part of the monetary authority. It is possible to sustain within Calvo and Reinhart's (2002) "fear of floating" argument that central banks should maintain in practice a fixed exchange rate regime without losing their discretion to allow exchange rate fluctuations. The credibility mechanism here would be the announcement of a flexible exchange rate regime. This possibility would then be captured by the interest rate rule and a shock on the nominal exchange rate target as proposed here.

The specification of the interest rate rule allows us to approximate the systematic behavior of monetary policy for a continuum of exchange rate regimes depending on the weight $\omega_s$ (See Monacelli, 2004). Hence, for $\omega_s = 0$ the rule approximates a pure floating exchange rate regime while larger values of $\omega_s$ approximate a managed float regime.

### 2.5 Market-Clearing Condition

Provided that a proportion $\gamma$ 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:

$$P_t Y_t = \gamma Q_t \left(K_{t+1} + C_t\right) + \frac{\psi_p}{2}\left(f_t^p - \bar{f}^p\right)^2 P_t Y_t + S_t X_t \tag{34}$$

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

$$\ln X_t - \ln \overline{X} = \zeta_x \left(\ln X_{t-1} - \ln \overline{X}\right) + \varepsilon_{xt} \tag{35}$$

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

To close the model, firms' stochastic discount factor must be specified. In standard models, where firms are owned by households and 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 purposes of simplicity, it is assumed that entrepreneurs discount profits at a rate equivalent to that of the marginal utility of consumption, i.e. $\frac{\Delta_{t+1}}{\Delta_t} = \beta \left( \frac{a_{t+1}}{a_t} \frac{C_t}{C_{t+1}} \right)$.

## 3. ECONOMETRIC METHODOLOGY

The empirical properties of DSGE models are often analyzed using calibration methods. In contrast with this approach, the model discussed in the previous section is estimated using econometric methods. As discussed by Ruge-Murcia (2003), econometric estimation of a DSGE offer several advantages. First, the parameter estimates are obtained after imposing restrictions that are consistent with the model. Second, it is possible to obtain parameter estimates that may be difficult to obtain using disaggregate data. Third, parameter uncertainty can be incorporated in impulse response functions if confidence intervals are constructed.

Recently, there have been a number of studies that estimate DSGE models. However, most of them have been applied to closed economies (Ireland, 2004a, 2004b; Dib, 2001; Smets and Wouters, 2003, Ruge-Murcia, 2003; or Kim, 2000). Very few have been applied to small open economies (Ambler, Dib and Rebei, 2003; Bergin, 2003; and Lubik and Schorfheide, 2003).[20] In these studies the main focus has been on relatively developed (Australia and New Zealand) or industrialized economies (Canada, US and UK). Here, I help fill a gap in the literature by estimating a DSGE model for a "less" developed economy such as South Korea. Furthermore, the results will be helpful for understanding the role of interest rate rules in open economies and, in particular, that of the nominal exchange rate. Only Lubik and Shorfheide (2003) have estimated a model in which the monetary authority reacts in response to output, inflation, and exchange rate movements. They find that only in the case of Canada does the central bank respond to exchange rate movements.

The literature has proposed several methods to estimate DSGE models such as Maximum Likelihood, Generalized Method of Moments, or the Simulated Method of Moments, among others. All have their strengths and weaknesses (see Ruge-Murcia, 2003). In this paper the Maximum Likelihood method is employed. A key issue that arises with this methodology is the stochastic singularity problem. The issue is that DSGE models predict certain combinations of the endogenous variables to be deterministic. Therefore, if exact linear definitions established by the model do not hold in the data, then any attempt to estimate it will fail. Two approaches have been proposed to address this. One is to incorporate additional structural disturbances until the number of shocks equals the number of series employed in estimation. Here this would be captured by the six shocks built into the model (technology, mark-up, preferences, nominal exchange rate target, exports, risk free international interest rate). The second is to add measurement errors. These are a way to capture the movements and co-movements in the data that the model, because of its simplified structure, cannot explain. An advantage of this is that it can

[20] Bergin (2004) estimates a two country model of the US and an aggregate of the G-7.

exploit information on a larger set of variables to estimate the parameters of the model.[21] In the present framework, as in Ireland (2004a), both structural shocks and measurement errors are incorporated to deal with the stochastic singularity problem.

The estimation process consists of four steps. First, the linear rational expectations model is solved for the reduced form state equation in its predetermined variables.[22] Second, the model is written in state-space form, and measurement errors are incorporated in the observation equation. Third, the Kalman filter is used to construct the likelihood function. Finally, the parameters are estimated by maximizing the likelihood function. The specific details of the implementation of the econometric methodology are discussed in appendix A.

## 4. DATA

The model is fit for South Korea. This country is chosen because it is a well known case where the balance sheet effect is thought to be important. Furthermore, it is a country where there are no abrupt structural changes, as could be the case in Latin American countries, which could question or invalidate the analytical methods employed. Finally, sufficiently long enough quarterly time series is available for South Korea.

Some background on the exchange rate regime in South Korea is useful for the reader. In 1980, the Korean won was allowed to float against the US dollar. This was done by introducing a multiple basket pegged exchange rate system. This system was modified in March 1990, when a average exchange rate system was adopted. The new system was thus meant to allow a further degree of floating. In December 1997, the daily fluctuation band was abandoned and a floating exchange rate regime was put in place.

The eight series employed for estimation are inflation, output, labor, private consumption, devaluation of the nominal exchange rate, interest rate, and the nominal exchange rate. The last two variables were introduced as definitional variables in the observation equation to exploit the information contained in them. All data are seasonally adjusted quarterly series for the period 1982:3 to 2003:3. GDP, population, employment, and private consumption were obtained from Datastream, while the consumer price index, money market interest rate, and nominal exchange rate were obtained from the IMF's International Financial Statistics. Output and consumption are measured in per capita terms. All data was logged and then Hodrick-Prescott filtered.[23] Figure 1 displays the data employed for estimation.

---

21 Ruge-Murcia (2003) analyzes alternative methods to estimate a particular DSGE and finds that parameter estimates are more efficient when measurement errors are incorporated.

22 Details of how this stage is solved for are found in Tovar (2005).

23 This approach has been employed here for simplicity. It is common in the literature to detrend the data running a regression with linear trend. Possibly it would be better to incorporate the trend into the model by adding a labor-augmenting technology

## 5. EMPIRICAL RESULTS

Successful estimation requires the calibration of some parameters whose values are summarized in Table 1. Parameter values for preferences and technology are standard so no major comments are necessary. An exception is the elasticity of substitution between different varieties of goods, $\theta = 6$, which was chosen following Galí and Monacelli (2002) so that the steady-state mark-up equals 20 percent.

Table 2 reports the maximum likelihood estimates and the corresponding standard errors of seven key structural parameters of the model.[24] These parameters capture the degree of nominal rigidities ($\psi_p, \psi_w$), the balance sheet effect ($\mu$), and the parameters associated to the interest rate rule ($\omega_i$, $\omega_p, \omega_y, \omega_s$). Point estimates are reasonable and indicate that there is an important degree of nominal rigidities. Point estimates for $\psi_p$ indicate that a 2 percent increase on the inflation rate above its steady-state level implies a 0.1 percent price adjustment cost in terms of domestic output for firms.

The parameter for the balance sheet effect, i.e. the elasticity of the risk premium to the investment-net worth ratio, which captures the degree of international capital market imperfections, falls within the upper range of what is considered normal in the literature. According to Carlstrom and Fuerst (1997), this parameter should lie within a value range of 0.2 to 0.4. The estimated value of $\mu = 0.4$ indicates a significant balance sheet effect for South Korea. Elekdag, Justiniano, and Tchakarov (2005) employ a prior for this parameter ranging from 0.03 to 0.47, with a mean of 0.2. They find a median value of 0.06 for this parameter in South Korea. This is small; however, it would reinforce the overall results found here and discussed later in the paper regarding the effect of devaluations on output and the relevance of the balance sheet effect. Berganza, Chang, and Herrero (2003) provide other empirical estimates using cross-section reduced form analysis. Their estimates for the elasticity of the risk premium to a devaluation are high, ranging between 0.5 and 0.6.

The parameter estimate for $\omega_i$ is indicative of a smooth interest rate adjustment in South Korea. The estimated weight on the expected inflation satisfies the *Taylor principle*, which indicates that the optimal policy response to a rise in inflation is to increase interest rates sufficiently as to induce an increase of real interest rates. Therefore, $\omega_p$ should exceed unity. The value estimated for this parameter indicates that, ceteris paribus, a one percentage point increase in quarterly expected inflation induces a 160 basis point increase in the quarterly real interest rate. The point estimate for the weight on output, $\omega_y$, implies that holding everything else constant, an increase in output is compensated by the monetary authority with a 140 basis point increase in the quarterly nominal interest rate. This suggests that monetary policy has been counter-cyclical, however, the coefficient on output is statistically insignificant. Finally, recall

shock.

24 Standard errors correspond to the square roots of the diagonal elements of minus one times the inverted matrix of second derivatives of the maximized log-likelihood function. See Appendix A and Ireland (2004a).

that in Section 2.4 it was shown that a value $\omega_s = 0$ would capture a flexible exchange rate regime, while $\omega_s = 1$ would indicate that the exchange rate regime is completely fixed. The estimated value of $\omega_s = 0.79$ indicates a high degree of intervention by the central bank during the period of analysis, which is well known to be the case for the South Korean economy.

Point estimates for the persistence parameters of the shocks and their standard errors are reported in Table 3. Estimates indicate that technology, mark-up, and international interest rate shocks are very persistent, while export and preference shocks are less persistent. The devaluationary policy shock, in turn, appears to have moderate persistence. Therefore it suggests that the monetary authorities in Korea were not systematically pursuing a devaluationary policy. This conclusion is further supported by a high volatility of monetary policy innovations.

Additional parameter estimates related to the measurement error dynamics are reported in Tables 4 and 5. The persistence and cross-correlations among measurement errors for different variables reported in Table 4 indicate that some of the residuals $u_t$ are quite persistent. Results in Table 5 show that standard errors for measurement errors innovations, $\xi_t$, are in general smaller that those associated with the standard innovations of the structural shocks reported in Table 3, with a main exception, the preference shock.

### 5.1 Impulse Responses

The model's implications are now analyzed using the calibrated and estimated values for the structural parameters. Four exercises using impulse response functions are performed. First, the impulse response to a devaluationary policy shock provides the key piece of evidence to answer the main question of the paper, i.e., whether a devaluation of the nominal exchange rate, in isolation to any other shock, is expansionary or contractionary in terms of output. Next, the behavior of the model is analyzed when the economy is exposed to adverse external shocks. In particular, two shocks are considered: an increase in the international risk free interest rate and an adverse shock on export demand. The motivation is to determine whether the model can explain key empirical features of the Asian crises. Finally, I draw some policy implications. In particular, I ask whether the monetary authority should devalue the currency in response to adverse external shocks. An answer is provided by analyzing impulse responses to a devaluation when facing an adverse external shock.

#### *5.1.1 Devaluationary Policy Shock*

Impulse response functions to a one percent devaluation of the nominal exchange rate target are reported in Figure 2. This shock induces an overshooting of the nominal exchange rate and output expands in the two quarters that follow the shock. This output dynamics is indicative of a expenditure-switching effect that dominates the contractionary balance sheet mechanism. The fact that output expansion takes place simultaneously with a contraction of total investment and consumption is clear evidence of a strong expenditure-switching effect. Tovar (2005) has shown that it is the low degree of flexibility of the exchange rate regime that allows the monetary authority to exploit the expansionary impact of the expenditure-switching effect.

Impulse responses also show that the balance sheet mechanism is operating in a contractionary manner. The devaluationary policy causes net worth to fall and the risk premium rises. As a result, capital investment collapses during the year and a half that follows the devaluation (see upper left panel of Figure 2). Also notice that the interest response is very weak as a result of the endogeneity of the risk premium. In particular, the increase in the risk premium has a feedback effect that reverses the initial interest rate decline induced by the shock. Intuitively, what happens is that after the devaluation, the monetary authority faces a possible exchange rate overshooting, so it responds with an increase of the interest rate, thus compensating for the initial decline.

It is worth noting that output expansion is achieved at a cost of higher inflation and, because of wage rigidities, at the expense of deteriorating workers' income (see bottom right panel in Figure 2). This inflationary and distributional trade-off of a devaluation is a sensitive issue in emerging economies with important political implications that may deter the use of devaluations as a policy tool.

Two conclusions are possible at this point. First, a devaluation of the nominal exchange rate, in isolation from any other shock to the economy, is expansionary in terms of output. Second, the most important transmission mechanism for this result is the expenditure-switching effect. A corollary is that the balance sheet effect, despite its contractionary impact, has a secondary role in the transmission of devaluations to output. This is also true of the monetary channel, but in this case it is due to the endogeneity of the risk premium.

#### *5.1.2 Adverse External Shocks*

In Krugman (1999) and Calvo (1999), reversals of capital flows are the main cause behind the output collapse and real exchange rate depreciation observed in the Asian financial crises of the late 1990s. To capture the possibility of a sudden stop or reversal of capital flows within the model, consider two shocks: an increase in the international interest rate and a decrease in export demand. Analyzing the economy's response to these shocks and comparing them vis-à-vis the case of a devaluationary policy shock provides two interesting results. First, it illustrates how the model can explain key features observed in the South Korean economy during the Asian crises. Second, it highlights the relevance of distinguishing between an isolated policy shock aimed at achieving a currency devaluation and an equilibrium response of the exchange rate that follows when the economy is hit by a different shock.

**International Interest Rate** Impulse response functions to a one percent increase in the international risk free interest rate are reported in Figure 3. The shock induces upon impact an increase of the nominal exchange rate via the interest parity condition. This higher level of the nominal exchange rate translates into a higher aggregate inflation and domestic interest rate. The higher levels of expected returns on capital lead to a decline in capital investment, and the higher cost of external funds forces firms to finance capital with their own resources rather than relying on external debt (see bottom left panel in Figure 3). Consumption also falls as real interest rates rise. Despite the collapse in aggregate demand, output does not decline immediately (see top right panel in Figure 3). Therefore, this suggests an expenditure-switching effect that delays output contraction. Output only falls a quarter later.

Notice that the model describes key features observed during the Asian crises such as output and aggregate demand collapse as well as the exchange rate increase. Equally important, it demonstrates that it is not the devaluation of the currency that triggered the output collapse but rather a completely different shock. An important empirical implication is that it would be misleading to conclude from the observed negative correlation between the nominal exchange rate and output that devaluations are contractionary, as is frequently the case in the literature.

**Export Demand** The behavior of the model to a one percent adverse shock on export demand is reported in Figure 4. This shock induces an immediate decline in output. Ceteris paribus, this would cause domestic interest rates to decline. However, endogenous feedbacks associated with the interest rate rule and the interest parity condition force the nominal exchange rate to overshoot and the risk premium to rise. This in turn forces an increase in the domestic interest rate (see top left panel in Figure 4). Also notice that aggregate demand collapses in response to the hike in interest rates, which forces inflation to fall.

Again, the key feature is that a collapse in export demand reproduces the negative correlation between the exchange rate and output, as well as the collapse in aggregate demand experienced by South Korea during the Asian crises. As before, this implies that it is not a devaluationary shock that triggers the output collapse, indicating that it would be misleading to conclude that devaluations are contractionary.

#### *5.1.3 Adverse External Shocks and Devaluationary Policies*

The framework is rich enough to ask whether it is desirable for the monetary authorities to devalue its currency in response to an adverse external shock. Below, I consider the case in which a monetary authority decides to devalue the nominal exchange rate when faced by an adverse external shock.

**International Interest Rate and Devaluations** Impulse responses to a one percent devaluationary shock together with a one percent increase in the international interest rate are displayed in Figure 5. The most relevant feature here is that the nominal exchange rate overshoots the levels observed in Figure 3. This is mainly the consequence of the devaluationary policy. Aggregate demand collapses immediately after the shock, while output increases initially and then declines with a lag. This initial output expansion together with the aggregate demand contraction is indicative of a strong expenditure-switching effect induced by the devaluation of the nominal exchange rate. The simple comparison of output behavior between Figures 3 and 5 (top right panel) indicates that monetary authorities can play a stabilizing role in terms of output if they devalue the currency at the time of the shock. In other words, in the short run, a policy that induces a currency devaluation can mitigate the contractionary effects of a sudden stop. However, important trade-offs arise in the form of inflationary pressures or the decline in workers' income, not to mention other competitiveness implications (e.g. beggar-thy-neighbor effects) that this policy might have.

The short-lived effects of a currency devaluation induce short-lived contractionary balance sheet effects. The bottom left panel in Figure 5 shows that it is only immediately after the shock that the risk premium rises and net worth falls. This behavior is reversed after two quarters as the external debt falls and, to a lesser extent, as the exchange rate returns to its steady state. However, the slow adjustment of the exchange rate perpetuates for some quarters the benefits of the expenditure-switching effect.

**Export Demand and Devaluations** The economy's behavior following a one percent devaluationary shock together with a one percent decline in export demand are shown in Figure 6. As before, the key result here is that output collapse induced by an adverse export demand shock can be partially reversed in the short run with a devaluation of the nominal exchange rate, i.e. monetary authorities can effectively implement counter-cyclical policies.

A difference between export demand and international interest rate shocks is that in the former the contractionary balance sheet effect is stronger in the sense that the risk premium increase and the net worth collapse are more persistent.

### 5.2 Variance Decompositions

To assess the explanatory power of the model, variance decompositions of k-step-ahead forecast errors are employed. This allows us to determine the percentage of the variation in each of the endogenous variables explained by the model. In particular, it is of interest how much output variation is explained by a devaluationary policy shock. Notice also that the robustness of the results can be assessed in the context of the model by attaching standard errors to the forecast error variance estimates as calculated in Runkle (1987).

The contributions of different shocks (six structural shocks and the measurement error shocks, $\xi_t$) to the forecast error variance of observable endogenous variables at various k-step ahead horizons are reported in Tables 6 and 7.[25] First, focus on the variance decomposition for aggregate output. Estimates indicate that structural shocks account for a non-negligible 50 percent of the one-quarter-ahead forecast error variance for aggregate output (see Table 6). Of this portion, three quarters of the variance is explained by the mark-up shock. The technology shock follows in order of importance, but its contribution is very low and at odds with standard real business cycle models. Galí (1999 and 2003) argues that in models with imperfect competition and sticky prices, a favorable technology shock is likely to induce a decline in employment. This is precisely the behavior (not shown) obtained in the present framework for the estimated parameters. Therefore the estimates support Galí's view, as well as results found by Smets and Wouters (2003) in an estimated DSGE model for the Euro area, that technology shocks are not the main source of aggregate fluctuations. Also, the devaluationary policy shock accounts for a non-negligible 3.4 percent of output's unconditional one-quarter-ahead forecast-error variance.

The statistical uncertainty associated with these estimates for output is similar to those in the literature. Even if the true fraction of output variation explained by the model is two standard deviations less than the point estimate of 50 percent, the model would be able to account for 38 percent of the one-quarter-ahead forecast error variance, and 26 percent of the four-quarters-ahead forecast error. Ireland's (2004a) estimates for the US economy are able to explain 60 percent of output's one-quarter-ahead forecast error with a standard error of 10 percent, and the four-quarters-ahead forecast error estimate indicates that the model explains 35 percent of output variation with a standard error of 7 percent.

It is important to note that reported forecast-error variance decompositions include the combined effects of the five measurement error shocks captured by $\xi_t$. The impact of measurement errors are far from negligible, and for longer forecast horizons they rapidly absorb all the variance in the forecast errors. Their significance is not surprising given that they capture the effects of all other shocks that have been omitted from the model (e.g. fiscal policy shocks).

The forecast-error variance decomposition for the nominal exchange rate shows that the devaluationary policy shock is the single most important variable explaining the behavior of the nominal exchange rate at all forecast horizons. This shock accounts for three fourths of the one-quarter-ahead forecast error variance, and its relevance declines monotonically from there on but remains very high after four years. Technology shocks appear to play an important role at short horizons, but their relevance disappears over time. The mark-up and the international interest rate shocks show an opposite pattern, with a contribution that increases with longer forecast horizons.

---

[25] The contribution of each component of the measurement error residuals is aggregated into a single component.

The model does a much better job in explaining other variables in the model over short-run horizons, such as inflation, employment, the real interest rate, or consumption. Roughly 90 percent of the one-quarter-ahead forecast error variance of these variables is explained by the model. The mark-up shock appears to be the most relevant shock in the model. For one-quarter and four-quarters-ahead forecast horizons, this shock accounts for 80 percent of inflation and labor variance. Results for inflation are consistent with results reported by Ireland (2004b) and Smets and Wouters (2003). Variance decompositions indicate that neither consumers' preference nor export demand are relevant. This is a major drawback, in particular in accounting for output and consumption variance, given that these shocks are the main shifting variables for the corresponding IS curve in the present framework (see Tovar, 2005). Ireland (2004b) and Smet and Wouters (2003) report a more significant role for preference shocks. However, neither of these studies incorporate measurement errors. This could reflect that in these author's estimates the preference shock operates as a measurement error. A good example of this is Bergin (2004), who reports variance decompositions for his model applied to Australian data where preference shocks account for less than one percent at all horizons in all of his endogenous variables, with the exception of the current account, where they account for over 80 percent. The author argues that this reflects the inability of his model to explain current account dynamics. This implies that in his setting the lack of measurement errors is forcing the preference shock to explain the current account.

Overall, variance decompositions suggest a better performance of the model in explaining output fluctuations over short rather than over longer horizons that exceed two years. Although the model's performance is not exceptional, it is reasonable for short-run horizons. It was also shown that a devaluationary policy shock plays a non-negligible role in explaining output and consumption dynamics.

## 6. CONCLUSIONS

This paper developed and estimated a model using data from South Korea to answer an old question in macroeconomics: whether currency devaluations are expansionary or contractionary in terms of output. The framework employed had two main purposes: first, to develop a structural model that would allow to study the effects of an explicit devaluationary policy shock in isolation from any other shock to the economy; second, to study the relative importance of the different mechanisms through which devaluations affect output. For this purpose, the model incorporated three transmission channels: the traditional expenditure-switching effect, the balance sheet effect, and a monetary channel associated with the fact that monetary authorities follow an interest rate rule that targets the nominal exchange rate.

In answering these questions the paper makes several contributions to the literature. First, impulse response functions analyses of the model allow us to conclude that in the absence of any other shock to the economy, a devaluation is expansionary in terms of output. A key implication of this result is that the balance sheet mechanism plays a secondary role in the transmission of a devaluation to output. Or, to put it differently, the dominating transmission mechanism in the model is the expenditure-switching effect. The monetary channel has limited effects due to endogenous feedbacks between the nominal exchange rate and the risk premium. Second, the parameters associated with the balance sheet mechanism are estimated. The relevance of this is twofold. On the one hand, parameter estimates that fall in the upper range of what the literature considers reasonable indicate that in South Korea the balance sheet effect was operating with significant strength. Despite this, the contractionary balance sheet effect was unable to dominate the expansionary expenditure-switching effect. This result coincides with recent microeconomic level studies that find a missing balance sheet effect (see Luengnaruemitchai, 2003). On the other hand, these parameter estimates will be useful for future calibration studies.

I showed that the model is able to capture key patterns observed in South Korea during the financial crisis of the late 1990s. I also showed the importance of distinguishing among the effects of different sources of shocks before reaching any conclusion regarding the contractionary or expansionary effects of a devaluation. In this regard, I argued that it would be misleading to conclude that devaluations are contractionary simply by observing a negative correlation between the nominal exchange rate and output. Impulse response exercises showed that a negative correlation among these variables could occur if the economy is hit by an adverse international shock that triggers capital outflows but not from an explicitly devaluationary policy shock.

Some policy lessons are also drawn from the analysis. A devaluation in response to an adverse external shock can stabilize output in the short run. A devaluation allows economies to take advantage of the expenditure-switching effect. However, the output gains associated with this policy involve inflationary and income distribution trade-offs, not to mention other beggar-thy-neighbor effects. The inflationary trade-off is a sensitive issue in emerging economies and should be carefully considered if there is a history of high inflation. Also, the income distribution trade-off, as captured by a deterioration of workers' income, indicates that devaluationary policies can be politically very difficult to implement and sustain.

There are aspects of the model which could improve the fit of the model to the data. It would be useful to incorporate additional mechanisms through which a currency devaluation can operate, for instance, fiscal policy. In addition, alternative assumptions should be considered on some key features of the model, the most important of which is possiblymodifying the assumption of perfect pass-through of exchange rates to inflation. Finally, some additional extensions would be interesting, such as incorporating a mechanism that could endogenously determine a switch in the exchange rate regime when the economy is hit by a shock.

Some readers might find the results regarding the balance sheet as evidence to disregard the third generation crises models. However, this would be an misinterpretation of the results. I have shown that the balance sheet is effectively operating in a contractionary manner, hence the mechanism is operating in the “right” direction. The issue is that it is not strong enough to overturn the expenditure-switching mechanism. If we really think that the balance sheet mechanism induces contractionary devaluations, that might be because the balance sheet effect is operating through other sectors of the economy and not only through an investment channel, for instance, through the banking sector as highlighted by Choi and Cook (2004). However, pursuing this is left for future research.

## References


Agénor, Pierre, and Peter Montiel. (1999). *Development macroeconomics*. 2nd edition. Princeton University Press. Princeton, New Jersey.

Ambler, Steve, Ali Dib, and Nooman Rebei. (2003). Nominal rigidities and exchange rate pass-through in a structural model of a small open economy. Working Paper 2003-29. Bank of Canada.

Benigno, Gianluca. (2004). Real exchange rate persistence and monetary policy rules. Journal of Monetary Economics. Vol. 51. pp. 473-502.

Benigno, Gianluca, and PierpaoloBenigno. (2000). Monetary Policy Rules and the exchange rate. CEPR Discussion Papers No. 208.

Berganza, Juan Carlos, Chang Roberto, and Alicia Herrero. (2003). Balance sheet effects and the country risk premium: an empirical investigation. DT 0316. Banco de España.

Bergin, Paul. (2004). How well can the New Open Economy Macroeconomics explain the exchange rate and current account?. NBER Working Paper No. 10356.

Bergin, Paul. (2003). Putting the “New Open Economy Macroeconomics” to a test. Journal of International Economics. Vol. 60. Issue 1. May.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist. (1999). The financial accelerator in a quantitative business cycle framework, in Taylor J.E. and Woodford M. (Eds.), Handbook of Macroeconomics. Vol. 1C. North-Holland. Amsterdam.

Blanchard, Olivier, and Charles Khan. (1980). The solution to linear difference models under rational expectations. Econometrica. Vol. 48. Issue 5, July. pp1305-1312.

Calvo, Guillermo. (1999). Capital flows and capital market crises: the simple economics of sudden stops. Journal of Applied Economics. Vol. 1, No.1. pp. 35-54.

Calvo, Guillermo, (1983). "Staggered prices in a utility-maximizing framework". Journal of Monetary Economics. Vol 12. pp 383-398.

Calvo, Guillermo, and Carmen Reinhart. (2002). Fear of floating. Quarterly Journal of Economics. Volume 177 Issue 2. pp.379-408.

Carlstrom, Charles, and Thimothy Fuerst. (1997). Agency costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. The American Economic Review, Vol. 87, Issue 5. December. pp. 893-910.

Cespedes, Luis Felipe, Roberto Chang, and AndrésVelasco. (2004). Balance Sheets and exchange rate policy. American Economic Review. Vol. 94 No. 4. pp. 1183-1193.

Cespedes, Luis Felipe, Roberto Chang, and AndrésVelasco. (2003). IS-LM-BP in the Pampas. IMF Staff Papers, Vol. 50. pp. 143-156.

Cho, Dongchul, and Kenneth West. (2003). Interest rates and exchange rates in the Korean, Philippine and Thai exchange rate crises. In Dooley M. and Frankel J. (Eds.) *Managing currency crises in emerging markets*. NBER. Chicago University Press.

Choi, Woon, and David Cook. (2004). Liability dollarization and the bank balance sheet channel. Forthcoming Journal of International Economics.

Christensen, I , and Ali Dib. (2004). Monetary policy in an estimated DSGE model with financial accelerator. Mimeo Bank of Canada. September.

Clarida, Richard, Jordi Galí, and Mark Gertler. (2001). Optimal monetary policy in open versus closed economies: an integrated approach. The American Economic Review, Papers and Proceedings Vol. 91 No. 2. May. pp. 248-252.

Clarida, Richard, Jordi Galí, and Mark Gertler. (2000). Monetary policy rules and macroeconomic stability: evidence and some theory. Quarterly Journal of Economics. Vol. 105. February. pp. 147 -180.

Clarida, Richard, Jordi Galí, and Mark Gertler. (1999). The science of monetary policy: A new Keynesian perspective. Journal of Economic Literature. Vol. XXXVII. December. pp. 1661-1707.

Clarida, Richard, Jordi Galí, and Mark Gertler. (1998). Monetary policy rule in practice: some international evidence. European Economic Review. Vol. 42. pp. 1033 -1067.

Cook, David. (2004). Monetary policy in emerging markets: can liability dollarization explain contractionary devaluations?. Journal of Monetary Economics. Vol. 51. pp. 1155-1181.

Dib, Ali. (2001). An estimated Canadian DSGE model with nominal and real rigidities. Canadian Journal of Economics, Vol. 36. No. 4. pp. 949-972.

Elekdag, Selim, Alejandro Justiniano, and Ivan Tchakarov. (2005). An estimated small open economy model of the financial accelerator. IMF Working Paper WP/05/44. March.

Galí, Jordi. (2003). New perspectives on Monetary policy, Inflation and the Business Cycle, in: Dewatripont, M., Hansen,L., Turnovsky S. (Eds.) Advances in Economic Theory, vol. III, 151-197, Cambridge University Press.

Galí, Jordi. (1999). Technology, employment and the business cycle: do technology shocks explain aggregate fluctuations. The American Economic Review. Vol. 89. No.1. March. pp 249-271.

Galí, Jordi, and Tommaso Monacelli. (2002). Monetary policy and exchange rate volatility in a small open economy. NBER Working Paper No. 8905.

Gertler, Mark, Simon Gilchrist, and Fabio Natalucci. (2003). “External constraints on monetary policy and the financial accelerator”. BIS Working Papers No. 139.

Gupta, Poonam, Deepak Mishra, and Ratna Sahay. (2003). “Output Response to Currency Crises”. IMF Working Papers 03/230, International Monetary Fund.

Hamilton, James. (1994a). *Time series analysis*. Princeton University Press. Princeton.

Hamilton, James. (1994b). State Space Models, in Engle R.F., McFadden D.L. (Eds.) *Handbook of Econometrics*. Volume IV. Elsevier Science.

Ireland, Peter. (2004a). A method for taking models to the data. Journal of Economic Dynamics and Control. Vol. 28, Issue 6, March. pp. 1205 - 1226.

Ireland, Peter. (2004b). Technology shocks in the new keynesian model. The Review of Economics and Statistics. Vol. 86. No.4. November.pp 923-936.

Ireland, Peter. (2001). Sticky-price models of the business cycle: specification and stability. Journal of Monetary Economics. Vol. 47 No. 1. pp 3-18.

Kim, Jinill. (2000). Constructing and estimating a realistic optimizing model of monetary policy. Journal of Monetary Economics. Vol 45. pp 329-359.

Kollman, Robert. (2001). “The exchange rate in a dynamic-optimizing business cycle model with nominal rigidities: a quantitative investigation”. Journal of International Economics. Vol. 55. pp.243-262.

Krugman, Paul. (1999). Balance sheets, the transfer problem, and financial crises, in Isard P., Razin A., Rose A. (Eds.) International Finance and Financial Crises: Essays in Honor of Robert Flood. Kluwer Academic Publishers-IMF.

Lubik, Thomas, and Frank Schorfheide. (2003). Do central banks respond to exchange rate movements? A structural investigation. Available at: http://www.econ.upenn.edu/~schorf/papers/soe.pdf

Luengnaruemitchai, Pipat. (2003). The Asian crises and the mystery of the missing balance sheet effect. Job Market Paper. University of California - Berkeley.

Magenzo, Igal. (2002). “Are devaluations really contractionary?”. Central Bank of Chile, Working Papers No.182. September.

McCallum, Bennet. (2001). Should monetary policy respond strongly with output gaps?. The American Economic Review. Papers and Proceedings. May. pp. 258-262.

Monacelli, Tommaso. (2004). Into the Mussa Puzzle: Monetary policy regimes and the real exchange rate in a small open economy. Journal of International Economics. Vol. 62 Issue 1, pp. 191-217. January.

Obstfeld, Maurice and Kenneth Rogoff. (2000). “New directions for stochastic open economy models”. Journal of International Economics, Vol. 50, pp. 117-153.

Obstfeld, Maurice and Kenneth Rogoff. (1996). *Foundations of international macroeconomics*. MIT Press. Cambridge.

Rotemberg, Julio. (1982). Sticky prices in the United States. Journal of Political Economy. Vol. 90. pp. 1187-1211.

Ruge-Murcia, Francisco. (2003). Methods to estimate dynamic stochastic general equilibrium models. Département de sciences économiques and C.I.R.E.Q., Université de Montréal. September. Available at: http://www.cirequationumontreal.ca/online/frm-Methods2-03-09-24.pdf.

Runkle, David. (1987). Vector autoregressions and reality. Journal of Business and Economic Statistics 5. pp. 437-442.

Sims, Christpher. (2001). Solving linear rational expectations models. Computational Economics. Vol. 20. pp. 1-20.

Smets, Frank and Ralph Wouters. (2003). "An estimated stochastic dynamic general equilibrium model for the Euro Area", Journal of the European Economic Association, vol. 1. pp. 1123-1175.

Taylor, John. (2001). The role of the exchange rate in monetary-policy rules. The American economic review. Papers and proceedings. May. pp. 263-267.

Tovar, Camilo. (2005). "The mechanics of devaluations and the output response in a DSGE model: how relevant is the balance sheet effect". BIS Working Papers No. 192. Bank for International Settlements. November.

Tovar, Camilo. (2004). Three essays in international finance: devaluations and output behavior. Department of Economics. University of Wisconsin - Madison.

Uhlig, Harald. (1997). A toolkit for analyzing nonlinear dynamic stochastic models easily. Available at: http://www.wiwi.hu-berlin.de/wpol/html/toolkit/toolkit.pdf.

Woodford, Michael. (2003). *Interest and prices: foundations of a theory of monetary policy*. Princeton University Press.

## A Appendix: Solving the model

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.[26] The estimation of the model starts by representing the model in state-space form. For this purpose, the system is log-linearized around the non-stochastic symmetric steady state and solved with the method of undetermined coefficients described by Uhlig (1997). For estimation purposes, two definitional equations were added: $\hat{\imath}_t = \hat{\imath}_t$ and $\hat{s}_t = \hat{\varrho}_t$.[27] With this in mind, let $\tilde{x} = \left[\hat{k}\; \hat{e}\; \hat{w}\; \hat{d}\; dB^*\; \hat{\imath}\; \hat{s}\right]'$ be the endogenous state vector, $\tilde{y} = \left[\hat{\pi}\; \hat{y}\; \hat{l}\; \hat{r}\; \hat{c}\; \hat{f}^s\; \hat{\imath}\; \hat{\varrho}\right]'$ the vector of endogenous variables, and $\tilde{z} = \left[\hat{\rho}\; \hat{x}\; \hat{A}\; \hat{\theta}\; \hat{\chi}\; \hat{a}\right]'$the vector of exogenous stochastic processes, so that the system is written as:

$$0 = \Gamma_A \tilde{x}_t + \Gamma_B \tilde{x}_{t-1} + \Gamma_C \tilde{y}_t + \Gamma_D \tilde{z}_t \tag{36}$$

$$0 = E_t[\Gamma_F \tilde{x}_{t+1} + \Gamma_G \tilde{x}_t + \Gamma_H \tilde{x}_{t-1} + \Gamma_J \tilde{y}_{t+1} + \Gamma_K \tilde{y}_t + \Gamma_L \tilde{z}_{t+1} + \Gamma_M \tilde{z}_t] \tag{37}$$

$$\tilde{z}_{t+1} = \Gamma_N \tilde{z}_t + \tilde{\varepsilon}_{t+1} \tag{38}$$

$$E_t\left[\tilde{\varepsilon}_{t+1}\right] = 0 \tag{39}$$

where $\Gamma_C$ is of size $(8 \times 8)$, and of rank $8$, $\Gamma_F$ is of size $(7 \times 8)$, and $\Gamma_N$ has only stable eigenvalues. 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:

$$\tilde{x}_t = \Gamma_P \tilde{x}_{t-1} + \Gamma_Q \tilde{z}_t \tag{40}$$

$$\tilde{y}_t = \Gamma_X \tilde{x}_t = \Gamma_R \tilde{x}_{t-1} + \Gamma_S \tilde{z}_t \tag{41}$$

where equation (40) is the state equation and equation (41) is the observation equation. Formally, the idea is to obtain matrices $\Gamma_P, \Gamma_Q, \Gamma_R$, and $\Gamma_S$ so that the equilibrium is stable.[28] Also notice that these

[26] The symmetric equilibrium, existence of the steady state, and the log-linearize system are discussed in Tovar (2004).

[27] This allows us to extract information about the nominal exchange rate and the interest rate in the estimation process.

[28] 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 employs Sims' (2001) QZ decomposition, which is numerically more stable.

matrices are nonlinear functions of the model's structural parameters.

### A1 Adding Measurement Errors

The state-space model can be augmented with error terms by adding serially correlated residuals to the observation equation. Although this is usually done to deal with the stochastic singularity problem, its motivation here is to improve the model's fit to the data. Formally, the state-space model is transformed so that the observation equation (41) is now replaced by:

$$\tilde{y}_t = \Gamma_X \tilde{x}_t + u_t \tag{42}$$

where $u_t = Du_{t-1} + \xi_t$ is an $(8 \times 1)$ vector of shocks of measurement errors that are allowed to follow a first-order vector autoregression, with a serially uncorrelated innovation $\xi_t \sim N(0, V)$ and $V = E\left(\xi_t \xi_t^{'}\right)$. It is further assumed that the measurement error contains no information about current or future shocks to the economy, that is $E(\tilde{z}_t \xi_t) = 0$. Notice that since the observation equation (42) contains some identities, the variables $\hat{f}^s$, $\hat{\imath}$, and $\hat{\varrho}$ have no measurement errors attached to them. More precisely, define $u_t = [u_{\pi t}\ u_{yt}\ u_{lt}\ u_{rt}\ u_{ct}\ 0\ 0\ 0]'$ and $\xi_t = \left[\xi_{\pi t}\ \xi_{yt}\ \xi_{lt}\ \xi_{rt}\ \xi_{ct}\ 0\ 0\ 0\right]' = \left[\xi_t^{*\prime}\ 0_{1\times 3}\right]'$with matrices $D$ and $V$ as follows:

$$D = \begin{bmatrix} d & 0_{5\times 3} \\ 0_{3\times 5} & 0_{3\times 3} \end{bmatrix} \text{ where } d = \begin{bmatrix} d_{\pi\pi} & d_{\pi y} & d_{\pi l} & d_{\pi r} & d_{\pi c} \\ d_{y\pi} & d_{yy} & d_{yl} & d_{yr} & d_{yc} \\ d_{l\pi} & d_{ly} & d_{ll} & d_{lr} & d_{lc} \\ d_{r\pi} & d_{ry} & d_{rl} & d_{rr} & d_{rc} \\ d_{c\pi} & d_{cy} & d_{cl} & d_{cr} & d_{cc} \end{bmatrix} \tag{43}$$

$$V = \begin{bmatrix} V^* & 0_{5\times 3} \\ 0_{3\times 5} & 0_{3\times 3} \end{bmatrix} \text{ where } V^* = E\left(\xi_t^* \xi_t^{*\prime}\right) = \begin{bmatrix} v_\pi^2 & v_{\pi y} & v_{\pi l} & v_{\pi r} & v_{\pi c} \\ v_{\pi y} & v_y^2 & v_{yl} & v_{yr} & v_{yc} \\ v_{\pi l} & v_{yl} & v_l^2 & v_{lr} & v_{lc} \\ v_{\pi r} & v_{yr} & v_{lr} & v_r^2 & v_{rc} \\ v_{\pi c} & v_{yc} & v_{lc} & v_{rc} & v_c^2 \end{bmatrix} \tag{44}$$

The structural parameters are constrained to satisfy the theoretical restrictions discussed in Section 2.

In addition, the eigenvalues of matrix $D$ are constrained to lie inside the unit circle. As a result, the residuals in $u_t$ must be stationary. Finally, the covariance matrix $V$ is constrained to be positive definite. This is done calculating a Choleski decomposition $V = \tilde{V}\tilde{V}'$ where $\tilde{V}$ is a lower triangular matrix.

Let $\tilde{S}_t = [\tilde{x}_t' \; \tilde{z}_t']'$ so that equations (40) and (38) are summarized by a single equation $\tilde{S}_t = \Gamma_\Pi \tilde{S}_{t-1} + \Gamma_W \tilde{e}_t$ where $\tilde{e}_t = \begin{bmatrix} 0_{7\times1} \\ \tilde{\varepsilon}_t \end{bmatrix}$, $\Gamma_\Pi = \begin{bmatrix} \Gamma_P & \Gamma_Q \\ 0_{6\times7} & \Gamma_N \end{bmatrix}$ and $\Gamma_W = \begin{bmatrix} 0_{7\times7} & 0_{7\times6} \\ 0_{6\times7} & I_{6\times6} \end{bmatrix}$.

Now define $\tilde{h}_t = \left[\tilde{S}_t' \; u_t'\right]'$ a $(21 \times 1)$ vector to track the model's unobserved state variables. This allows us to re-write the model in compact state-space form as:

$$\tilde{h}_t = \Gamma_V \tilde{h}_{t-1} + v_t \tag{45}$$

$$\tilde{y}_t = \Gamma_Z \tilde{h}_t \tag{46}$$

where $\Gamma_V = \begin{bmatrix} \Gamma_\Pi & 0_{13\times8} \\ 0_{8\times13} & D \end{bmatrix}$, $v_t = \begin{bmatrix} \Gamma\tilde{e}_t \\ \xi_t \end{bmatrix}$ and $\Gamma_Z = [\Gamma_X \; 0_{8\times6} \; I_{8\times8}]$. The serially uncorrelated innovation vector, $v_t$, has variance-covariance matrix equal to:

$$E\left(v_t v_t'\right) = Q = \begin{bmatrix} \Gamma_W \Omega \Gamma_W' & 0_{13\times8} \\ 0_{8\times13} & V \end{bmatrix} \tag{47}$$

where $\Omega = E\left(\tilde{e}_t \tilde{e}_t'\right) = \begin{bmatrix} 0_{7\times7} & 0_{7\times6} \\ 0_{6\times7} & \Lambda \end{bmatrix}$ and $\Lambda = E\left[\varepsilon_t \varepsilon_t'\right]$ is the $(6 \times 6)$ diagonal variance-covariance matrix for the shock's innovations.

### A2 Kalman Filter and Maximum Likelihood Function

With the model in state-space form as captured by equations (45) and (46), it is possible to construct the likelihood function using the Kalman filter. For this purpose, first collect the structural parameters in the $(31 \times 1)$ vector:

$$\Theta = \begin{bmatrix} \alpha \; \gamma \; \beta \; \psi_p \; \psi_w \; \sigma \; \mu \; \nu \; \eta \; \omega_i \; \omega_\pi \; \omega_y \; \omega_s \; A \; \theta \; a \; \chi \; \rho \; x \\ \zeta_A \; \zeta_\theta \; \zeta_a \; \zeta_\chi \; \zeta_\rho \; \zeta_x \; \sigma_A \; \sigma_\theta \; \sigma_a \; \sigma_\chi \; \sigma_\rho \; \sigma_x \end{bmatrix}' \tag{48}$$

Observe that in addition to the structural parameters, the maximum likelihood function incorporates 25 elements of the matrix $D$ that governs the persistence of the measurement errors and 15 elements of the variance-covariance matrix $V$ associated to the measurement error residuals. Furthermore, assume as in Ireland (2004a) and Ruge-Murcia (2003) that the state vector is unobserved, and let the observed data obtained through date $t-1$ be summarized by the vector $\aleph_{t-1} \equiv \left(\tilde{y}'_{t-1},\ \tilde{y}'_{t-2}, ..., \tilde{y}'_1\right)'$.

Now define $\hat{h}_{t|t-1} = E\left(\tilde{h}_t|\aleph_{t-1}\right)$ as the best estimate of the unobservable state vector $\tilde{h}_t$ for period $t$ based on past observations of $\tilde{y}_t$, and let $\Sigma_{t|t-1} = E\left\{\left(\tilde{h}_t - \hat{h}_{t|t-1}\right)\left(\tilde{h}_t - \hat{h}_{t|t-1}\right)'\right\}$be the associated forecast error covariance matrix. Finally, let the best forecast of $\tilde{y}_t$ based on past observations be $\hat{y}_{t|t-1} = E\left(\tilde{y}_t|\aleph_{t-1}\right)$. Therefore, observe that these results and equation (46) imply that $\hat{y}_{t|t-1} = \Gamma_Z \hat{h}_{t|t-1}$.

The Kalman filter is an algorithm for calculating the sequence $\left\{\hat{h}_{t|t-1}\right\}_{t=1}^{T}$ and $\left\{\Sigma_{t|t-1}\right\}_{t=1}^{T}$, where $T$ is the sample size. Following Hamilton (1994a and 1994b), these sequences are calculated as : $\hat{h}_{t+1|t} = \Gamma_V \hat{h}_{t|t-1} + \tilde{K}_t\left(\tilde{y}_t - \Gamma_Z \hat{h}_t\right)$ and $\Sigma_{t+1|t} = \Gamma_V \Sigma_{t|t-1}\Gamma'_V - \tilde{K}_t \Gamma_Z \Sigma_{t|t-1}\Gamma'_V + Q$ where $\tilde{K}_t \equiv \Gamma_V \Sigma'_{t|t-1}\Gamma'_Z\left(\Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right)$ is the "Kalman gain" or "gain matrix". To start the recursion, the values are initialized with the unconditional mean and variance of $\tilde{h}_1$, i.e.$\hat{h}_{1|0} = 0$ and $\Sigma_{1|0} = E\left\{\left(\tilde{h}_1 - \hat{h}_{1|0}\right)\left(\tilde{h}_1 - \hat{h}_{1|0}\right)'\right\}$ where $\Sigma_{1|0}$ is calculated using $vec\left(\Sigma_{1|0}\right) = \left[I_{21^2 \times 21^2} - \Gamma_V \otimes \Gamma_V\right]^{-1} \cdot vecQ$ assuming that the expression in brackets is non-singular.

Now, let the innovations of the model be normally distributed. It follows then that the density of $\tilde{y}_t$ conditional on $\aleph_{t-1}$ is $f\left(\tilde{y}_t|\aleph_{t-1}, \Theta\right) = N\left(\Gamma_Z \hat{h}_{t|t-1}, \Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right)$. Therefore, the Maximum Likelihood estimator of $\Theta$ is $\hat{\Theta}_{ml} = \underset{\{\Theta\}}{\text{Max}}\, L\left(\Theta\right)$ where $L\left(\Theta\right)$ denotes the log likelihood function:

$$L\left(\Theta\right) = -\frac{Tn}{2}\ln\left(2\pi\right) - \frac{1}{2}\sum_{t=1}^{T}\ln\left|\Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right| - \frac{1}{2}\sum_{t=1}^{T}\left(\tilde{y}_t - \Gamma_Z \hat{h}_t\right)'\left(\Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right)^{-1}\left(\tilde{y}_t - \Gamma_Z \hat{h}_t\right) \quad (49)$$

and $n = 8$, i.e. the number of observed variables in $\tilde{y}_t$.

Now it is possible to evaluate the likelihood function for any given set of parameters. Therefore, a search algorithm can be used to find the parameter values that maximizes it. To implement the procedure, the model's structural parameters are transformed so that they can take any value on the real line. To ensure the numerical search always satisfies the theoretical restrictions imposed on the parameters, the likelihood function is re-parameterized. As suggested by Hamilton (1994, Ch. 5), a vector $\lambda$ for which $\Theta = \text{g}(\lambda)$, where the function g:$R^a \rightarrow R^a$ incorporates the desired restrictions. Therefore, given the data and initial value for the transformed vector of parameters $\lambda$, it is possible to set $\Theta = \text{g}(\lambda)$ and calculate $L\left(\Theta\right)$. Once the value of $\hat{\lambda}$ that maximizes the likelihood function is found, it is possible to obtain $\hat{\Theta} = \text{g}\left(\hat{\lambda}\right)$. For estimation purposes, the following transformations are used. For parameter values $\lambda_i$, the original parameters are recovered as follows[29]. For $\theta_i \in (0, 1)$ then $\theta_i = \frac{\lambda_i^2}{1+\lambda_i^2}$; For parameter values

[29] With some abuse of notation, in this appendix $\theta_i$ represents an element of $\Theta$. Therefore, $\theta$ should not be confused with the

such that $\theta_i \geq 0$ then $\theta_i = |\lambda_i|$ and for $\theta_i > 1$ then $\theta_i = 1 + |\lambda_i|$ .

To calculate the standard errors, I rely on the fact that for a large sample size, the distribution of the maximum likelihood estimate $\hat{\Theta}$ can be well approximated by $\hat{\Theta} \approx N\left(\Theta_o, T^{-1}\vartheta^{-1}\right)$ where $\Theta_o$ denotes the true parameter vector and $\vartheta$ is the information matrix. The information matrix is estimated using the second-derivative of the information matrix $\hat{\vartheta} = -T^{-1} \left.\frac{\partial^2 L(\Theta)}{\partial\Theta\partial\Theta'}\right|_{\Theta=\hat{\Theta}}$. With these results it is possible to approximate the variance-covariance matrix of $\hat{\Theta}$ by $E\left(\hat{\Theta} - \Theta_o\right)\left(\hat{\Theta} - \Theta_o\right) \cong \left[- \left.\frac{\partial^2 L(\Theta)}{\partial\Theta\partial\Theta'}\right|_{\Theta=\hat{\Theta}}\right]^{-1}$ where the term inside the brackets is calculated numerically as $\hat{D}_T = \left(\frac{1}{T}\right)\sum_{t=1}^{T} \left.\frac{\partial^2 \log f(\tilde{y}_t|\aleph_{t-1},\Theta)}{\partial\Theta\partial\Theta'}\right|_{\Theta=\hat{\Theta}}$ .see Hamilton (1994, Ch. 14).

Standard errors for $\hat{\Theta}$ cannot be calculated directly using the re-parameterization discussed above. To obtain them, the likelihood function is first parameterized in terms of $\lambda$ to find the MLE, and then the MLE is re-parameterized in terms of $\Theta$ to calculate the matrix of second derivatives evaluated at $\hat{\Theta}$. Finally, to calculate the standard errors, it is necessary to evaluate numerically the matrix of second derivatives of the log-likelihood function and then invert that full matrix. These two steps can introduce significant approximation errors into the statistics, so it is important to interpret these statistics with caution.

model's mark-up parameter.

Table 1: **Benchmark parameter values for estimation**

| Preferences | | Technology | |
|---|---|---|---|
| - Discount factor | $\beta = 0.99$ | | |
| - Elasticity of labor supply | $\nu = 2$ | -Capital share | $\alpha = 0.4$ |
| - Consumption share of home goods | $\gamma = 0.65$ | -Elast. of labor demand | $\sigma = 2$ |
| - Elast. of substitution b/w different varieties | $\theta = 6$ | | |

Table 2: **Main structural parameter estimates**

| Parameters | | Estimates | Standard Errors |
|---|---|---|---|
| - Degree of price rigidity | $\psi_p$ | $5.69540$ | $0.69672$ |
| - Degree of wage rigidity | $\psi_w$ | $1.35920$ | $0.32488$ |
| - International capital market imperfections | $\mu$ | $0.40796$ | $0.04356$ |
| Interest rate response to: | | | |
| - Lagged interest rate | $\omega_i$ | $0.74992$ | $0.03066$ |
| - Expected inflation | $\omega_p$ | $2.60610$ | $0.58025$ |
| - Output | $\omega_y$ | $1.40660$ | $0.96648$ |
| - Nominal exchange rate | $\omega_s$ | $0.79997$ | $0.05510$ |

Table 3: **Structural shocks' persistence and standard deviation estimates**

| | Persistence | Estimates | Stand. Errors | Stand. Dev. | Estimates | Stand. Errors |
|---|---|---|---|---|---|---|
| - Technology | $\zeta_A$ | $0.75731$ | $0.21200$ | $\sigma_A$ | $0.18344$ | $0.02143$ |
| - Mark-up | $\zeta_\theta$ | $0.95164$ | $0.00058$ | $\sigma_\theta$ | $0.28992$ | $0.02289$ |
| - Preferences | $\zeta_a$ | $0.19833$ | $2.79140$ | $\sigma_a$ | $0.03564$ | $0.36334$ |
| - Devaluationary policy | $\zeta_\chi$ | $0.70724$ | $0.07222$ | $\sigma_\chi$ | $0.22594$ | $0.02642$ |
| - Intern. risk free interest rate | $\zeta_\rho$ | $0.97727$ | $0.01084$ | $\sigma_\rho$ | $0.19539$ | $0.01996$ |
| - Exports | $\zeta_x$ | $0.67179$ | $0.09137$ | $\sigma_x$ | $0.11976$ | $0.02018$ |

Table 4: **Structural shocks' persistence and standard deviation estimates**

| | Estimates | Stand. Errors | | Estimates | Stand. Errors | | Estimates | Stand. Errors |
|---|---|---|---|---|---|---|---|---|
| $d_{\pi\pi}$ | $-0.45032$ | $0.27128$ | $d_{yc}$ | $-1.19340$ | $0.33730$ | $d_{rr}$ | $-2.53960$ | $0.47408$ |
| $d_{\pi y}$ | $-0.08308$ | $0.45714$ | $d_{l\pi}$ | $2.22130$ | $1.56100$ | $d_{rc}$ | $1.74410$ | $0.53392$ |
| $d_{\pi l}$ | $1.16410$ | $0.19991$ | $d_{ly}$ | $-0.16508$ | $1.10630$ | $d_{c\pi}$ | $-0.32944$ | $0.52576$ |
| $d_{\pi r}$ | $1.62170$ | $0.10208$ | $d_{ll}$ | $1.15960$ | $0.75864$ | $d_{cy}$ | $0.16810$ | $0.36421$ |
| $d_{\pi c}$ | $-1.16190$ | $0.33235$ | $d_{lr}$ | $3.31880$ | $0.39500$ | $d_{cl}$ | $0.23261$ | $0.50553$ |
| $d_{y\pi}$ | $3.21800$ | $1.62140$ | $d_{lc}$ | $-1.80150$ | $0.30935$ | $d_{cr}$ | $0.81599$ | $0.47265$ |
| $d_{yy}$ | $-0.20090$ | $1.58340$ | $d_{r\pi}$ | $0.45866$ | $0.92773$ | $d_{cc}$ | $0.03989$ | $0.28112$ |
| $d_{yl}$ | $-0.60675$ | $0.88232$ | $d_{ry}$ | $-0.60586$ | $0.74194$ | | | |
| $d_{yr}$ | $2.57230$ | $0.50659$ | $d_{rl}$ | $-1.10540$ | $0.55559$ | | | |

Table 5: **Structural shocks' persistence and standard deviation estimates**

| | Estimate | Stand. Errors | | Estimate | Stand. Errors | | Estimate | Standard Error |
|---|---|---|---|---|---|---|---|---|
| $v_\pi^2$ | $0.04755$ | $0.00714$ | $v_l^2$ | $0.14226$ | $0.02455$ | $v_{\pi c}$ | $-0.00006$ | $0.00149$ |
| $v_{\pi y}$ | $0.00046$ | $0.00153$ | $v_{\pi r}$ | $-0.00123$ | $0.00056$ | $v_{yc}$ | $-0.00068$ | $0.00077$ |
| $v_y^2$ | $0.15236$ | $0.00861$ | $v_{yr}$ | $0.00635$ | $0.00170$ | $v_{lc}$ | $0.00126$ | $0.00131$ |
| $v_{\pi l}$ | $-0.00134$ | $0.00116$ | $v_{lr}$ | $-0.00360$ | $0.00248$ | $v_{rc}$ | $0.00040$ | $0.00186$ |
| $v_{yl}$ | $-0.01457$ | $0.00396$ | $v_r^2$ | $0.07827$ | $0.01244$ | $v_c^2$ | $0.05042$ | $0.00830$ |

Table 6: **Forecast-error variance decomposition**

| | Technology | | Mark-up | | Preference | | Devaluation | | Intl. Interest | | Export | | Meas. Error | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coef. | s.e. | coef. | s.e | coef. | s.e | coef. | s.e. | coef. | s.e. | coef. | s.e | coef. | s.e |
| | | | | | | | Output | | | | | | | |
| 1 | 8.03 | 1.510 | 37.45 | 7.418 | 0.05 | 0.057 | 3.40 | 0.636 | 0.00 | 0.009 | 0.15 | 0.017 | 50.93 | 6.597 |
| 4 | 3.80 | 1.086 | 17.80 | 4.370 | 0.01 | 0.008 | 0.36 | 0.078 | 0.27 | 0.065 | 0.02 | 0.003 | 77.75 | 3.844 |
| 8 | 0.02 | 0.006 | 0.13 | 0.032 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 99.85 | 0.026 |
| 16 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 100.00 | 0.000 |
| | | | | | | | Inflation | | | | | | | |
| 1 | 2.59 | 0.438 | 81.84 | 3.448 | 0.12 | 0.123 | 4.16 | 0.676 | 0.23 | 0.141 | 0.56 | 0.154 | 10.51 | 1.300 |
| 4 | 1.17 | 0.284 | 77.72 | 2.456 | 0.03 | 0.027 | 1.00 | 0.177 | 0.05 | 0.057 | 0.12 | 0.029 | 19.91 | 0.941 |
| 8 | 0.02 | 0.012 | 6.23 | 0.824 | 0.00 | 0.001 | 0.02 | 0.004 | 0.02 | 0.088 | 0.00 | 0.000 | 93.71 | 0.869 |
| 16 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 100.00 | 0.000 |
| | | | | | | | Labor | | | | | | | |
| 1 | 2.71 | 0.471 | 80.60 | 4.187 | 0.12 | 0.123 | 2.75 | 0.449 | 0.08 | 0.083 | 0.09 | 0.014 | 13.66 | 2.731 |
| 4 | 1.23 | 0.313 | 65.55 | 4.896 | 0.02 | 0.027 | 0.61 | 0.076 | 0.02 | 0.036 | 0.03 | 0.004 | 32.55 | 4.269 |
| 8 | 0.02 | 0.009 | 3.48 | 0.251 | 0.00 | 0.000 | 0.01 | 0.002 | 0.01 | 0.004 | 0.00 | 0.000 | 96.49 | 0.203 |
| 16 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 100.00 | 0.000 |
| | | | | | | | Real Interest Rate | | | | | | | |
| 1 | 25.33 | 3.012 | 63.51 | 4.757 | 0.11 | 0.109 | 0.74 | 0.084 | 0.00 | 0.003 | 1.78 | 0.366 | 8.53 | 1.049 |
| 4 | 7.73 | 1.397 | 71.70 | 4.064 | 0.03 | 0.030 | 0.84 | 0.134 | 0.37 | 0.185 | 0.22 | 0.052 | 19.12 | 4.269 |
| 8 | 0.15 | 0.071 | 7.62 | 1.121 | 0.00 | 0.001 | 0.02 | 0.007 | 0.02 | 0.005 | 0.00 | 0.000 | 92.19 | 0.203 |
| 16 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 100.00 | 0.000 |

Table 7: **Forecast-error variance decomposition (continued)**

| | Technology | | Mark-up | | Preferences | | Devaluations | | Intl. Interest | | Exports | | Meas. Error | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coef. | s.e. | coef. | s.e | coef. | s.e | coef. | s.e. | coef. | s.e. | coef. | s.e | coef. | s.e |
| | | | | | | | Consumption | | | | | | | |
| 1 | 38.50 | 6.668 | 26.95 | 2.435 | 0.00 | 0.003 | 3.09 | 0.381 | 16.13 | 2.187 | 1.98 | 0.346 | 13.35 | 1.654 |
| 4 | 13.12 | 4.190 | 6.43 | 0.412 | 0.00 | 0.001 | 0.78 | 0.135 | 3.79 | 0.979 | 0.62 | 0.057 | 75.27 | 5.327 |
| 8 | 0.03 | 0.014 | 0.02 | 0.004 | 0.00 | 0.000 | 0.00 | 0.000 | 0.03 | 0.017 | 0.00 | 0.000 | 99.91 | 0.036 |
| 16 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 0.00 | 0.000 | 100.00 | 0.000 |
| | | | | | | | Devaluation Rate | | | | | | | |
| 1 | 3.01 | 0.320 | 86.37 | 2.616 | 0.11 | 0.108 | 9.67 | 2.021 | 0.84 | 0.323 | 0.00 | 0.000 | 0.00 | 0.000 |
| 4 | 1.19 | 0.254 | 96.02 | 0.805 | 0.04 | 0.038 | 2.54 | 0.618 | 0.20 | 0.076 | 0.01 | 0.002 | 0.00 | 0.000 |
| 8 | 0.33 | 0.081 | 98.59 | 0.383 | 0.01 | 0.013 | 0.52 | 0.140 | 0.53 | 0.272 | 0.01 | 0.003 | 0.00 | 0.000 |
| 16 | 0.06 | 0.015 | 98.65 | 0.467 | 0.00 | 0.005 | 0.10 | 0.029 | 1.18 | 0.437 | 0.01 | 0.002 | 0.00 | 0.000 |
| | | | | | | | Nominal Interest Rate | | | | | | | |
| 1 | 24.70 | 5.869 | 39.03 | 3.020 | 0.01 | 0.003 | 16.50 | 4.782 | 17.92 | 2.098 | 1.84 | 0.364 | 0.00 | 0.000 |
| 4 | 23.07 | 5.712 | 48.40 | 1.039 | 0.02 | 0.018 | 16.44 | 4.138 | 10.29 | 1.275 | 1.77 | 0.348 | 0.00 | 0.000 |
| 8 | 9.80 | 2.319 | 64.38 | 2.410 | 0.02 | 0.015 | 10.49 | 2.555 | 14.45 | 2.813 | 0.87 | 0.173 | 0.00 | 0.000 |
| 16 | 4.74 | 1.026 | 71.06 | 3.626 | 0.01 | 0.007 | 5.17 | 1.422 | 18.62 | 2.247 | 0.40 | 0.084 | 0.00 | 0.000 |
| | | | | | | | Nominal Exchange Rate | | | | | | | |
| 1 | 19.06 | 0.497 | 3.31 | 1.464 | 0.00 | 0.002 | 75.10 | 6.025 | 2.11 | 1.314 | 0.42 | 0.085 | 0.00 | 0.000 |
| 4 | 17.00 | 0.203 | 5.76 | 1.518 | 0.01 | 0.007 | 68.30 | 2.461 | 8.70 | 1.298 | 0.24 | 0.067 | 0.00 | 0.000 |
| 8 | 13.84 | 1.078 | 19.67 | 4.811 | 0.00 | 0.006 | 51.53 | 3.193 | 14.80 | 1.840 | 0.15 | 0.043 | 0.00 | 0.000 |
| 16 | 10.63 | 0.853 | 31.93 | 8.418 | 0.00 | 0.005 | 38.21 | 1.119 | 19.12 | 4.905 | 0.11 | 0.031 | 0.00 | 0.000 |

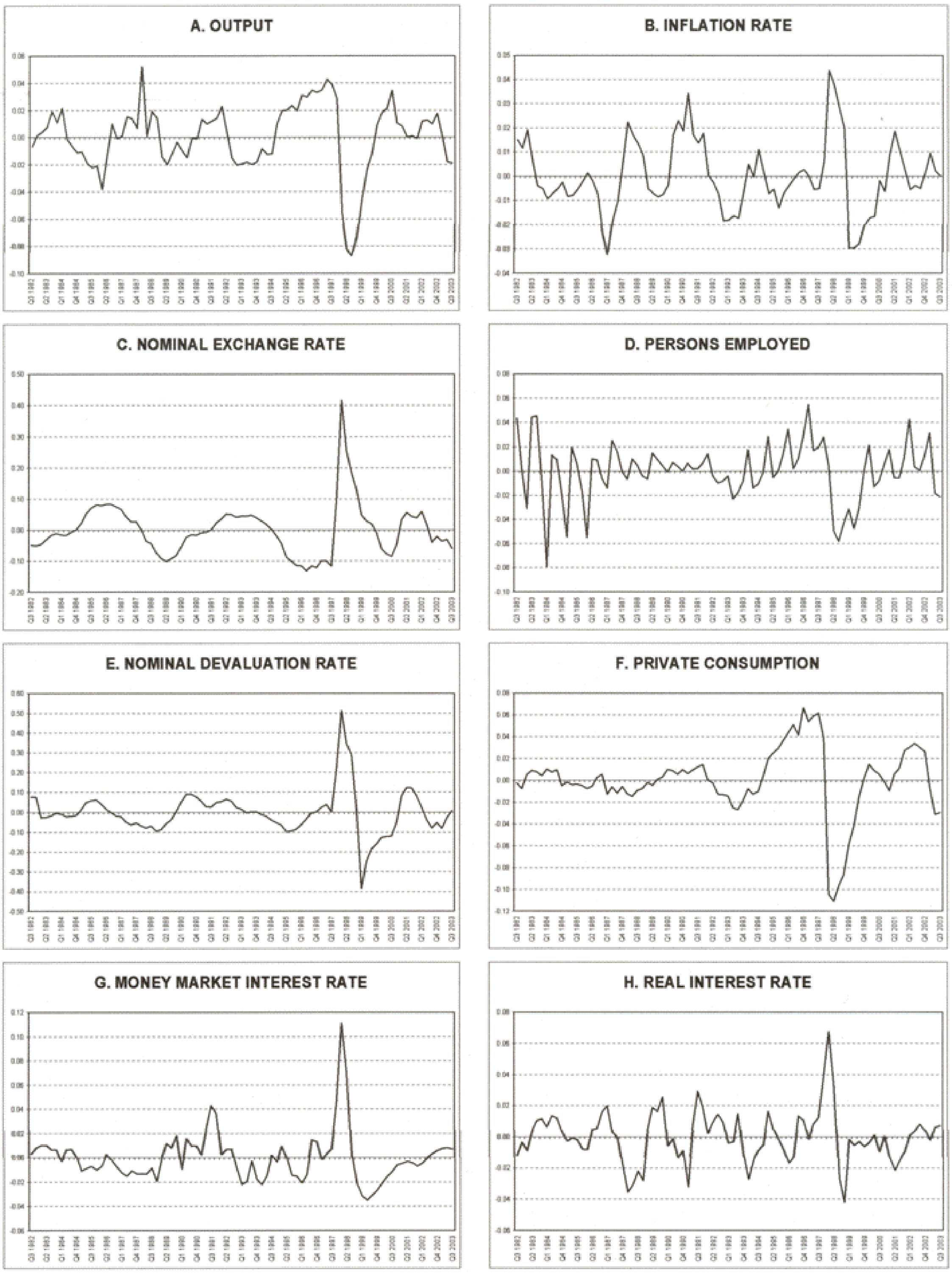


Figure 1: **South Korea 1982:3 to 2003:3. Main economic variables in logs and HP filtered.**

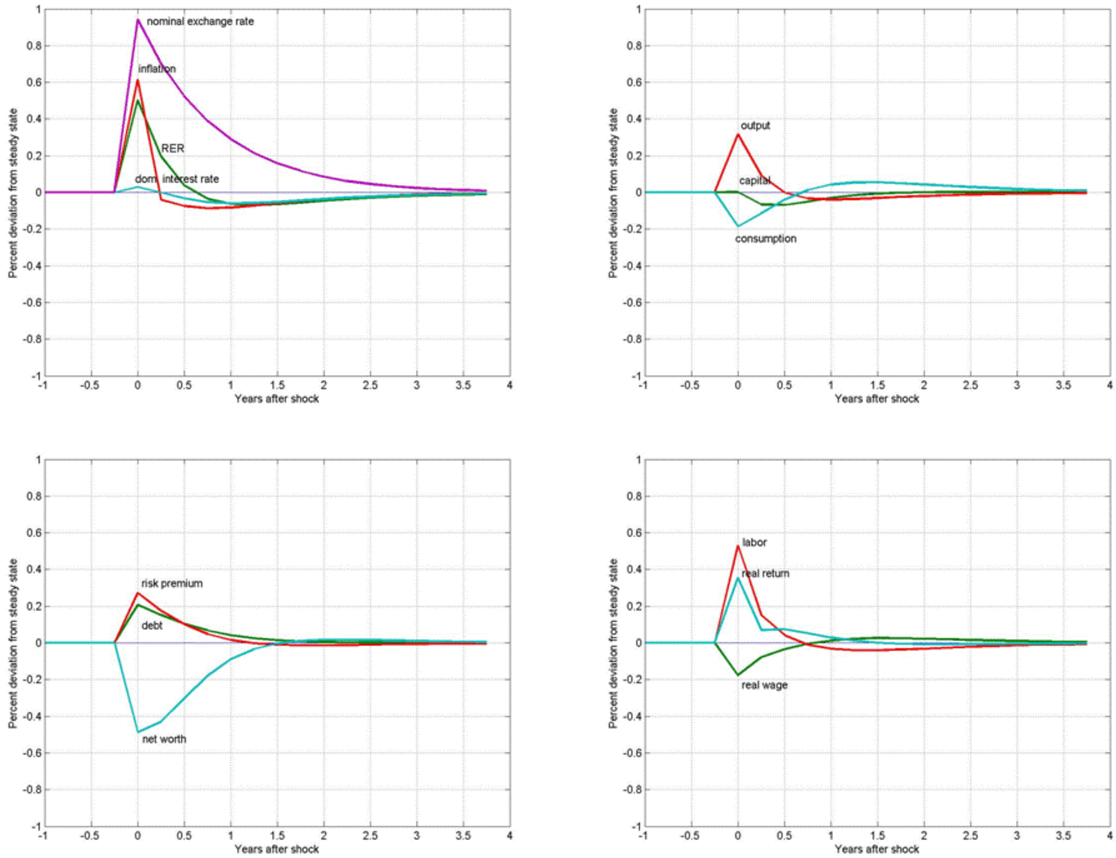


Figure 2: **Impulse response to a one percent devaluationary shock.**

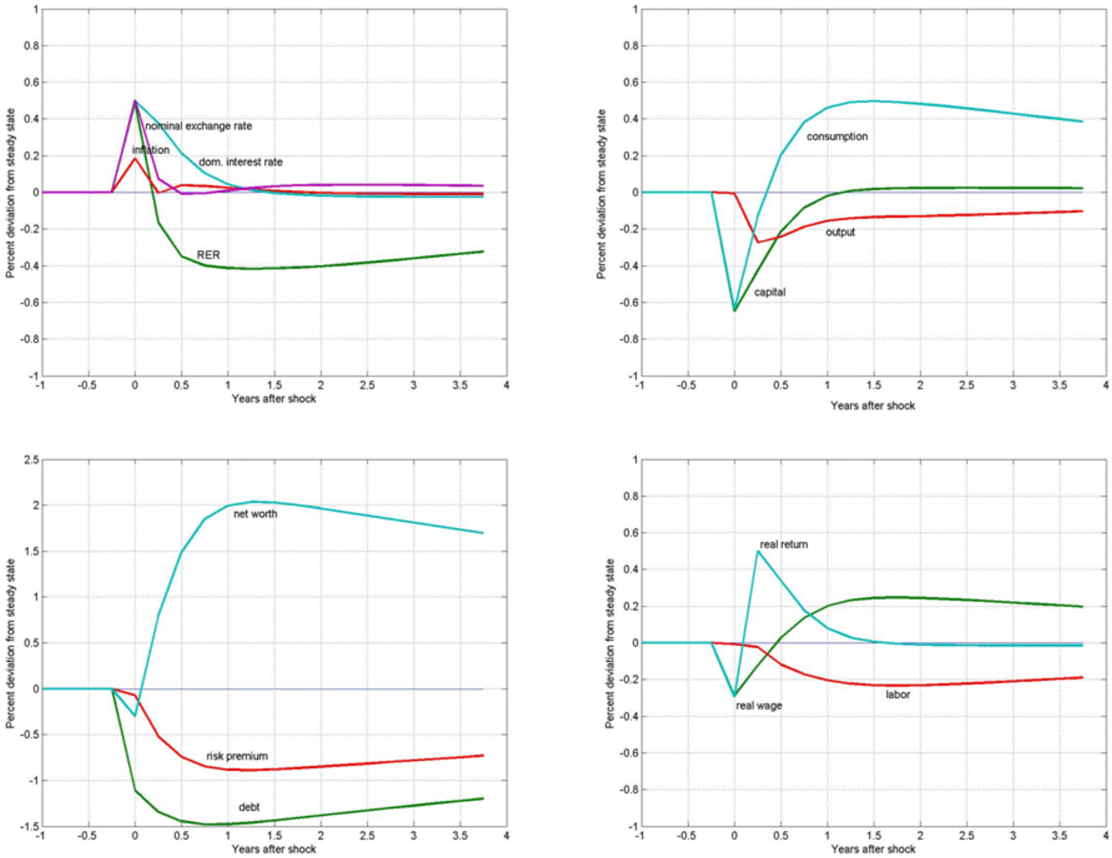


Figure 3: **Impulse response to a one percent increase in the international risk free interest rate.**

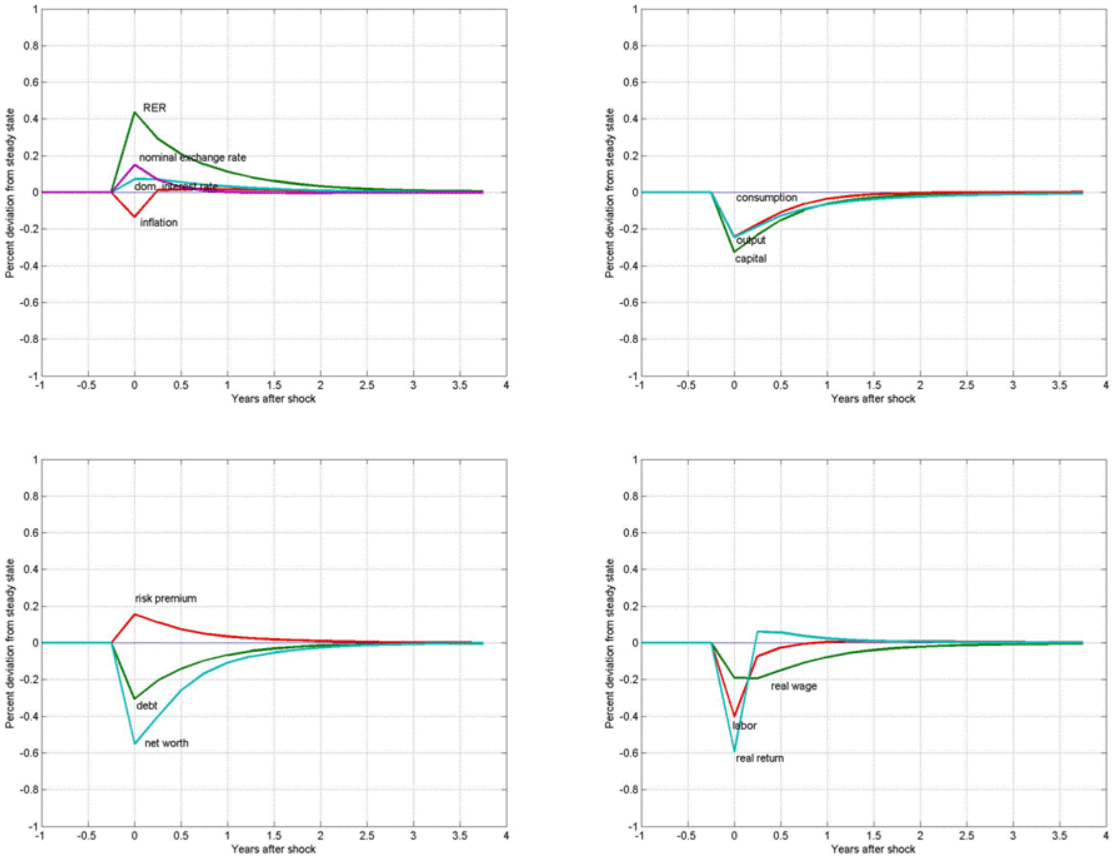


Figure 4: **Impulse response to a one percent adverse export demand shock.**

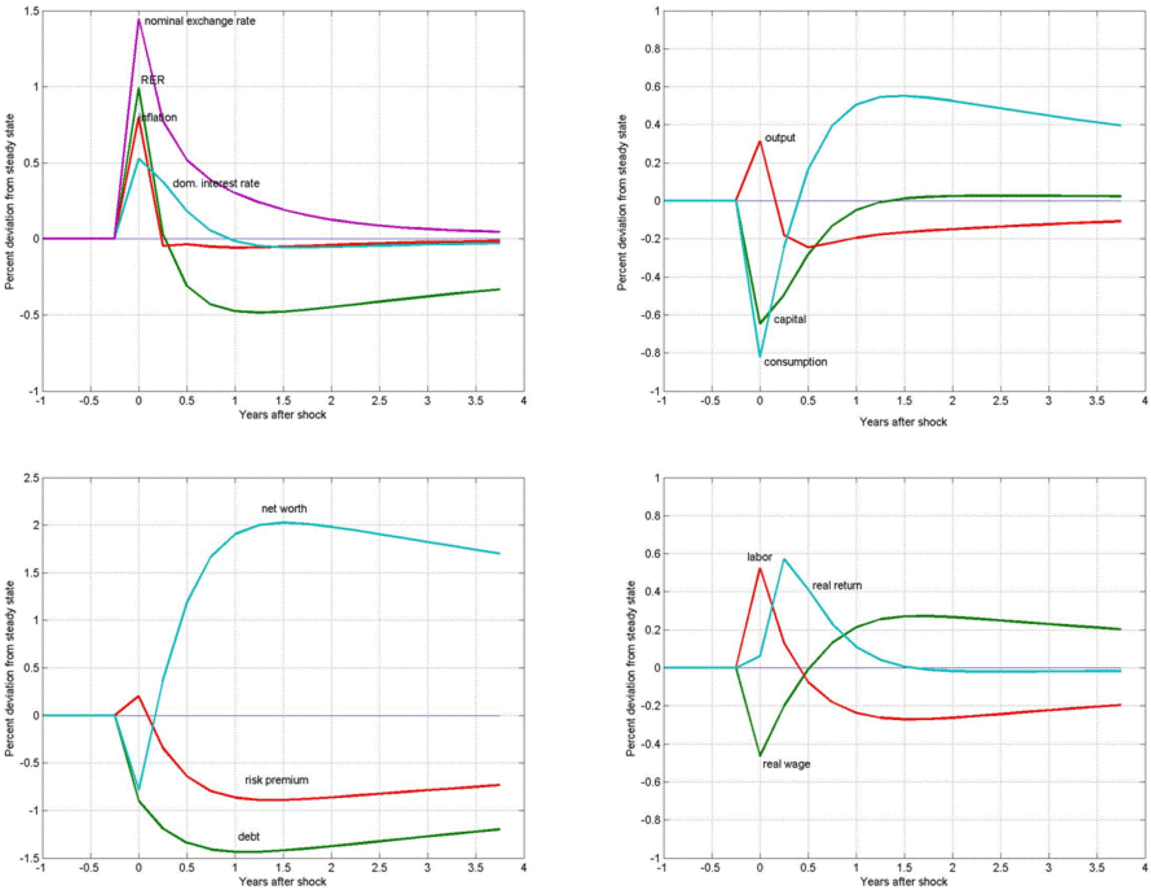


Figure 5: **Impulse response to a one percent devaluation and international interest rate shock.**

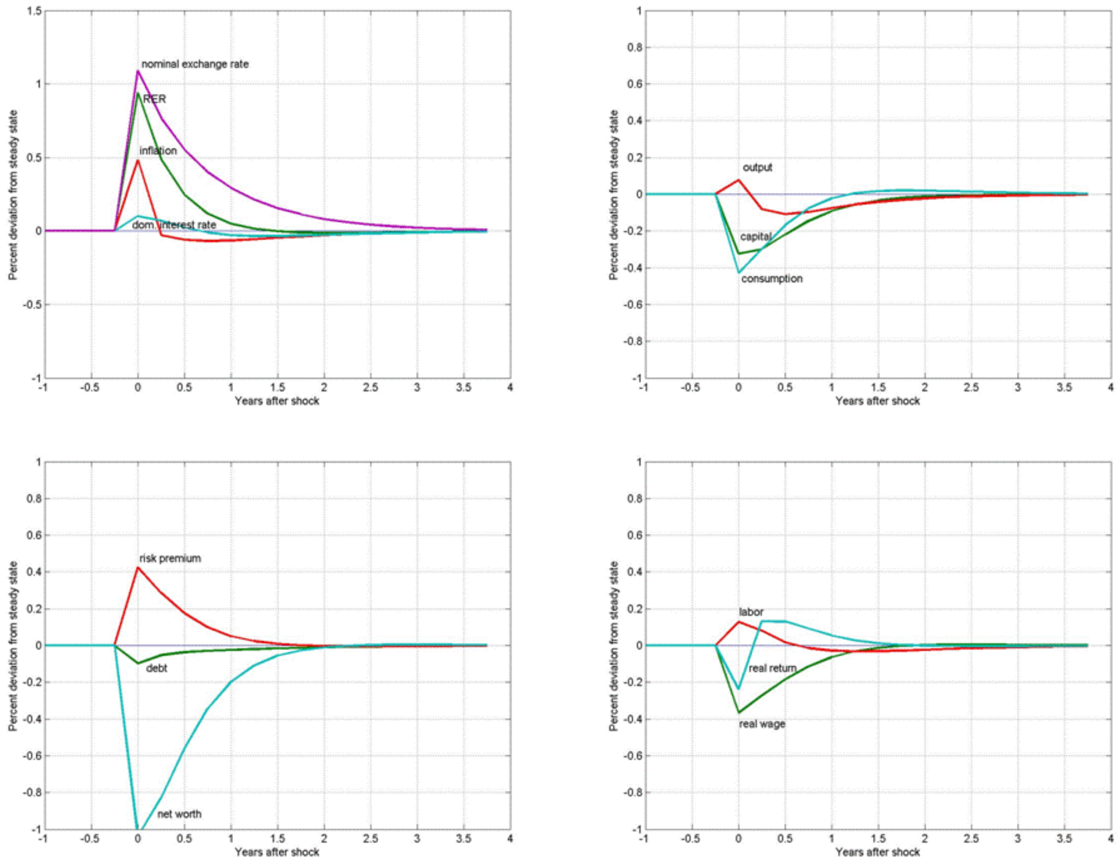


Figure 6: **Impulse response to a one percent devaluation and adverse export demand shock.**