

# MUNDELL-FLEMING REVISITED: THE ROLE OF TRADE OPENNESS

Guillermo Calvo, Columbia University and NBER

Ondra Kamenik, Czech National Bank and International Monetary Fund

Michael Kumhof, International Monetary Fund

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## **Abstract**

The paper evaluates the net welfare gains of domestic goods price inflation targeting over a fixed exchange rate as a function of a country's trade openness. For foreign real (terms of trade) shocks the net gains are positive, while for domestic nominal (price markup) shocks they are negative. In each case, and for most plausible calibrations, net gains are increasing in trade openness. Overall net gains can be negative for empirically reasonable volatilities of price markup shocks. The main exception is heavily indebted countries, where welfare gains are large for very closed economies, but decreasing over the relevant range of trade openness. Similar results would hold if domestic wage rather than price inflation could be targeted, but in practice this would suffer from implementability and credibility problems.

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# 1 Introduction

It has long been well known that optimal monetary policy in an open economy should allow nominal exchange rates to adjust to external real shocks such as terms of trade shocks. Seminal papers that implied this conclusion include Friedman (1953) and the Mundell-Fleming model (Mundell (1963), Fleming (1962)). The advantage of a flexible exchange rate in this context is that it quickly realigns international relative prices without the need for drawn-out fluctuations in domestic inflation that are, under nominal rigidities, associated with undesirable fluctuations in the output gap. In the presence of such shocks an inflation targeting monetary regime, which implies exchange rate flexibility, must therefore be superior to exchange rate targeting from a welfare point of view.

Several important recent papers have found that, in the extreme, welfare optimizing monetary policy in an open economy results in a complete stabilization of the domestic price level, with no trade-off between output gap stabilization and domestic price stability, and with no need for monetary policy to explicitly consider the exchange rate.<sup>1</sup> If the producer currency pricing assumption of these models is replaced with local currency pricing, it can be shown that it becomes optimal to have a very significant role for the exchange rate in the monetary policy rule, but a completely fixed exchange rate is still only called for in special cases.<sup>2</sup> The empirical evidence for the pricing assumption is a subject of much debate, with Corsetti and Pesenti (2005) arguing that an intermediate degree of pass-through may be most appropriate, with developing countries likely closer to a high pass-through than industrialized countries.<sup>3</sup> This would make a floating exchange rate more advisable to developing countries, the focus of this paper, than to industrialized countries.

But on the other hand, several authors have cautioned that the foregoing arguments ignore other important factors. For example, Calvo and Reinhart (2001, 2002) state that policy credibility and financial vulnerability are very important issues for emerging markets and may advise against floating exchange rates. Kollmann (2004) shows that with a significant role for shocks to uncovered interest parity a fixed exchange rate may be preferable, because

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<sup>1</sup> See Gali and Monacelli (2005), Benigno and Benigno (2003) and Obstfeld and Rogoff (2002).

<sup>2</sup> See Smets and Wouters (2002), Devereux and Engel (2003), Corsetti and Pesenti (2005), Corsetti (2006) and Duarte and Obstfeld (2007). 2

<sup>3</sup> Goldberg and Knetter (1997) and Campa and Goldberg (2005) find that in industrialized countries the degree of short-run pass-through to import prices is roughly 50 percent, and close to 100 percent in the long run. But for many developing countries the consensus is that pass-through to import prices is very much higher, for example Burstein, Eichenbaum and Rebelo (2005).

it completely eliminates such shocks. And Elekdag and Tchakarov (2008) show that in the presence of strong financial accelerator effects and dollarization a stable exchange rate is preferable.

But there is another argument for fixed exchange rates that appears to have received little attention recently, despite the fact that it constitutes the second half of the Mundell-Fleming model's seminal policy prescriptions. It relates to the performance of monetary policy in the presence of domestic nominal shocks, specifically money supply shocks, and shows that for that case a fixed exchange rate is superior at stabilizing output. As we will show, this argument is much broader than money supply shocks and also applies to price markup shocks, a type of shock that is typically found to be empirically important in modern estimated DSGE models. The optimal policy response to higher markups induces a simultaneous contraction in demand, and monetary policy can accomplish this by not providing monetary accommodation to higher domestic prices. Exchange rate targeting is shown to provide much less accommodation than inflation targeting.

Our paper attempts to answer two questions. The first question is the familiar one discussed above: What determines the net welfare gain of flexible exchange rates, modeled as an inflation targeting rule for nominal interest rates, versus fixed exchange rates? The key factors determining the answer to this question are the relative volatilities of price markup and terms of trade shocks<sup>4</sup>, and the structural parameters determining their dynamic effects. The main result is that price markup shocks can quite easily be large enough for fixed exchange rates to be preferable, even when terms of trade shocks are very large. This conclusion is based on a theoretical model calibrated to recent data for Chile, a country that has experienced very large terms of trade shocks. The second question is more specific: How does the benefit of choosing flexible versus fixed exchange rates vary with the degree of trade openness? The conventional view among economists seems to go back to McKinnon (1963), who stated that the benefit of allowing the exchange rate to float is greatest for very

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<sup>4</sup> The model contains three other shocks, but they turn out to be of only marginal importance for the results.

closed economies.<sup>5,6</sup> But among policymakers in economies that are relatively closed to trade the opposite view is sometimes found. They tend to consider external shocks to be of little importance, so that the gains from a flexible exchange rate response are expected to be small. This conjecture was used by policymakers in Argentina under its 1990s currency board, Argentina being a very closed economy. We will show that in general this view, rather than the conventional view, is better supported by our model. But, as one might guess (and hope, for the model's sake), this is not true for the specific case of Argentina. The reason is that there is one major exception to our findings - in highly indebted and very closed economies a flexible exchange rate is far preferable to a fixed rate, and this advantage declines as the economy becomes more open.

There is one other exception that is mainly of theoretical interest: In a final set of results we show that inflation targeting does become unambiguously superior, and that its advantage decreases in openness, if domestic wage rather than price inflation can be targeted. But this alternative suffers from major problems of data availability and of monetary policy transparency (potential for data manipulation), especially in emerging markets.

We use a two country model (Home and Foreign) to correctly capture the full general equilibrium effects of shocks. But because our Home economy is calibrated to Chile, it is very small. The calibration of the model's steady state is based on a very detailed analysis of Chilean national accounts data. We take care to model all trade linkages that are relevant to the economy's overall trade openness, so as to avoid obtaining results that are mainly attributable to simplifications of the model and therefore may not generalize to a more complete model. For example, in a good part of the literature the only trade linkage is in consumption goods. But in Chile's case this is by far the least important linkage, with much

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<sup>5</sup> Few if any subsequent papers address this question directly. But a number of papers explore the role of trade openness without addressing the question of the welfare benefits of exchange rate flexibility. Lane (1997) investigates the relationship between openness and the average inflation rate under a time consistent monetary policy. Hau (2000, 2002) investigates the relationship between openness and real exchange rate volatility. Both papers assume producer currency pricing for imported goods.

<sup>6</sup> Kollmann (2004) recently found the same result, based on assuming a very prominent role for uncovered interest parity shocks under flexible exchange rates and the absence of such shocks under fixed exchange rates. In Chilean data for the most recent period, we have not found uncovered interest parity shocks to be important.

higher import shares in capital goods and intermediate goods. Our model especially takes the latter seriously by replicating the input-output structure of Chile's national accounts between import, export, investment and nontradable goods. Following much of the literature, we assume that prices for internationally traded goods are flexible<sup>7</sup> while domestic prices exhibit nominal rigidities. This feature is important for our welfare results. The calibration of the model's adjustment cost, shock process and policy reaction function parameters is based on matching the volatility and persistence properties of key macroeconomic aggregates. The model is too complex for full estimation of these parameters, but we are able to provide an exhaustive analysis of the sensitivity of our welfare results to changes in these parameters.

We adopt a very natural concept of trade openness that is based entirely on preferences and technologies. Specifically, increasing openness means increasing *international goods expenditure shares* in both domestic production and consumption. To obtain economies with different degrees of openness the steady state of the model, specifically its preference and technology share parameters, is therefore recalibrated for 17 different economies, ranging from essentially closed to a 150% steady state imports to GDP ratio. To give content to the notion of the benefit of exchange rate flexibility we evaluate the response of our model economy to shocks under either a fixed or a flexible exchange rate regime and at different degrees of trade openness. Flexible exchange rates are defined as inflation forecast based interest rate rules. The benefit of exchange rate flexibility is the *incremental welfare gain of flexible over fixed exchange rates*.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 presents its calibration. Section 4 discusses impulse responses and welfare results. Section 5 concludes. The paper is accompanied by two appendices. A Technical Appendix contains the complete derivation of the model's equilibrium conditions, and shows some additional illustrations including flow charts of the model's goods and factor flows. A Data Appendix explains the methodology used to obtain a calibration of the model's input-output structure from Chile's national accounts.

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<sup>7</sup> We maintain this assumption throughout for exports, but for imports we also explore the alternative local currency pricing assumption.

## 2 The Model

We consider two open economies, Home representing Chile and Foreign representing the rest of the world, that each consist of households, firms, import agents and a government. The size of Home equals  $\alpha$  and that of Foreign equals  $1 - \alpha$ .

Home production consists of four sectors, nontraded goods (index  $n$ ), investment goods (index  $v$ ), export goods (index  $x$ ) and import goods (index  $m$ ). The latter combine foreign intermediate inputs with a significant local factor content, while international goods (index  $f$ ) are direct imports sold by the Foreign owned import agents of Foreign producers. The empirical production and consumption shares of these goods categories, as well as their capital, labor and intermediates factor shares, are derived by aggregating (for the base year 1996) over appropriate subsets of 73 different industrial sectors, where subsets are distinguished by import and export shares and by their shares in the final demand for investment goods.

Households are infinitely lived and identical except for differences in the timing of their nominal wage setting. They consume the five available consumption goods types. Their labor services are supplied to the four domestic production sectors subject to nominal wage rigidities, but with free mobility of labor across sectors. Households also accumulate capital and rent it to firms, but capital is not mobile across sectors so that households separately accumulate four capital stocks.

All firms are competitive in all factor markets. Export sector firms are perfectly competitive in the market for their output, while all remaining, domestic, firms are monopolistically competitive. They use capital and labor inputs, but they also use international goods and part of the output of firms in all other sectors as intermediate inputs. Their sales are to final consumers (all sectors), to users of intermediate inputs (all sectors), to investors (only the investment goods sector), and to foreigners (only the export goods sector).

Households and firms face a number of different real adjustment and transactions costs. We assume that most of these costs are reimbursed to households in a lump-sum fashion. There are two exceptions, the foreign exchange risk premium which represents a wealth

transfer between Home and Foreign households, and quantity adjustment costs in the Foreign imports sector.

The government's fiscal policy is Ricardian. Monetary policy either targets the exchange rate, or it targets a domestic inflation index via an inflation forecast based rule for nominal interest rates.

## 2.1 Households

The preferences of household  $i$  depend on consumption  $C_t^i$ , labor supply  $L_t^i$  and real money balances  $j_t^i = J_t^i/P_t$ , where  $P_t$  is the consumption based price index. Preferences have the functional form

$$\mathcal{E}_t \sum_{t=0}^{\infty} \beta^t \left\{ (1 - v_c) S_t^c \ln (C_t^i - v_c C_{t-1}) - \frac{\kappa}{1 + \psi} (L_t^i)^{1+\psi} + \frac{\Upsilon}{1 - \chi} (j_t^i)^{1-\chi} \right\}, \quad (1)$$

where  $\mathcal{E}_t$  represents expectation conditional on information available at time  $t$ . Consumption habits (of the external type) are parameterized by  $v_c$ <sup>8</sup>, and  $S_t^c$  is a shock to the marginal utility of consumption.<sup>9</sup> The wage elasticity of labor supply is equal to  $1/\psi$  while the parameter  $\chi$  determines the interest elasticity of money demand. We will ignore the optimality condition for money given that money is separable in utility, and that monetary policy will be specified as an interest rate reaction function. For the purpose of welfare analysis we will furthermore assume the cashless limit case of Woodford (2003) by setting  $\Upsilon$  arbitrarily close to zero. The consumption aggregator  $C_t^i$  is given by

$$C_t^i = A_c (c_t^{n,i})^{\sigma_n} (c_t^{v,i})^{\sigma_v} (c_t^{x,i})^{\sigma_x} (c_t^{m,i})^{\sigma_m} (c_t^{f,i})^{\sigma_f}, \quad (2)$$

where  $A_c = \prod_{j=n,v,x,m,f} \sigma_j^{-\sigma_j}$  and  $\sum_{j=n,v,x,m,f} \sigma_j = 1$ . The consumption based price index for this economy is

$$P_t = (P_t^n)^{\sigma_n} (P_t^v)^{\sigma_v} (P_t^x)^{\sigma_x} (P_t^m)^{\sigma_m} (P_t^f)^{\sigma_f}. \quad (3)$$

<sup>8</sup> The constant  $(1 - v_c)$  ensures that the steady state marginal rate of substitution between consumption and labor is independent of the habit parameter  $v_c$ .

<sup>9</sup> We also consider the case of CRRA consumption preferences  $\frac{(1-v_c)^{\frac{1}{\xi}}}{1-\frac{1}{\xi}} S_t^c (C_t^i - v_c C_{t-1})^{1-\frac{1}{\xi}}$  to explore the role of utility function curvature in our welfare results.

CPI inflation is denoted as  $\pi_t = P_t/P_{t-1}$ , and similarly for sectorial inflation rates  $\pi_t^j$ . To maintain the notation of a typical small open economy model we express all relative prices in terms of the producer price of international goods.<sup>10</sup> This equals  $P_t^*S_t$  in Home, where  $P_t^*$  is the foreign producer price level and  $S_t$  is the nominal exchange rate. The real exchange rate according to this convention is given by  $s_t = S_tP_t^*/P_t$ , and Home relative prices by  $p_t^j = P_t^j/S_tP_t^*$ ,  $j = n, v, x, m, f$ . Each household earns nominal wage income  $W_t^iL_t^i(1 + \zeta_w)$ , where the nominal wage  $W_t^i$  is sticky and can be reoptimized at random intervals as in Calvo (1983) and Erceg, Henderson and Levin (2000), with updating at the steady state inflation rate as in Yun (1996). The term  $\zeta_w$  is a government labor subsidy that is used to fully offset the monopolistic distortion in the labor market.<sup>11</sup> All producers demand part of a homogenous labor aggregate

$$L_t = \left( \int_0^1 (L_t^i)^{\frac{\theta_w-1}{\theta_w}} di \right)^{\frac{\theta_w}{\theta_w-1}}, \quad (4)$$

so that each household faces a demand

$$L_t^i = \left( \frac{W_t^i}{W_t} \right)^{-\theta_w} L_t, \quad W_t = \left( \int_0^1 (W_t^i)^{1-\theta_w} di \right)^{\frac{1}{1-\theta_w}}. \quad (5)$$

Households also accumulate physical capital stocks

$$K_{t+1}^{j,i} = (1 - \Delta)K_t^{j,i} + I_t^{j,i}S_t^I, \quad j = n, v, x, m, \quad (6)$$

where  $I_t^{j,i}$  ( $K_t^{j,i}$ ) is investment (capital stock) in sector  $j$  by household  $i$ ,  $\Delta$  is the common depreciation rate, and  $S_t^I$  is an investment shock. The price of final investment goods is  $P_t^k$ . Nominal quadratic (external) investment adjustment costs are  $(u_I/2)P_t^k K_t^{j,i} \left( (I_t^{j,i}/K_t^{j,i}) - (I_{t-1}^j/K_{t-1}^j) \right)^2$ . The nominal returns to capital are  $R_t^j$ , and real returns in terms of the respective sectorial outputs are  $r_t^j = R_t^j/P_t^j$ . Total firm profits of each sector  $\tilde{\Pi}_t^{j,i} = \int_0^1 \tilde{\Pi}_t^{j,i}(k)dk$ ,  $j = n, v, x, m, h^*$ <sup>12</sup> (where  $k$  indexes the continuum of

<sup>10</sup> The difference between the Foreign producer and consumer price levels is negligible due to the very small size of Home. Use of the producer price level is more convenient.

<sup>11</sup> This assumption makes the results of our welfare analysis easier to interpret. It would be straightforward to relax it as part of our sensitivity analysis.

<sup>12</sup> The sector  $h^*$  refers to the Home owned import agents in Foreign, who sell Home export goods. For details see the subsection ‘‘Import Agents’’.

firms in each sector) are distributed to households in a lump-sum fashion. A final source of household income is nominal lump-sum transfers  $T_t^i$  from the government.

Households invest in four types of financial assets. Domestic nominal money balances are denoted by  $J_t^i$ . Domestic currency government bonds, bought in period  $t$  and maturing in  $t+1$ , and paying off  $i_t$  units of domestic currency in  $t+1$ , are denoted by  $\tilde{B}_t^i$ . Households have access to a complete set of domestic state-contingent claims that allow them to insure themselves against the risk associated with the timing of their wage setting. We denote by  $\varphi_{t,t+1}(\mathfrak{s})$  the price of a claim at time  $t$  that will pay one unit of domestic currency in a particular state of nature  $\mathfrak{s}$  at time  $t+1$ , while  $\check{B}_t^i(\mathfrak{s})$  denotes the quantity of such claims purchased by household  $i$  at time  $t$ . Thus the gross outlay on new state-contingent claims at time  $t$  is given by integrating over all states at time  $t+1$ , while  $\check{B}_{t-1}^i$  indicates the value of existing claims given the realized state of nature. Finally, households can borrow and lend freely in international capital markets, but those markets are incomplete in that only nominally non-contingent one-period bonds denominated in foreign currency, denoted by  $B_t^i$ , are available. They are assumed to pay off  $i_t^*(1 + \xi_t)$  units of foreign currency in  $t+1$ , where  $i_t^*$  is the nominal interest rate in the rest of the world and  $\xi_t$  is the foreign currency risk premium, which is paid to an intermediary that redistributes the additional interest earnings to foreign households in a lump-sum fashion. The premium term  $\xi_t$  is assumed to take the functional form (letting  $b_t = B_t/P_t$ )<sup>13</sup>

$$\xi_t = \omega_1 + \frac{\omega_2}{\left(\frac{b_t}{4*gdpt} - \omega_4\right)^{\omega_3}} . \quad (7)$$

The risk premium term is required, as usual, to ensure stationarity of the open economy's foreign asset position.<sup>14</sup> We assume that the risk premium is external to households' decisions, in that aggregate bonds  $b_t$  rather than individual bondholdings enter into the denominator of (7). The parabolic functional form we choose has one important advantage over conventional quadratic bondholding costs when it comes to modeling the risk premium

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<sup>13</sup> To ensure a zero premium at a zero net foreign asset position we impose the condition  $\omega_1 = -\omega_2/(\omega_4)^{\omega_3}$ .

<sup>14</sup> See Schmitt-Grohé and Uribe (2002) for a discussion.

facing many emerging markets, namely the asymmetry of its elasticity with respect to net foreign asset positions.<sup>15</sup> This elasticity becomes extremely high at high levels of foreign indebtedness, while at positive net foreign asset positions its elasticity is very close to zero. Finally, we allow for the possibility that the steady state level of net foreign assets is different from zero, and that at that level the foreign exchange risk premium drives a permanent wedge between domestic and foreign real interest rates. To make sure that this does not give rise to degenerate consumption dynamics, we allow household rates of time preference to be different across countries. Specifically, we set  $\beta = \beta^*/(1 + \bar{\xi})$ , where  $\bar{\xi}$  is a function of the steady state debt to GDP ratio according to (7).<sup>16</sup>

Taking all the above together, we have the following nominal budget constraint for household  $i$ :

$$\begin{aligned}
S_t B_t^i + \tilde{B}_t^i + J_t^i &= i_{t-1}^*(1 + \xi_{t-1})S_t B_{t-1}^i + J_{t-1}^i + \check{B}_{t-1}^i + \left( i_{t-1} \tilde{B}_{t-1}^i - \int_{\mathfrak{s}} \varphi_{t,t+1}(\mathfrak{s}) \check{B}_t^i(\mathfrak{s}) \right) \\
&+ W_t^i L_t^i (1 + \zeta_w) + \sum_{j=n,v,x,m} \left( \tilde{\Pi}_t^{j,i} + p_t^j r_t^j K_t^{j,i} \right) + \tilde{\Pi}_t^{h^*,i} + T_t^i \\
&- P_t C_t^i - P_t^k \sum_{j=n,v,x,m} \left( I_t^{j,i} + \frac{u_I}{2} K_t^{j,i} \left[ \frac{I_t^{j,i}}{K_t^{j,i}} - \frac{I_{t-1}^j}{K_{t-1}^j} \right]^2 \right) .
\end{aligned} \tag{8}$$

The household maximizes (1) subject to (2), (5), (6), (8) and the no-Ponzi condition

$$\lim_{k \rightarrow \infty} \mathcal{E}_t \frac{S_{t+k} B_{t+k}^i + \tilde{B}_{t+k}^i + J_{t+k}^i}{\prod_{s=0}^{k-1} i_s} \geq 0 . \tag{9}$$

We assume that all households have identical initial stocks of capital and financial assets. Taken together with the assumption of complete domestic contingent claims markets this implies that all households obtain identical optimality conditions except for their wage setting. We can therefore drop the household index  $i$  in what follows. The first-order conditions for the optimal choice of the consumption basket are, for  $j = n, v, x, m, f$ :

$$s_t p_t^j c_t^j = \sigma_j C_t . \tag{10}$$

<sup>15</sup> See the Technical Appendix for an illustration. The risk premium is also asymmetric in that households in the rest of the world are not subject to a similar cost and instead collect the profits associated with the intermediation rents.

<sup>16</sup> A bar above a variable denotes its steady state value.

We denote the marginal value of an extra unit of domestic currency by  $\Lambda_t$ , and the marginal value of an extra unit of international goods is  $\lambda_t = \Lambda_t S_t P_t^*$ . Then we have the following optimality conditions for consumption, foreign currency bonds and domestic currency bonds:

$$\frac{s_t(1 - v_c)S_t^c}{C_t - v_c C_{t-1}} = \lambda_t \quad , \quad (11)$$

$$1 = \mathcal{E}_t \frac{\lambda_{t+1} i_t^* (1 + \xi_t)}{\lambda_t \pi_{t+1}^*} \quad , \quad (12)$$

$$1 = \mathcal{E}_t \frac{\lambda_{t+1}}{\lambda_t} \frac{i_t}{\pi_{t+1}^* \varepsilon_{t+1}} \quad . \quad (13)$$

The first-order conditions for investment and capital are, for  $j = n, v, x, m$ :

$$q_t^j S_t^I = 1 + u_I \left( \frac{I_t^j}{K_t^j} - \frac{I_{t-1}^j}{K_{t-1}^j} \right) \quad , \quad (14)$$

$$\lambda_t p_t^k q_t^j = \beta \mathcal{E}_t \lambda_{t+1} p_{t+1}^k \left( \frac{p_{t+1}^j r_{t+1}^j}{p_{t+1}^k} + q_{t+1}^j (1 - \Delta) + u_I \frac{I_{t+1}^j}{K_{t+1}^j} \left[ \frac{I_{t+1}^j}{K_{t+1}^j} - \frac{I_t^j}{K_t^j} \right] - \frac{u_I}{2} \left[ \frac{I_{t+1}^j}{K_{t+1}^j} - \frac{I_t^j}{K_t^j} \right]^2 \right) \quad , \quad (15)$$

where  $q_t^j$  is the shadow value, in units of final investment goods, of a unit of installed capital.

Households receive random opportunities to change their nominal wage  $W_t^i$ . These follow a geometric distribution, with a probability  $1 - \delta_w$  of being able to set a new wage. They choose that wage taking account of labor demand (5). We use the notation  $z_t^w$  to denote the ratio of the time  $t$  nominal wage chosen by a time  $t$  wage setter,  $Z_t^w$ , and the market average nominal wage  $W_t$ . Because all households solving the time  $t$  wage setting problem choose identical values, we can drop the index  $i$  in the optimality conditions. They are derived in the Technical Appendix:

$$(z_t^w)^{1+\theta_w \psi} = \kappa \frac{A_t^w}{B_t^w} \quad , \quad (16)$$

$$A_t^w = L_t^{1+\psi} + \beta \delta_w \mathcal{E}_t \left( \frac{\bar{\pi}}{\pi_{t+1}^w} \right)^{-\theta_w(1+\psi)} A_{t+1}^w \quad , \quad (17)$$

$$B_t^w = \lambda_t w_t L_t + \beta \delta_w \mathcal{E}_t \left( \frac{\bar{\pi}}{\pi_{t+1}^w} \right)^{1-\theta_w} B_{t+1}^w \quad , \quad (18)$$

$$1 = \delta_w \left( \frac{\pi_t^w}{\bar{\pi}} \right)^{\theta_w - 1} + (1 - \delta_w) (z_t^w)^{1 - \theta_w} . \quad (19)$$

In deriving these conditions we have assumed that the subsidy satisfies  $\zeta_w = 1/(\theta_w - 1)$ . As we will evaluate the model using second and third order approximations we need to keep the optimality conditions in this form rather than the more familiar linearized New Keynesian Phillips curve for wages. Similar comments apply to nominal rigidities in pricing below.

## 2.2 Firms

Firms in each of the four domestic production sectors, indexed as above by  $j = n, v, x, m$ , have unit mass and are indexed by  $i$ . The domestic sectors  $n, v$  and  $m$  are monopolistically competitive while the export sector is perfectly competitive. Therefore, as long as producer currency pricing is assumed for Home imports, all international trade of Home is conducted at flexible prices while all domestic trade, except for the very small domestic sales of the export sector, is conducted at sticky goods prices. Firms' gross production functions employ not only capital and labor but also intermediate inputs from all other sectors of the economy and from the rest of the world. Letting  $A_j = \prod_{\iota=k,l,n,v,x,m,f} (\alpha_j^\iota)^{-\alpha_j^\iota}$  and  $\sum_{\iota=k,l,n,v,x,m,f} \alpha_j^\iota = 1$ , we have

$$y_t^{j,i} = A_j (k_t^{j,i})^{\alpha_j^k} (l_t^{j,i} S_t^a)^{\alpha_j^l} (n_t^{j,i})^{\alpha_j^n} (v_t^{j,i})^{\alpha_j^v} (x_t^{j,i})^{\alpha_j^x} (m_t^{j,i})^{\alpha_j^m} (f_t^{j,i})^{\alpha_j^f} , \quad (20)$$

where  $S_t^a$  is an aggregate labor-augmenting productivity shock. We only consider the net output supplied by each sector to all other sectors and ignore inputs supplied by a sector to another firm in the same sector, which implies that  $\alpha_j^j = 0$ . Because all factor markets are competitive so that relative prices of all pairs of individual inputs are equalized across all varieties, the aggregate production function takes an identical form to (20) but with the  $i$  index dropped and aggregate output defined as  $\tilde{y}_t^j = \int_0^1 y_t^{j,i} di$ . In the final set of optimality conditions  $y_t^j$  needs to be carefully distinguished from  $\tilde{y}_t^j$ . The Technical Appendix derives the relationships between these and other similar aggregates. Real marginal cost for each

sector is given by

$$mC_t^j = \frac{MC_t^j}{P_t^j} = \frac{1}{P_t^j} (r_t^j p_t^j)^{\alpha_j^k} \left( \frac{w_t}{S_t^a} \right)^{\alpha_j^l} (p_t^n)^{\alpha_j^n} (p_t^v)^{\alpha_j^v} (p_t^x)^{\alpha_j^x} (p_t^m)^{\alpha_j^m} (p_t^f)^{\alpha_j^f}, \quad (21)$$

where  $mC_t^x = 1$  because of perfect competition in that sector. Cost minimization implies a number of additional factor demand conditions that are listed in the Technical Appendix.

Firms in the three domestic sectors  $j = n, v, m$  face price rigidities of the Calvo-Yun type, similar to households' wage rigidities, with probabilities of being able to set a new price of  $(1 - \delta_p)$ . All buyers of their products demand part of a homogenous aggregate

$$y_t^j = \left( \int_0^1 (y_t^{j,i})^{\frac{\theta_{p_t}-1}{\theta_{p_t}}} di \right)^{\frac{\theta_{p_t}}{\theta_{p_t}-1}}, \quad (22)$$

so that each firm faces a demand that depends on its chosen price level  $P_{t+k}^{j,i} = Z_t^{j,i} \bar{\pi}^k$ :

$$y_t^{j,i} = \left( \frac{P_{t+k}^{j,i}}{P_t^j} \right)^{-\theta_{p_t}} y_t^j, \quad P_t^j = \left( \int_0^1 (P_t^{j,i})^{1-\theta_{p_t}} di \right)^{\frac{1}{1-\theta_{p_t}}}. \quad (23)$$

The elasticity of substitution  $\theta_{p_t}$  is assumed to be time-varying, reflecting shocks to the markup  $S_t^p$ , defined as  $S_t^p = \theta_{p_t} / (\theta_{p_t} - 1)$ . At the time of receiving a price setting opportunity, the problem of a producer of an individual variety is to maximize profits by choosing its price  $Z_t^{j,i}$ . As firms are owned by households, their discount factor for nominal cashflows equals the intertemporal marginal rate of substitution of households. In the same manner as for wages, we assume that firms receive an output subsidy  $\zeta_p$  to fully offset the monopolistic distortion that causes output to be suboptimally low in steady state. Firms also pay a lump-sum tax in the nominal amount  $P_t^j \omega_t^j y_t^j$  to the government. We have the objective function

$$Max_{Z_t^{j,i}} \mathcal{E}_t \sum_{k=0}^{\infty} (\beta \delta_p)^k \Lambda_{t+k} \left[ (Z_t^{j,i} \bar{\pi}^k (1 + \zeta_p) - MC_{t+k}^j) y_{t+k}^{j,i} - P_{t+k}^j \omega_{t+k}^j y_{t+k}^j \right] \quad (24)$$

subject to (21) and (23). We assume that  $\zeta_p = 1 / (\bar{\theta}_p - 1)$ , and that in equilibrium nominal taxes are exactly equal to the nominal output subsidy. We obtain the following optimality conditions, after recognizing that all time  $t$  price setters will behave identically so that the index  $i$  can be dropped:

$$z_t^j = \frac{S_t^p A_t^j}{\bar{S}^p B_t^j}, \quad (25)$$

$$A_t^j = \lambda_t p_t^j y_t^j m c_t^j + \beta \delta_p \left( \frac{\bar{\pi}}{\pi_{t+1}^j} \right)^{-\theta_{p_t}} A_{t+1}^j , \quad (26)$$

$$B_t^j = \lambda_t p_t^j y_t^j + \beta \delta_p \left( \frac{\bar{\pi}}{\pi_{t+1}^j} \right)^{1-\theta_{p_t}} B_{t+1}^j , \quad (27)$$

$$1 = \delta_p \left( \frac{\pi_t^j}{\bar{\pi}} \right)^{\theta_{p_t}-1} + (1 - \delta_p) (z_t^j)^{1-\theta_{p_t}} . \quad (28)$$

### 2.3 Aggregate Investment Goods Producers

For many emerging markets the investment goods sector has a particularly large direct import component, and this is also true for Chile. To model this feature we assume that aggregate final investment goods  $y_t^k$  are produced by a perfectly competitive sector that combines domestically produced investment goods  $y_t^I$  and directly imported foreign produced investment goods  $y_t^f$ , using the Cobb-Douglas technology ( $A_k = \gamma^{-\gamma} (1 - \gamma)^{-(1-\gamma)}$ )

$$y_t^k = A_k (y_t^I)^{1-\gamma} (y_t^f)^\gamma , \quad (29)$$

with price

$$p_t^k = (p_t^v)^{1-\gamma} (p_t^f)^\gamma . \quad (30)$$

### 2.4 Import Agents

Import agents allow us to distinguish between producer currency pricing and local currency pricing of imports in a tractable fashion, that is without further changes to the remainder of the model. Producer currency pricing is observed when import agents' prices are flexible, and local currency pricing when their prices are sticky.

Foreign owns a continuum of import agents, indexed by  $i$ , in Home. They are perfectly competitive in their input market and monopolistically competitive in their output market. They receive an output subsidy  $\zeta^f$  from and pay lump-sum taxes to the Foreign government, and in equilibrium these are again assumed to be equal. Import agents buy Foreign goods imports at the world market price, which is given by purchasing power parity as  $S_t P_t^*$ .

They then sell it to all Home users (consumers, investors, firms) at the price  $P_t^{f,i}$ , subject to nominal rigidities of the Calvo-Yun variety. Home users demand a CES aggregate of imported varieties, with elasticity of substitution  $\theta_f$ . Their demands for variety  $i$  can therefore be aggregated as

$$m_t^{ports,i} = m_t^{ports} \left( \frac{P_t^{f,i}}{P_t^f} \right)^{-\theta_f}. \quad (31)$$

Taking account of the fact that import agents are owned by Foreign households, their objective function is

$$Max_{Z_t^f} \mathcal{E}_t \sum_{k=0}^{\infty} (\beta^* \delta_f)^k \frac{\Lambda_{t+k}^*}{S_{t+k}} \left[ \left( Z_t^f \bar{\pi}^k (1 + \zeta_f) - S_{t+k} P_{t+k}^* \right) m_{t+k}^{ports,i} - S_{t+k} P_{t+k}^* m_{t+k}^{ports} \omega_{t+k}^f \right] \quad (32)$$

subject to (31). We obtain a set of optimality conditions identical in form to those of firms, (25)-(28). The dividends of Home import agents are part of the export earnings of foreigners and therefore enter the current account. Given our assumptions about output subsidies and lump-sum taxes they are given by

$$d_t = p_t^f m_t^{ports} - \tilde{m}_t^{ports}, \quad (33)$$

where  $\tilde{m}_t^{ports} = \int_0^1 m_t^{ports,i} di$ .

## 2.5 Foreign Private Agents

The optimization problems of Foreign households and firms are identical in nature to those of the respective Home agents, except that the Foreign economy only has one firm sector and therefore lacks a domestic input-output structure. Because the optimality conditions largely parallel those of the preceding sections their discussion is relegated to the Technical Appendix. The aggregated production function of Foreign is

$$\tilde{y}_t^* = \tilde{A}_t^* (k_t^*)^{\alpha_t^{k^*}} (l_t^*)^{\alpha_t^{l^*}} (h_t^*)^{S_t^{tot}} \mathfrak{S}, \quad (34)$$

where  $\alpha_t^{k^*} + \alpha_t^{l^*} + S_t^{tot} = 1$ ,  $\tilde{A}_t^* = (\alpha_t^{k^*})^{-\alpha_t^{k^*}} (\alpha_t^{l^*})^{-\alpha_t^{l^*}} (S_t^{tot})^{-S_t^{tot}}$ , and where  $h_t^*$  are international goods inputs purchased from Home owned import agents in Foreign at the price  $p_t^{h^*}$ . The technology scale factor  $\mathfrak{S}$  allows us to equalize steady state per capita GDP

between Home and Foreign while normalizing the steady state real exchange rate to one.<sup>17</sup> Foreign firms sell their products subject to the same type of nominal rigidities as Home firms. The time-varying share parameter  $S_t^{tot}$  is subject to shocks that generate Home terms of trade fluctuations.

The utility function of Foreign households is identical to that of Home households (with the appropriate change of notation), while their consumption aggregator is given by

$$C_t^* = \tilde{A}_{c,t}^* (c_t^{h*})^{S_t^{tot}} (c_t^{f*})^{1-S_t^{tot}}, \quad (35)$$

where  $\tilde{A}_{c,t}^* = (S_t^{tot})^{-S_t^{tot}} (1 - S_t^{tot})^{(S_t^{tot}-1)}$ ,  $c_t^{f*}$  are Foreign produced international goods and  $c_t^{h*}$  are Home export goods purchased from Home owned import agents in Foreign at the price  $p_t^{h*}$ . Note that we have set the coefficients on imports  $S_t^{tot}$  to be the same in consumption and production, as we wish to model terms of trade shocks as a single shock to preferences and technologies in Foreign.<sup>18</sup>

The structure of Chilean exports, and therefore of Foreign imports, is very different from that of Chilean imports, the latter having a large component of manufactured goods. Chilean exports do have a growing share of such goods, too, but during the period of interest to us the major category of Chilean exports has been commodities, particularly copper. Commodities are traded in world markets and their prices are highly flexible. To assume that Chilean exports are sold in the rest of the world subject to nominal rigidities would therefore not be appropriate. Furthermore, the data reveal that since 1999 the Chilean terms of trade have been roughly four times more volatile (in terms of their standard deviation) than the real export volume. For the model to replicate this feature it is therefore essential to introduce real rather than nominal rigidities, in other words to constrain the Home supply response to Foreign demand shocks.<sup>19</sup>

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<sup>17</sup> Chile's per capita GDP was roughly equal to world average per capita GDP during the relevant period. Due to the modeling asymmetries between Home and Foreign this equality is not automatically ensured in the model even when identical parameter values are chosen where possible.

<sup>18</sup> There is of course no evidence that would allow us to sensibly calibrate separate consumption and production shares for Chilean goods in the world economy.

<sup>19</sup> We make our by now familiar assumptions about output subsidies  $\zeta_h^*$  (paid by Home government) and lumps-sum taxes (equal to subsidies).

We therefore assume that Home import agents in Foreign solve the following simple intratemporal pricing-to-market problem:

$$\underset{m_t^{ports^*,i}}{Max} \quad P_t^{h^*,i} m_t^{ports^*,i} (1 + \zeta_h^*) - \frac{P_t^x}{S_t} m_t^{ports^*,i} - \frac{P_t^x}{S_t} G_{m,t}^* - \frac{P_t^x}{S_t} m_t^{ports^*} \omega_t^{h^*}, \quad (36)$$

subject to quantity adjustment costs

$$G_{m,t}^* = \frac{\phi_h^*}{2} \frac{\left(m_t^{ports^*,i} - \bar{m}^{ports^*}\right)^2}{\bar{m}^{ports^*}}, \quad (37)$$

and subject to a CES-type demand that implies

$$P_t^{h^*,i} = P_t^{h^*} \left( \frac{m_t^{ports^*,i}}{\bar{m}^{ports^*}} \right)^{-\frac{1}{\theta_h^*}}. \quad (38)$$

The adjustment cost (37) ensures that persistent deviations of the export volume from its steady state value can cause persistent and potentially much larger deviations of export prices from their steady state. We obtain the pricing condition

$$p_t^{h^*} = p_t^x \left( 1 + \phi_h^* \left( \frac{m_t^{ports^*} - \bar{m}^{ports^*}}{\bar{m}^{ports^*}} \right) \right). \quad (39)$$

The dividends of these import agents are part of the export revenue of Home. In Foreign per capita terms they equal

$$d_t^* = (p_t^{h^*} - p_t^x) m_t^{ports^*} - p_t^x \frac{\phi_h^*}{2} \frac{\left(m_t^{ports^*} - \bar{m}^{ports^*}\right)^2}{\bar{m}^{ports^*}}. \quad (40)$$

## 2.6 Governments

In presenting the Home government's budget constraint we net out, for simplicity, the mutually offsetting output subsidies to and lump-sum taxes on firms. We are left with

$$\tilde{B}_t + J_t = i_{t-1} \tilde{B}_{t-1} + J_{t-1} + T_t + \zeta_w \int_0^1 W_t^i L_t^i di. \quad (41)$$

We assume that the initial stock of government bonds is equal to zero. Furthermore, we assume that the government's fiscal policy is Ricardian, specifically lump-sum transfers adjust to balance the budget on a period-by-period basis:

$$T_t + \zeta_w \int_0^1 W_t^i L_t^i di = J_t - J_{t-1}. \quad (42)$$

This implies that government debt remains in zero net supply at all times,  $\tilde{B}_t = 0 \forall t$ . The same assumptions are made about Foreign fiscal policy.

Our main interest is in different monetary policy rules permitting different degrees of exchange rate flexibility. The first monetary policy we consider is **exchange rate targeting**:<sup>20</sup>

$$\varepsilon_t = \bar{\pi} . \quad (43)$$

The second is **inflation targeting**, with the target variable denoted by  $\pi_t^{tg}$ . In practice the latter is invariably a version of the consumer price index (CPI). But it is well-known that setting the target equal to overall CPI inflation,  $\pi_t^{tg} = \pi_t$  is far from optimal. The reason is that monetary policy should aim to stabilize inflation only in domestic production sectors that are subject to nominal rigidities, while allowing the nominal exchange rate to realign external relative prices following a shock. This suggests that inflation in international and export goods should be excluded from the targeted inflation variable. We therefore assume

$$\pi_t^{tg} = \tilde{\pi}_t = (\pi_t^n)^{\tilde{\sigma}_n} (\pi_t^v)^{\tilde{\sigma}_v} (\pi_t^m)^{\tilde{\sigma}_m} , \quad \tilde{\sigma}_j = (\bar{p}^j \bar{y}^j) / \sum_{i=n,v,m} (\bar{p}^i \bar{y}^i) , \quad j = n, v, m , \quad (44)$$

where the weights on the three inflation sub-indices sum to one and correspond to the relative weights of the respective goods in the overall consumption basket. We specify our baseline monetary rule under inflation targeting as a conventional inflation forecast based rule<sup>21</sup>

$$i_t = (i_{t-1})^{\lambda_i} \left( \frac{\bar{\pi}}{\beta} \right)^{1-\lambda_i} \left( \frac{\pi_{4,t+3}^{tg}}{\bar{\pi}} \right)^{(1-\lambda_i)\lambda_\pi} \left( \frac{gdp_t^{fisher}}{gdp_{ss}^{fisher}} \right)^{(1-\lambda_i)\lambda_y} , \quad (45)$$

$$\pi_{4,t}^{tg} = (\pi_t^{tg} \pi_{t-1}^{tg} \pi_{t-2}^{tg} \pi_{t-3}^{tg})^{\frac{1}{4}} , \quad (46)$$

where  $gdp_t^{fisher}$  is Fisher-indexed real GDP, and the subscript  $ss$  indicates the steady state value..

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<sup>20</sup> Exchange rate targeting is sometimes modeled as an exchange rate term that enters an interest rate rule. This may be appropriate for exchange rate targeters in industrialized countries, but in many emerging markets a fixed exchange rate is implemented simply by a central bank buying and selling foreign exchange at a fixed parity.

<sup>21</sup> We will also briefly consider an interest difference rule, where  $\lambda_i = 1$ , and  $\tilde{\lambda}_\pi, \tilde{\lambda}_y$  are the coefficients on inflation and the output gap.

The coefficient  $\lambda_\pi$  determines the response of nominal interest rates to deviations of three quarters ahead year-on-year target inflation  $\pi^{tg}$  from the inflation target  $\bar{\pi}$ . The coefficient  $\lambda_y$  determines the response of nominal interest rates to the current year-on-year output gap.

Monetary policy in Foreign is assumed to always follow an inflation targeting rule, and we will hold the Foreign interest rate rule constant when considering different monetary policy options for Home. We assume that the monetary policy rule for Foreign is identical in form and calibration to that for Home, except of course for the definition of the respective target variables.

## 2.7 Equilibrium and Balance of Payments

*An equilibrium satisfies the following conditions:*

(1) *Households maximize lifetime utility (1) and its foreign equivalent, given prices and the set of government policies.*

(2) *Firms maximize the present discounted value of lifetime cashflows (24) and its Foreign equivalent, given prices and the set of government policies.*

(3) *Import agents maximize the present discounted value of lifetime cashflows (32) and (36), given prices and the set of government policies.*

(4) *All markets clear at all times:*

$$y_t^n = c_t^n + n_t^v + n_t^x + n_t^m, \quad (47)$$

$$y_t^m = c_t^m + m_t^n + m_t^v + m_t^x, \quad (48)$$

$$y_t^v = c_t^v + v_t^n + v_t^x + v_t^m + y_t^I, \quad (49)$$

$$y_t^k = I_t^n + I_t^m + I_t^x + I_t^k, \quad (50)$$

$$y_t^x = c_t^x + x_t^n + x_t^v + x_t^m + x_t^{ports} + \frac{1-\alpha}{\alpha} G_{m,t}^*, \quad (51)$$

$$m_t^{ports} = c_t^f + y_t^f + f_t^n + f_t^v + f_t^x + f_t^m, \quad \tilde{m}_t^{ports} = \frac{1-\alpha}{\alpha} x_t^{ports*}, \quad (52)$$

$$y_t^* = c_t^{f*} + I_t^* + x_t^{ports*}, \quad (53)$$

$$m_t^{ports*} = c_t^{h*} + h_t^* = \frac{\alpha}{1-\alpha} x_t^{ports}, \quad (54)$$

$$L_t = l_t^n + l_t^m + l_t^x + l_t^k. \quad (55)$$

Equations (41), (8) and the definition of equilibrium imply that the following aggregate budget constraint, or current account equation, must hold:

$$b_t = b_{t-1} \frac{i_{t-1}^* (1 + \xi_{t-1})}{\pi_t^*} + p_t^x x_t^{ports} - \tilde{m}_t^{ports} + \frac{1 - \alpha}{\alpha} d_t^* - d_t . \quad (56)$$

The model's five shock processes are given by autoregressive processes. We have

$$S_t^x = (1 - \rho^x) \bar{S}^x + \rho^x S_{t-1}^x + \bar{S}^x u_t^x , \quad x = c, I, a, p, tot .$$

### 3 Calibration and Openness

We calibrate the model for the quarterly frequency. Home is calibrated so that Chile, as in the data, represents 0.25% of world GDP, or  $\alpha = 0.0025$ , where the maintained assumption is that per capita GDP is equal in Home and Foreign, which is again roughly true in the data. The world real interest rate is set equal to 5.5% per annum by assuming the corresponding value for  $\beta^*$ . This is close to the value typically used in the U.S. real business cycle literature. We fix the steady state net foreign liabilities to GDP ratio at 50%, which is in line with Chilean data for the mid-1990s,<sup>22</sup> and we parameterize the risk premium function so as to generate an average risk premium  $\bar{\xi}$  at that level of indebtedness of around 1% per annum, consistent with Chilean sovereign bond spread data for the 1990s. We obtain this by choosing  $\omega_2 = 15$ ,  $\omega_3 = 1.8$ ,  $\omega_4 = -135$  and  $\omega_1$  set to ensure that  $\xi$  is zero at a zero net foreign asset position.

In household preferences we choose a standard baseline calibration, with consumption habits equal to  $v = 0.7$  and a wage elasticity of labor supply equal to  $1/\psi = 1$ . The parameter  $\kappa$  is fixed by normalizing the baseline deterministic steady state labor supply to one. The depreciation rate of physical capital is 10% per annum, and investment adjustment costs are  $u_I = 25$ . Households set a wage markup of 10%,  $\theta_w = 11$ . Firms' average markups in price setting are the same,  $\bar{\theta}_p = 11$ , and import agents' markups are 5%,  $\theta_f = 21$ . The Calvo price and wage stickiness parameters  $\delta_p$  and  $\delta_w$  are, in line with recent empirical estimates in the literature, set equal to 0.85, implying an average contract length of over 6

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<sup>22</sup> It has since dropped very significantly.

quarters. For the price stickiness of import agents  $\delta_f$  we assume either  $\delta_f = 0$  (producer currency pricing) or  $\delta_f = 0.85$  (local currency pricing). The consensus in Chile is that foreign suppliers do not price significantly to the Chilean market, which suggests  $\delta_f \simeq 0$ . We nevertheless explore local currency pricing because this is of some theoretical interest in the light of the recent literature. The inflation target is set at 3% per annum for Foreign and 4% for Home. We maintain all of the foregoing parameters unchanged as we vary trade openness.

The calibration of the economy's production functions (20) and (29), and of the consumption aggregator (2), is described in detail in a separate Data Appendix. Here we give a brief overview. Production functions are calibrated using Chilean national accounts data for 1996 that contain value added tables and input-output tables for 73 different industries.<sup>23</sup> These are classified into our four sectors by choosing appropriate criteria concerning their use as investment goods, their export shares, and their imports shares. The Cobb-Douglas coefficients  $\alpha_j^\iota$  are the expenditure shares of labor, capital and intermediate goods  $\iota$  in the gross expenditure of the consolidated industry  $j$ . They are given by Table 1. Next we calculate  $\gamma = 0.309$  for the final investment goods production function (29) and for the consumption aggregator (2) we have  $\sigma_f = 0.093$ ,  $\sigma_n = 0.742$ ,  $\sigma_v = 0.044$ ,  $\sigma_x = 0.033$  and  $\sigma_m = 0.088$ . The share of direct imports is therefore far higher in production than in consumption.

The above baseline calibration, when applied to our model, implies an imports to GDP ratio of 32.7%. We designate this ratio as our baseline measure of openness. It depends on the six Home international goods share parameters of the model, five for production and one for consumption, namely  $\alpha_n^f$ ,  $\alpha_v^f$ ,  $\alpha_x^f$ ,  $\alpha_m^f$ ,  $\gamma$  and  $\sigma^f$ . We vary openness by continuously recalibrating the economy's steady state. We do so by multiplying each of the international goods share parameters by a scaling factor while changing all remaining production and consumption share parameters accordingly. We do this subject to the constraints that the sum of all share parameters equals one, and that *relative to each other* the non-international goods

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<sup>23</sup> Chile only publishes national accounts with the detail required for our calibration at five-yearly intervals, and at the time of starting this project the most recent data available were for 1996.

share parameters do not change. Because in each case we also maintain the requirement that the real exchange rate is normalized to one and per capita GDP levels are equal, increasing (decreasing) the scaling factor in Home requires a simultaneous change in the steady state of the Foreign import share parameter  $\bar{S}^{tot}$  that increases (decreases) demand for imports from Home. The scaling factor is allowed to differ across industries to account for the fact that the import goods sector and the final investment goods sector already have very large and similar import shares in the baseline and can therefore not be expected to increase their import shares at the same rate as the other sectors as the economy becomes more open. We therefore recalibrate the share coefficients as  $\alpha_n^f \tilde{s}$ ,  $\alpha_v^f \tilde{s}$ ,  $\alpha_x^f \tilde{s}$ ,  $\sigma^f \tilde{s}$ ,  $\alpha_m^f \tilde{s}^{\frac{2}{3}}$  and  $\gamma \tilde{s}^{\frac{2}{3}}$ , with  $\tilde{s}$  chosen to yield the desired degree of openness in steady state. Overall, this procedure ensures that openness can be varied continuously while leaving other structural characteristics of the economy unchanged.

We evaluate welfare for economies with steady state imports to GDP ratios of 1%, 5%, 10%, and thereafter in 10% increments up to a maximum of 150%. For each of these economies we assume that the standard deviation of shocks is the same as in our baseline economy. This is of course a nontrivial assumption, as a *given country's* growth in trade openness may well involve increasing diversification and therefore a lower standard deviation of foreign demand shocks.<sup>24</sup> Our experiments are therefore best thought of as applicable to a comparison *across countries* that share certain structural characteristics, but that differ in trade openness. For example, all oil or grain exporters are exposed to the same volatility of world oil or grain prices, but their dependence on such exports may differ greatly.

Finally we turn to the calibration of the five shock processes, the quantity adjustment cost parameter  $\phi_x$  and the parameters of the monetary policy reaction function. We do so by matching the autocorrelations and standard deviations of a number of log-linearly detrended Chilean macroeconomic aggregates for the period 1999Q3-2007Q4. This has been a period of relative stability for Chile, without major changes in trend growth. Table 2 reports the results of our calibration. Table 3 shows the associated model variance decomposition (in

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<sup>24</sup> But this is not necessarily the case, as the case of many oil exporters attests.

percent). The associated parameter values are  $\rho^{tot} = 0.7$ ,  $\rho^p = \rho^c = \rho^I = 0$ ,  $\rho^a = 0.5$ ,  $\sigma^{tot} = 0.07$ ,  $\sigma^p = 0.04$ ,  $\sigma^c = 0.0225$ ,  $\sigma^I = 0.0075$ ,  $\sigma^a = 0.01$ ,  $\phi_x = 2.0$ ,  $\lambda_i = 0.8$ ,  $\lambda_\pi = 1.6$ ,  $\lambda_y = 0.025$ .

A few comments are in order. First, in order to generate a terms of trade standard deviation even close to what is seen in the data, the model needs to assign a major role to foreign demand shocks, which in our calibration end up being responsible for almost three quarters of the variation in GDP and even more of the variation in demand. The reason is that the terms of trade shock experienced by Chile around 2003 has indeed been massive, terms of trade having doubled and remained persistently high. Second, the import adjustment cost function, while capable of generating high terms of trade volatility, necessarily gives rise to similar persistence in both the quantities and prices of exports, while in the data prices are far more persistent than quantities. We adopted a compromise with relatively high persistence. This is hard to resolve without further complicating the model. Third, the model produces too much persistence of demand and GDP relative to the data. This is due to the assumption of consumers with infinite horizons, who smooth their consumption in response to the foreign asset accumulation following terms of trade shocks. A model with liquidity constrained agents might be able to address this issue. Fourth, shocks to consumption, investment and technology have comparatively minor effects. This will be reflected in the welfare analysis, which will therefore concentrate almost exclusively on terms of trade and price markup shocks.

In a comparison of exchange rate and inflation targeting the baseline calibration may give an unfair advantage to exchange rate targeting because the coefficients of the monetary rule may not be at or at least near welfare maximizing values. For the final calibration the coefficients of the monetary rule (45) are therefore changed. We use our baseline calibration for all preference and technology parameters and then perform a grid search over the coefficients  $\lambda_i$ ,  $\lambda_\pi$  and  $\lambda_y$ , evaluating welfare for each grid point. We find that the optimal  $\lambda_y$  is approximately zero, the optimal  $\lambda_i$  is close to (from below) but not equal to one, while welfare is fairly flat in  $\lambda_\pi$  unless it gets close to one. We therefore adopt a calibration that

takes this into account while remaining close to specifications that are actually likely to be adopted in practice:  $\lambda_i = 0.9$ ,  $\lambda_\pi = 1.5$  and  $\lambda_y = 0$ .

For our final welfare computations we changed one more variable relative to the baseline. A steady state net foreign liabilities to GDP ratio of zero provides a more natural starting point than the 50% in our baseline, but we will return to the 50% case as a very important part of our sensitivity analysis. In the following section we will refer to our finalized baseline calibration as the standard model.

## 4 Model Evaluation

### 4.1 Impulse Responses

To build intuition we first report impulse responses for a number of economies, concentrating on terms of trade and price markup shocks. To maximize the contrast we compare impulse responses of the lowest and highest possible imports to GDP ratios. In the case of price markup shocks the lowest ratio is 10% because our welfare computations did not converge for 1% or 5%. For terms of trade shocks a 1% minimum is presented. In each plot the impulse response for inflation targeting is a solid line and that for exchange rate targeting is a broken line.

Figure 1 shows a very closed economy for our standard model and subjected to a one standard deviation terms of trade shock. In this case the positive wealth effect of the shock is very small because it only affects production equal to one percent of steady state GDP. The changes in the current account and net foreign assets are therefore minimal. But the wealth effect is not small relative to the very small external trade volumes of the country, which can therefore only be reequilibrated by a sizeable real exchange rate appreciation. Under inflation targeting this happens through a nominal appreciation with almost no change in the real interest rate. Demand and output are therefore barely affected, they only respond to the small wealth effect. But under exchange rate targeting the real appreciation requires higher domestic inflation and, given the inability to affect the nominal interest rate, a significantly

lower real interest rate. This stimulates investment, the capital stock and labor supply, as well as consumption. This additional volatility is clearly suboptimal.

Figure 2 shows the same shock when the economy is highly open. The wealth effect of the shock is now very much larger, with net foreign assets rising by up to 5 percent. As a consequence the changes in demand are also much larger, and not just under exchange rate targeting but also under inflation targeting. But again the sizes of the wealth effect and of the underlying trade volumes have grown at essentially the same rate between Figure 1 and 2. The real exchange rate change required to reequilibrate trade is therefore of the same order of magnitude as in a closed economy, and so is the real interest differential between inflation and exchange rate targeting. Domestic inflation also rises by roughly the same amount as in Figure 1, despite the much larger surge in demand. The reason is that import prices constitute a much higher share of costs in the highly open economy, and these prices fall rather than rise in response to a terms of trade shock, thereby offsetting a larger rise in domestic costs. This is despite the fact that the central bank has already done the best it could possibly be expected to do by choosing a measure of domestic inflation that excludes export and direct import prices.<sup>25</sup> This “contamination” of the targeted measure of inflation in highly open economies limits the welfare gains available under inflation targeting. This insight is a critical benefit of the multisectoral production structure we have adopted - imagine a central bank trying to extract a measure of domestic costs from the tangle of input-output and factor supply channels that is still only a pale reflection of the real world. The only possibility may be wage inflation targeting, which we will discuss below.

Because of the similar profile of the real interest rate differential in Figure 2 compared to Figure 1, the differences between the determinants of welfare, that is between consumption and labor supply, are also similar, despite the overall larger magnitudes. But in this it does matter that the overall effects are so much larger, because given the curvature of the utility function a similar size difference is significantly more costly when it happens further away from steady state. This anticipates our finding that the welfare gains of flexible exchange

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<sup>25</sup> In practice the theoretical notion of targeting a purely domestic inflation rate has no usable counterpart in the data.

rates are increasing in trade openness.

This finding does however not hold for arbitrarily high openness. Eventually almost all domestic resources would be employed in the export sector, and imports would account for an extremely high cost share even of the “domestic” price index targeted by the central bank. At that point inflation targeting would become almost identical to exchange rate targeting. However, while we will find that this effect can account for some flattening of the marginal welfare gains of inflation targeting at high openness, the point at which the two regimes become indistinguishable is far beyond the empirically relevant range of trade to GDP ratios.

Figure 3 returns to our original baseline assumption of a 50% net foreign liabilities to GDP ratio, but in this case for the extremely closed economy. We observe that all the real effects of a terms of trade shock observed in Figure 1 are magnified dramatically, mostly for exchange rate targeting but also for inflation targeting. The reason is a very strong positive feedback effect between the wealth effect of higher export prices and the effect of the associated real appreciation on the real foreign debt burden. A large wealth effect combined with very small trade volumes causes increases in import volumes, and decreases in export volumes that are very large in percentage terms, and they therefore require much larger changes in real exchange rates than observed in Figure 1. This accounts for the dramatically larger real effects under exchange rate targeting. As we will see, this effect fades with increasing trade openness, as trade volumes come into balance with debt volumes. This will therefore turn out to be the one scenario where increasing trade openness reduces the welfare disadvantages of exchange rate targeting.

Figure 4 turns to price markup shocks, in this case for 10% trade openness. The size of these shocks - required to generate a empirically observed standard deviation of inflation that is in fact not excessively large - is very significant. They represent a distortion to domestic production that is clearly welfare reducing, and furthermore given sticky goods prices their effect on relative prices is far more persistent than the original shock. The optimal response of the economy to markup shocks is a commensurate reduction in demand. Under exchange rate targeting this is accomplished, because higher domestic prices cause a large

real appreciation and a corresponding increase in real interest rates. But under inflation targeting the nominal exchange rate is allowed to depreciate so much that the real exchange rate barely appreciates, leaving real interest rates significantly lower than under exchange rate targeting. In other words, under inflation targeting the central bank provides monetary accommodation to the price shock, and as a consequence demand contracts by far less, and in fact starts to expand after a few quarters. Therefore, as in Mundell-Fleming, under domestic nominal shocks a fixed exchange rate regime is more desirable than inflation targeting.

Figure 5 shows the same shock for the highly open economy. Unlike for the terms of trade shock, here we observe that the difference between the two regimes has become smaller. The reason is that price markup shocks only affect the domestic production sectors and exclude the competitive exports sector, which accounts for an increasing share of production as openness grows. The size of the distortionary shocks therefore declines with openness, and so does the disadvantage of inflation targeting.

To summarize, the impulse responses show that under our assumptions the shocks that favor inflation targeting, namely terms of trade shocks, become more important with openness, while the shocks that favor exchange rate targeting, price markup shocks, become less important with openness.

## 4.2 Welfare

The appendix explains how we compute the unconditional welfare differences between exchange rate targeting and inflation targeting. In the following figures the quantity reported along the horizontal axis represents the steady state imports to GDP ratio. The vertical axis shows the percentage reduction in consumption that would have to be suffered by agents under inflation targeting to make them indifferent to an exchange rate targeting regime.<sup>26</sup>

Figure 6 shows the overall result under all five shocks, followed by the contributions of terms of trade and price markup shocks. We observe that virtually all of the overall welfare result is accounted for by these two shocks. Under terms of trade shocks the net

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<sup>26</sup> See Lucas (1987).

welfare gain of inflation targeting is positive, and increasing in trade openness. Under price markup shocks the net welfare gain is negative, but also increasing in trade openness. For our particular calibration the latter effect dominates, with a welfare advantage of exchange rate targeting of between 0.5% and 0.2% of consumption.

However, we do not want to overemphasize this ranking. There are several reasons for this. First, as we will see, it depends on parameter values, and an exhaustive sensitivity analysis that explores the role of different parameters is far more interesting than one specific ranking. Second, we may have understated the role of terms of trade shocks. As shown above, our calibrated model does generate a high volatility of the terms of trade, but it is still below that of the data. Third, we may have overstated the role of price markup shocks. For example, an important alternative explanation for inflation volatility that is often applied in estimated DSGE models is measurement errors.

Figure 7 explores the factors that drive the effects of terms of trade shocks. An interest difference rule alternative to our chosen calibration of the monetary policy rule would imply strict price level targeting of the chosen price index (as long as the output coefficient remains at zero). It performs slightly worse than our rule. Under local currency pricing in the Home market the exchange rate loses part of its effectiveness in switching expenditures. This reduces the welfare gain from exchange rate flexibility especially for very open economies where expenditure on such imports is significant. The middle column explores the effects of utility function curvature. Without habit persistence welfare gains are significantly reduced, while with a lower intertemporal elasticity of substitution or a lower labor supply elasticity they increase significantly. The last column shows that the degree of wage stickiness has a fairly small effect on terms of trade related losses, while lower price stickiness significantly reduces the advantage of exchange rate flexibility. Finally, with a 50% net foreign liabilities to GDP ratio the welfare gain for a virtually closed (1%) economy rises from less than 0.1% of consumption to more than 0.8%, a very large number by the standards of this literature. As openness increases, for reasons explained above, the welfare gain declines, eventually to levels similar to the standard model.

Figure 8 explores the factors that drive the effects of price markup shocks. We only comment on the most interesting results. As for terms of trade shocks, and for similar reasons, there is a monotonically decreasing relationship between trade openness and the net welfare gain of inflation targeting at low levels of openness. Lower nominal rigidities in wage setting reduce the difference between the two monetary regimes, because they permit a more rapid adjustment of real wages following the shock. But lower nominal rigidities in price setting have the opposite effect, because they imply that any price markup shock has a much larger effect on aggregate inflation, which therefore becomes more volatile and causes greater distortions. At over 1% of consumption the associated losses are very large.

### **4.3 A Theoretical Alternative: Wage Inflation Targeting**

Figure 9 shows the performance of a wage inflation targeting rule, which is assumed to be identical to our conventional price inflation targeting rule except that  $\pi_t^{tg} = \pi_t^w$ , under price markup shocks.<sup>27</sup> Such shocks *ceteris paribus* reduce demand for domestic output and therefore domestic factors, thus putting downward pressure on wage inflation. This means that nominal interest rates fall rather than rise in the short run, which by itself would stimulate demand even relative to exchange rate targeting. Goods price inflation is therefore higher on impact but lower thereafter, thereby raising real interest rates and reducing the amount of monetary accommodation of the price markup shock. GDP and demand are therefore lower than even under exchange rate targeting, which turns out to be desirable from a welfare perspective. This is shown in Figure 10, where inflation targeting now outperforms exchange rate targeting under price markup shocks, and therefore also overall.

## **5 Summary**

We summarize our results by restating what, to the best of our knowledge, is the conventional wisdom in economics regarding the net welfare benefits of floating exchange rates, or more specifically of price inflation targeting, over fixed exchange rates. First, the

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<sup>27</sup> It was discussed above why a rule targeting domestic cost must be superior under terms of trade shocks.

net welfare gain is almost invariably positive unless financial frictions of some sort are introduced. And second, the net welfare gain is decreasing in a country's trade openness. There is a vast literature on the first point, but only very little on the second. We therefore set out mainly to more thoroughly investigate the second point, but in the process we found that we had valuable insights to offer also on the first. Namely, we found that if price markup shocks are large enough relative to terms of trade shocks, the net welfare gain of price inflation targeting can be negative. Our quantitative results did indeed produce a negative net gain for an economy with extraordinarily large terms of trade shocks and fairly moderate inflation volatility. As for the second point, we found that the net welfare gain is monotonically increasing in trade openness, with possibly a maximum, or "hump", in the welfare difference at very large levels of trade openness.

The intuition for this latter result can be stated in the simplest possible terms as follows: The more open the economy, the larger is the role of shocks that favor inflation targeting, namely terms of trade shocks that have much larger wealth effects in open economies, and the smaller is the role of shocks that favor exchange rate targeting, namely price markup shocks that affect a much smaller volume of production in open economies if the export sector is competitive, a reasonable assumption for many smaller economies and especially for raw materials exporters.

There are two exceptions to these results. The first is highly relevant in practice: If an economy whose trade volume is very small simultaneously has a very large foreign debt volume, then the net welfare gains of a flexible exchange rate become very large. And in this case they are decreasing in the level of trade openness.

Similar results hold for the second exception: Even in economies without debt, welfare gains of a flexible exchange rate become unambiguously positive, and decreasing in openness, if monetary policy can target wage rather than price inflation. But this is less relevant in practice because of concerns about the implementability, transparency and credibility of such a policy.

## Appendix: Welfare Computations

The period utility of an individual agent at time  $t$  is given by

$$u_t^i = (1 - v_c)S_t^c \ln(C_t - v_c C_{t-1}) - \frac{\kappa}{1 + \psi} (L_t^i)^{1+\psi},$$

where we have made use of the cashless limit assumption for money, and of the presence of complete contingent markets which implies  $C_t^i = C_t$ . The Technical Appendix shows that the unconditional expectation of period utility is

$$u_t = \int_0^1 u_t^i di = (1 - v_c)S_t^c \ln(C_t - v_c C_{t-1}) - \frac{\kappa}{1 + \psi} L_t^{1+\psi} \left( \frac{w_t}{\tilde{w}_t} \right)^{\theta_w(1+\psi)}, \quad (57)$$

where  $\tilde{w}_t = \tilde{W}_t / (S_t P_t^*)$  and  $\tilde{W}_t$  is

$$\tilde{W}_t = \left( \int_0^1 (W_t^i)^{-\theta_w(1+\psi)} di \right)^{\frac{-1}{\theta_w(1+\psi)}}. \quad (58)$$

Welfare is given by

$$\mathcal{W}_t = u_t + \beta \mathcal{W}_{t+1}. \quad (59)$$

Finally, we define the compensating consumption variation  $ccv$  as the percentage reduction in consumption that agents would be willing to tolerate under inflation targeting while remaining indifferent between the unconditional expectations of welfare under inflation targeting and exchange rate targeting. Denote the unconditional expectations of welfare under the two regimes as  $E\mathcal{W}^{ET}$  and  $E\mathcal{W}^{IT}$ . Furthermore, denote the compensated welfare under inflation targeting as

$$E\tilde{\mathcal{W}}^{IT} = E\mathcal{W}^{IT} + \frac{(1 - v_c) \ln(1 - \frac{ccv}{100})}{(1 - \beta)}.$$

The compensating variation is obtained by equating  $E\mathcal{W}^{ET}$  and  $E\tilde{\mathcal{W}}^{IT}$ , which yields the following expression:

$$ccv = 100 \left( 1 - \exp \left( \frac{(\beta - 1)}{(1 - v_c)} (E\mathcal{W}^{IT} - E\mathcal{W}^{ET}) \right) \right). \quad (60)$$

We consider mostly second order approximations of the model to compute expected welfare, but we also recompute our baseline under a third order approximation to explore whether this leads to significant differences. Unconditional expectations can be computed in several ways, by using the stochastic fixed point implemented in DYNARE++<sup>28</sup>, the second-order accurate approximation used in DYNARE, or by way of simulations. In this paper we

<sup>28</sup> See Juillard and Kamenik (2005).

present results using the stochastic fixed point.<sup>29</sup> This is the solution of a system of nonlinear equations that represents the state in which agents decide to stay if ex-ante they expect to be in the fully stochastic economy but ex-post no shocks ever materialize. In this sense it is the precise equivalent of the deterministic steady state in log-linearly approximated models.

## Bibliography

- [1] Benigno, G. and Benigno, P. (2003), “Price Stability in Open Economies”, *Review of Economic Studies*, **70**, 743-764.
- [2] Burstein, A., Eichenbaum, M. and Rebelo, S. (2005), “Large Devaluations and the Real Exchange Rate”, *Journal of Political Economy*, **113(4)**, 742-84.
- [3] Calvo, G.A. (1983), “Staggered Prices in a Utility-Maximizing Framework”, *Journal of Monetary Economics*, **12**, 383-398.
- [4] Calvo, G.A. and Reinhart, C.M. (2001), “Fixing for Your Life”, in S. Collins and D. Rodrik, eds. , *Brookings Trade Forum 2000* (Washington, DC: Brookings Institution).
- [5] Calvo, G.A. and Reinhart, C.M. (2002), “Fear of Floating”, *Quarterly Journal of Economics*, **117(2)**, 379-408.
- [6] Campa, M and Goldberg, L. (2005), “Exchange Rate Pass-Through into Imports Prices”, *Review of Economics and Statistics*, **87(4)**, 679-690.
- [7] Corsetti, G. (2006), “Openness and the Case for Flexible Exchange Rates”, *CEPR Discussion Papers*, No. 5612.
- [8] Corsetti, G. and Pesenti, P. (2005), “International Dimensions of Optimal Monetary Policy”, *Journal of Monetary Economics*, **52(2)**, 281-305.
- [9] Devereux, M. and Engel, C. (2003), “Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility”, *Review of Economic Studies*, **70(4)**, 765-83.
- [10] Duarte, M. and Obstfeld, M. (2007), “Monetary Policy in the Open Economy Revisited: The Case for Exchange Rate Flexibility Restored”, *Journal of International Money and Finance* (forthcoming).
- [11] Elekdag, S. and Tchakarov, I. (2008), “Balance Sheets, Exchange Rate Policy, and Welfare”, *Journal of Economic Dynamics and Control*, **31(12)**.
- [12] Erceg, C., Henderson, D. and Levin, A. (2000), “Optimal Monetary Policy with Staggered Wage and Price Contracts”, *Journal of Monetary Economics*, **46**, 281-313.
- [13] Fleming, J.M. (1962), “Domestic Financial Policies under Fixed and Floating Exchange

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<sup>29</sup> Given the large size of the model and the very large number of required welfare evaluations in this paper, an adequate number of simulations would be computationally very costly.

- Rates”, *IMF Staff Papers*, **9**, 369-379.
- [14]Friedman, M. (1953), “The Case for Flexible Exchange Rates”, in: *Essays in Positive Economics*, Chicago: University of Chicago Press, 157-203.
- [15]Gali, J. and Monacelli, T. (2005), “Monetary Policy and Exchange Rate Volatility in a Small Open Economy”, *Review of Economic Studies*, **72**, 707-734.
- [16]Goldberg, P. and Knetter, M. (1997), “Goods Prices and Exchange Rates: What Have We Learned?”, *American Economic Review*, **35(3)**, 1243-1272.
- [17]Hau, H. (2000), “Exchange Rate Determination: The Role of Factor Price Rigidities and Nontradables”, *Journal of International Economics*, **50**, 421-447.
- [18]Hau, H. (2002), “Real Exchange Rate Volatility and Economic Openness: Theory and Evidence”, *Journal of Money, Credit and Banking*, **34(3)**, 611-630.
- [19]Juillard, M. and Kamenik, O. (2005), “Solving DSGE Models: Approximation About the Stochastic Steady State”, Working Paper, CEPREMAP and Czech National Bank.
- [20]Kollmann, R. (2004), “Welfare Effects of a Monetary Union: The Role of Trade Openness”, *Journal of the European Economic Association*, **2 (2-3)**, 289-301.
- [21]Lane, P.R. (1997), “Inflation in Open Economies”, *Journal of International Economics*, **42**, 327-347.
- [22]Lucas, R.E. Jr. (1987), *Models of Business Cycles* (Oxford, New York: Basil Blackwell).
- [23]McKinnon, R. (1963), “Optimum Currency Areas”, *American Economic Review*, **53**, 717-725.
- [24]Mundell, R.A. (1963), “Capital Mobility and Stabilization Policy under Fixed and Flexible Exchange Rates”, *Canadian Journal of Economics*, **29**, 475-485.
- [25]Obstfeld, M. and Rogoff, K. (2002), “Global Implications of Self-Oriented National Monetary Rules”, *Quarterly Journal of Economics*, **117(2)**, 503-35.
- [26]Schmitt-Grohe, S. and Uribe, M. (2003), “Closing Small Open Economy Models”, *Journal of International Economics*, **61**, 163-185.
- [27]Smets, F., and Wouters, R. (2002). “Openness, Imperfect Exchange Rate Pass-Through and Monetary Policy”, *Journal of Monetary Economics*, **49**, 947-81.
- [28]Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton: Princeton University Press.
- [29]Yun, T. (1996), “Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles”, *Journal of Monetary Economics*, **37**, 345-370.

$\alpha_j^i$	<i>n</i> -Sector	<i>v</i> -Sector	<i>x</i> -Sector	<i>m</i> -Sector
<i>Labor</i>	0.3414	0.2691	0.1778	0.1783
<i>Capital</i>	0.4287	0.2369	0.3571	0.2574
<i>Nontraded</i>	-	0.1331	0.2741	0.2163
<i>Investment</i>	0.0302	-	0.0132	0.0081
<i>Export</i>	0.0175	0.0523	-	0.0512
<i>Import</i>	0.1027	0.1971	0.0911	-
<i>International</i>	0.0796	0.1115	0.0867	0.2888

Table 1: Production Function Share Coefficients

	Standard <i>Data</i>	Deviation <i>Model</i>	Auto- <i>Data</i>	Correlation <i>Model</i>
<i>GDP</i>	1.49	1.47	0.80	0.90
<i>Inflation (yoy)</i>	1.24	1.19	0.65	0.72
<i>Consumption</i>	2.52	2.52	0.90	0.96
<i>Investment</i>	5.92	5.91	0.84	0.97
<i>Real Exports</i>	2.67	2.66	0.28	0.68
<i>Terms of Trade</i>	10.94	7.30	0.89	0.72

Table 2: Moments - Data versus Model

	$u^{tot}$	$u^p$	$u^c$	$u^I$	$u^a$
<i>GDP</i>	72.7	10.9	10.2	4.7	1.6
<i>Inflation (yoy)</i>	9.0	89.7	0.2	0.3	0.8
<i>Consumption</i>	83.7	3.5	12.6	0.1	0.1
<i>Investment</i>	80.2	6.8	0.3	12.7	.
<i>Real Exports</i>	99.4	0.3	.	0.1	0.2
<i>Terms of Trade</i>	99.9	.	.	.	.

Table 3: Model Variance Decomposition

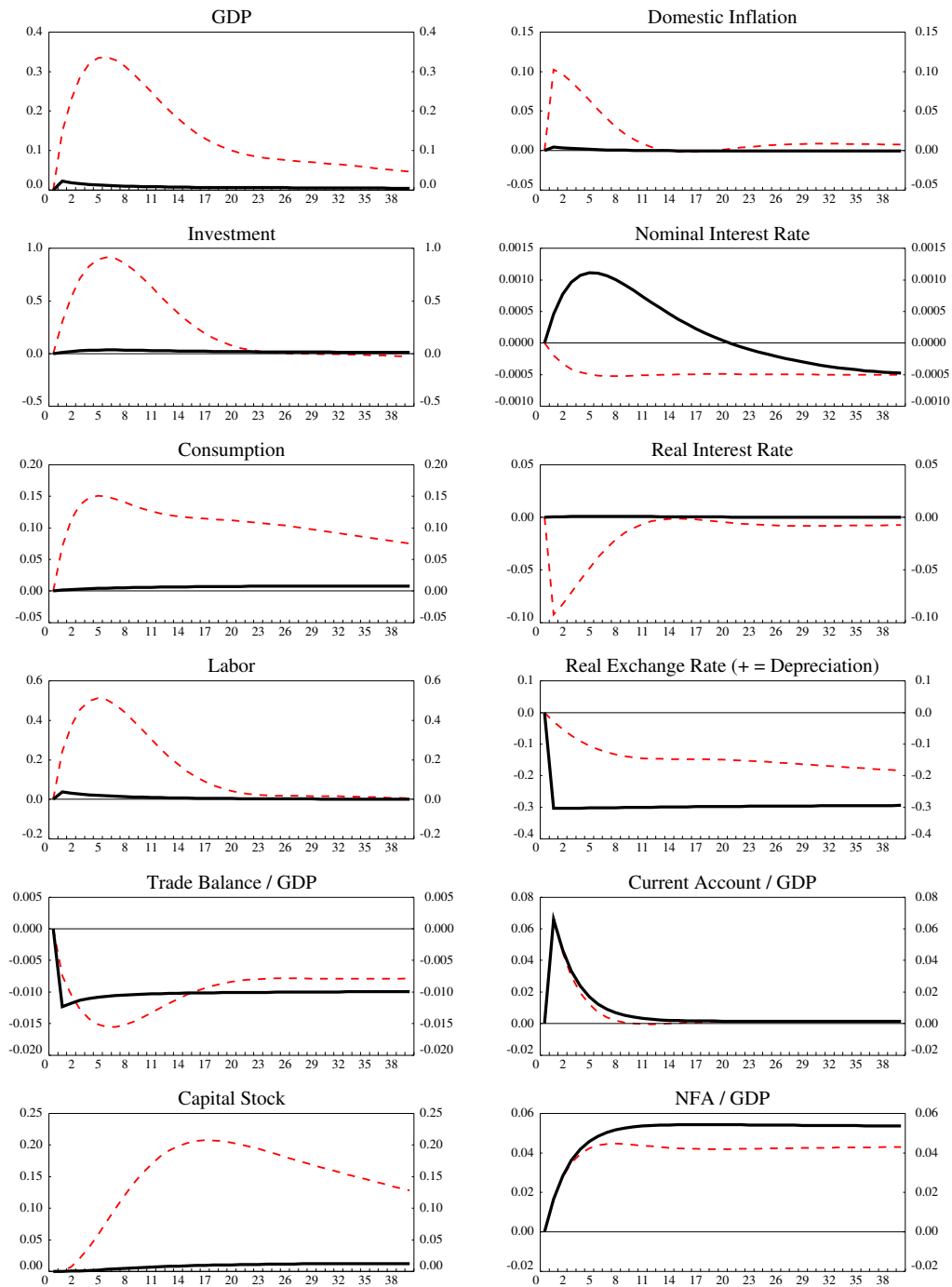


Figure 1: Terms of Trade Shock, 1% Openness

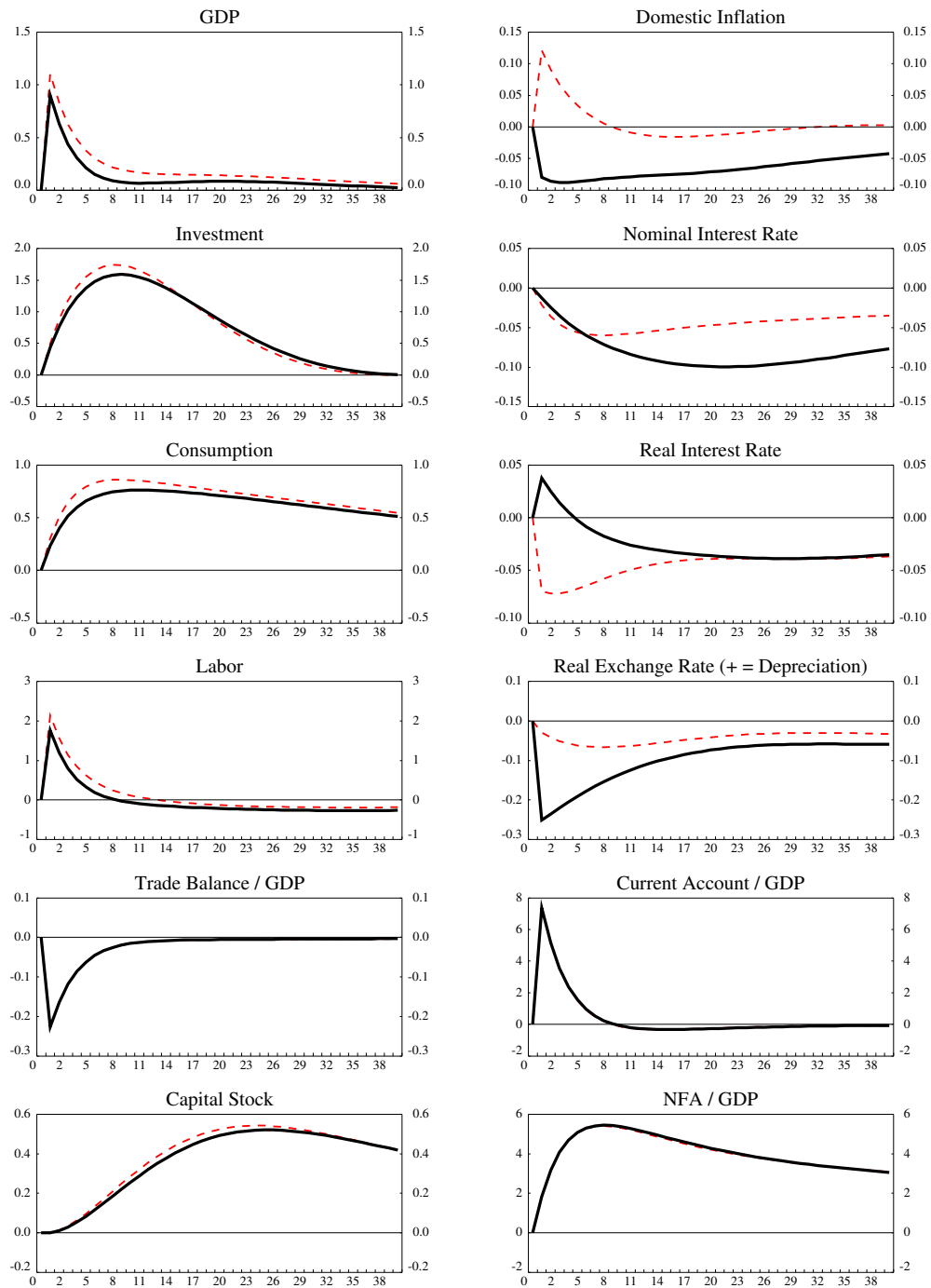


Figure 2: Terms of Trade Shock, 150% Openness

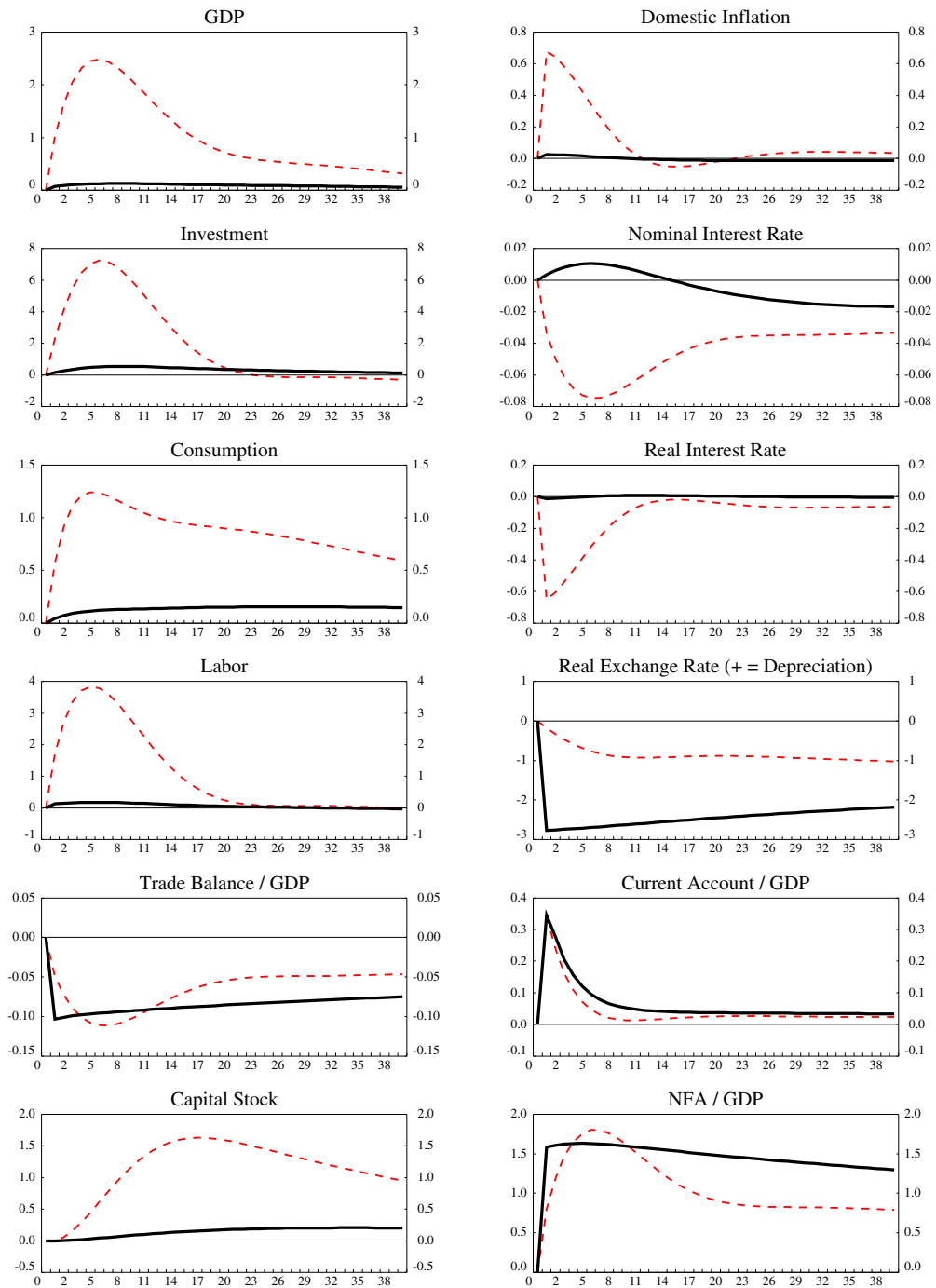


Figure 3: Terms of Trade Shock, 1% Openness, 50% NFL

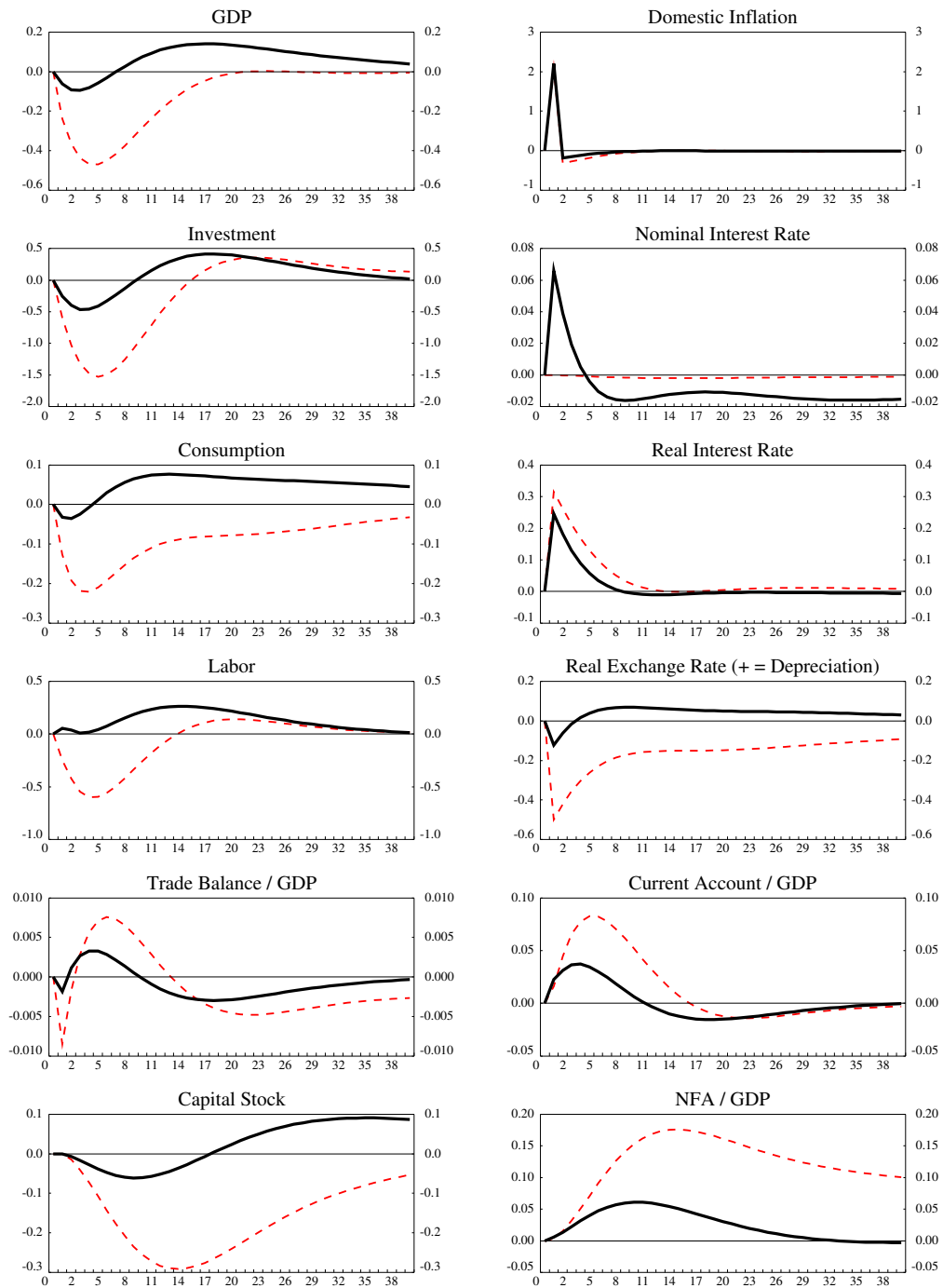


Figure 4: Inflation Shock, 10% Openness

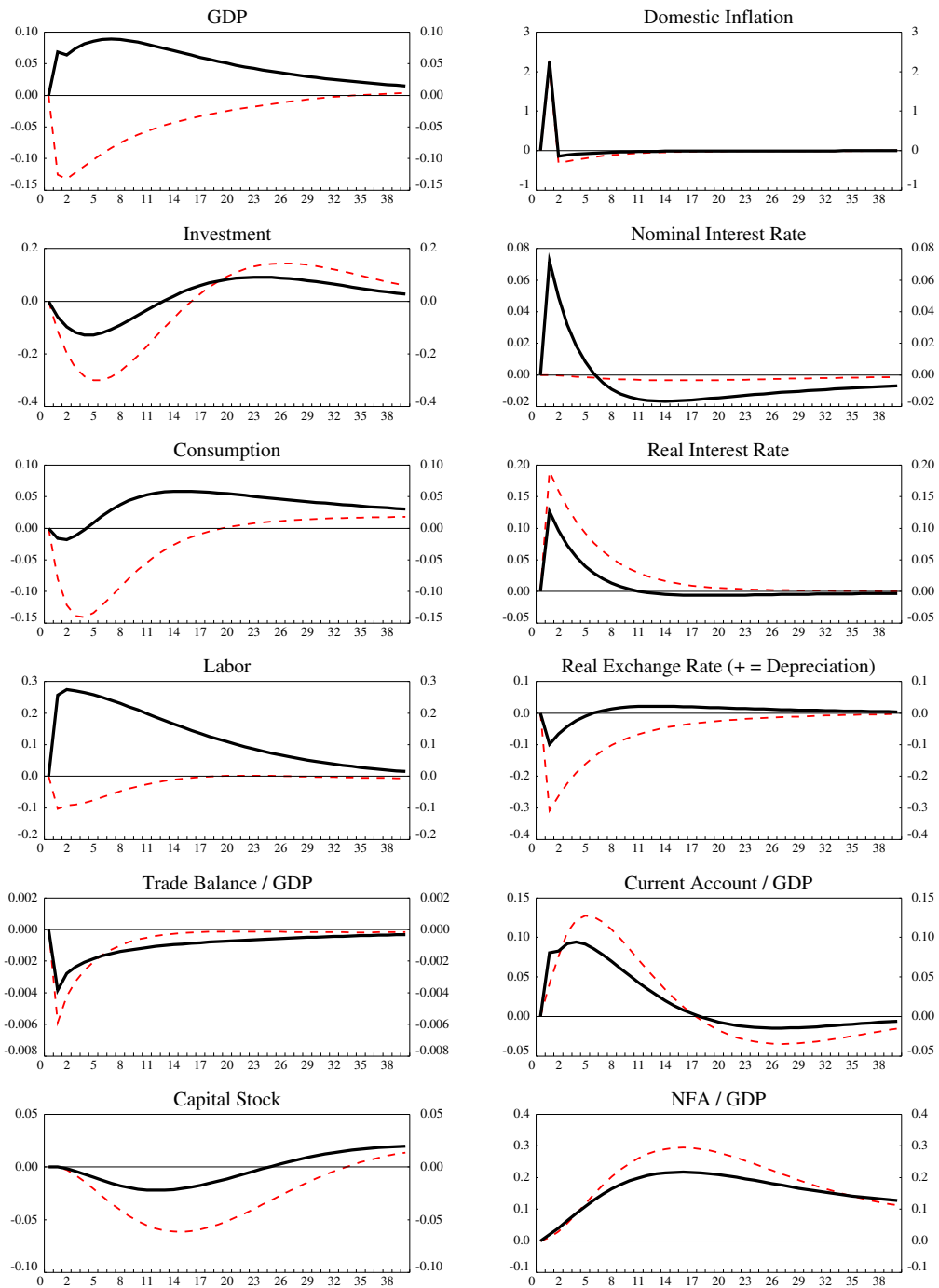


Figure 5: Inflation Shock, 150% Openness

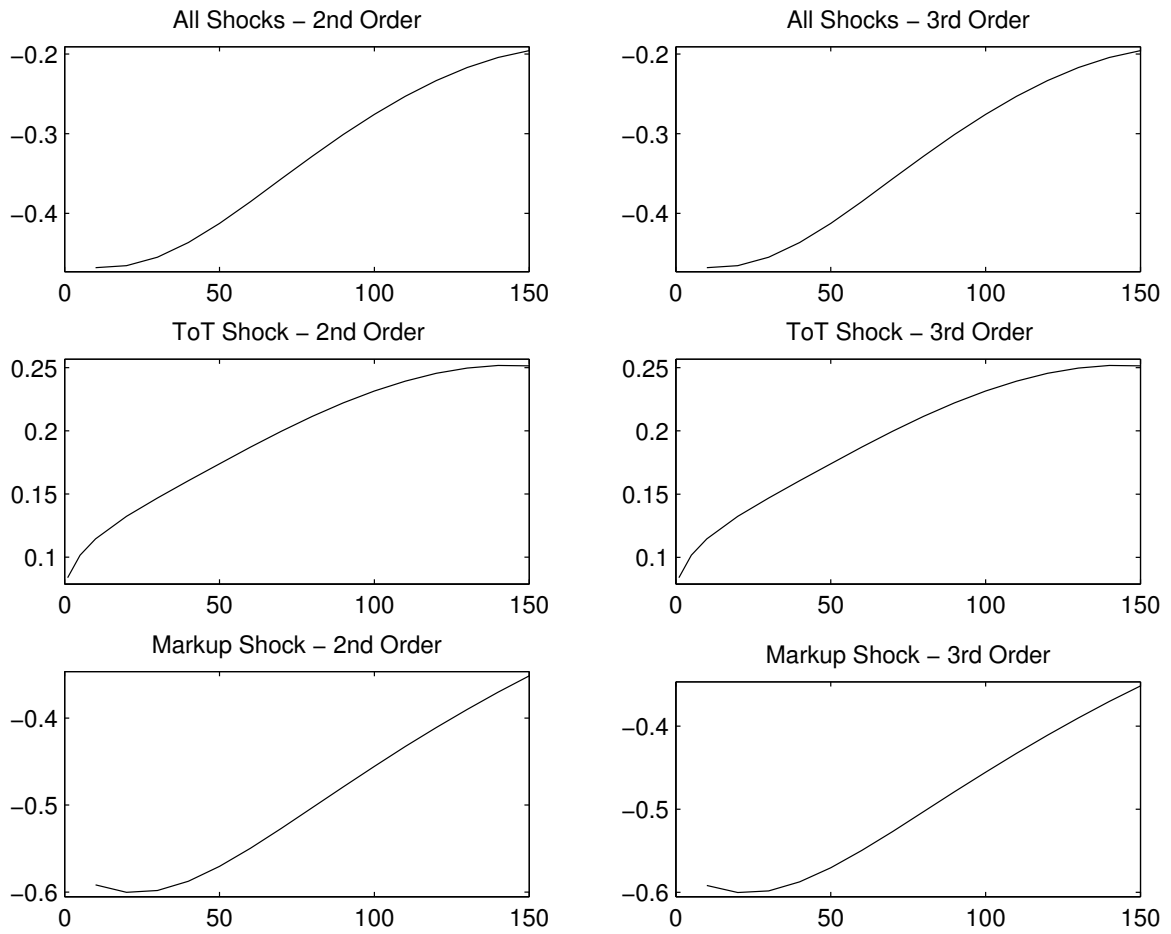


Figure 6: Welfare Results - All Shocks

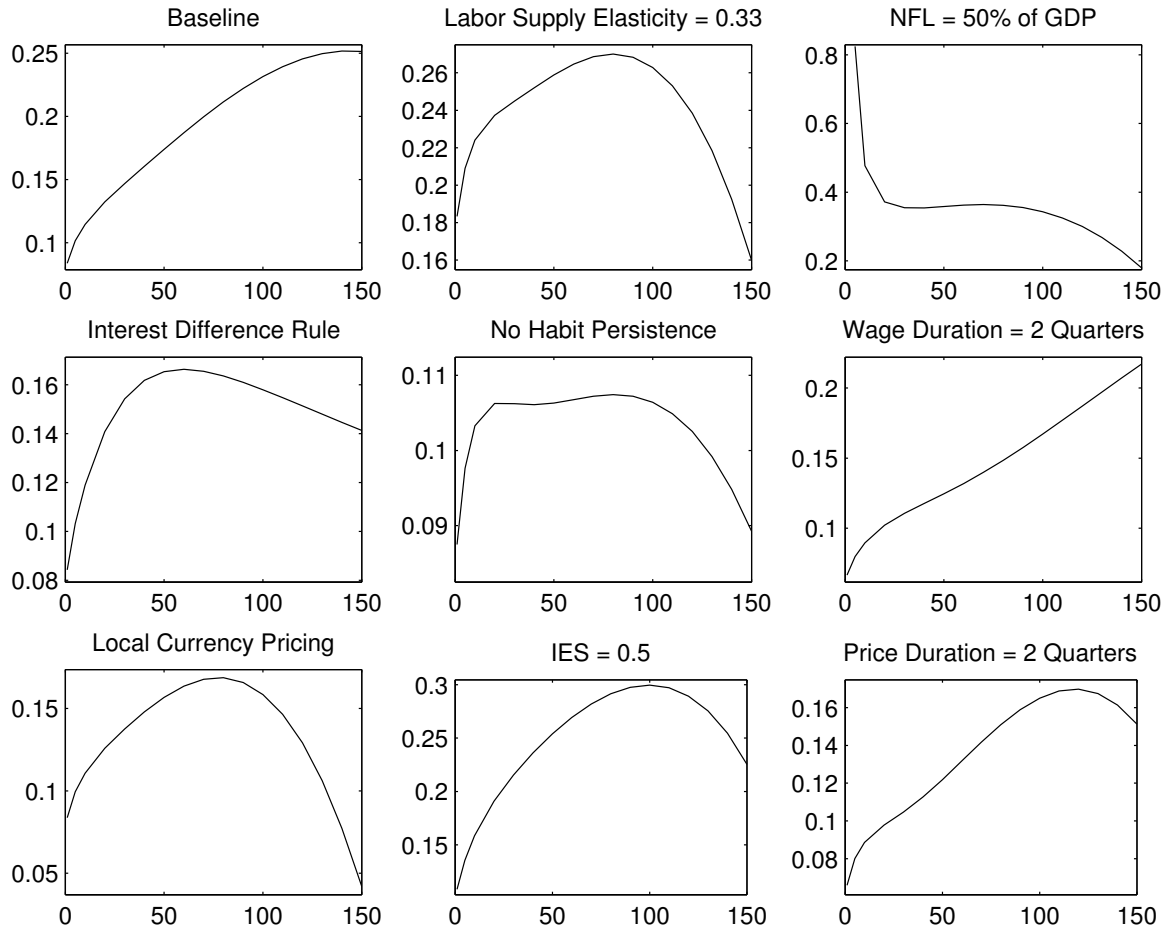


Figure 7: Welfare Results - Terms of Trade Shocks

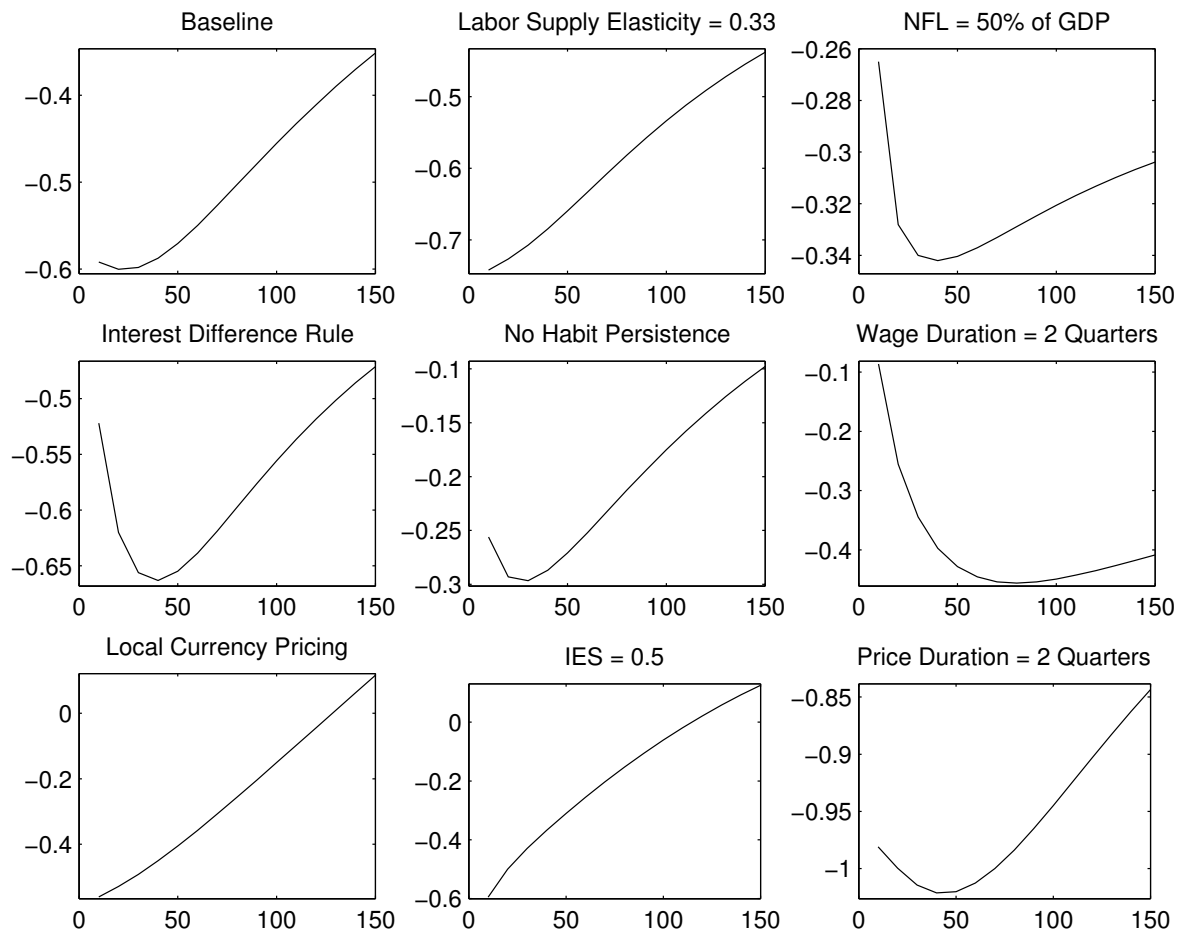


Figure 8: Welfare Results - Price Markup Shocks

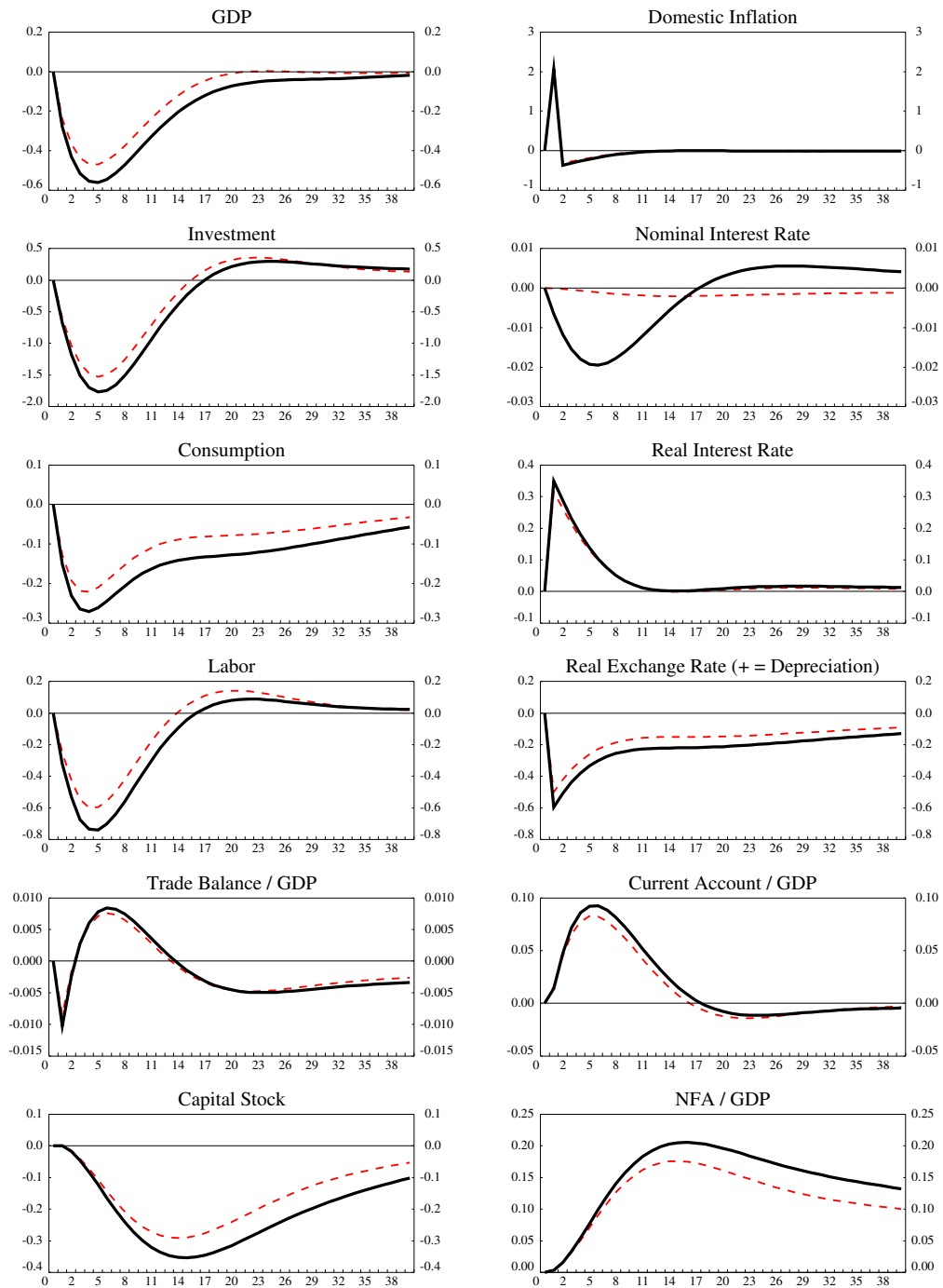


Figure 9: Inflation Shock, 10% Openness, Wage Inflation Targeting

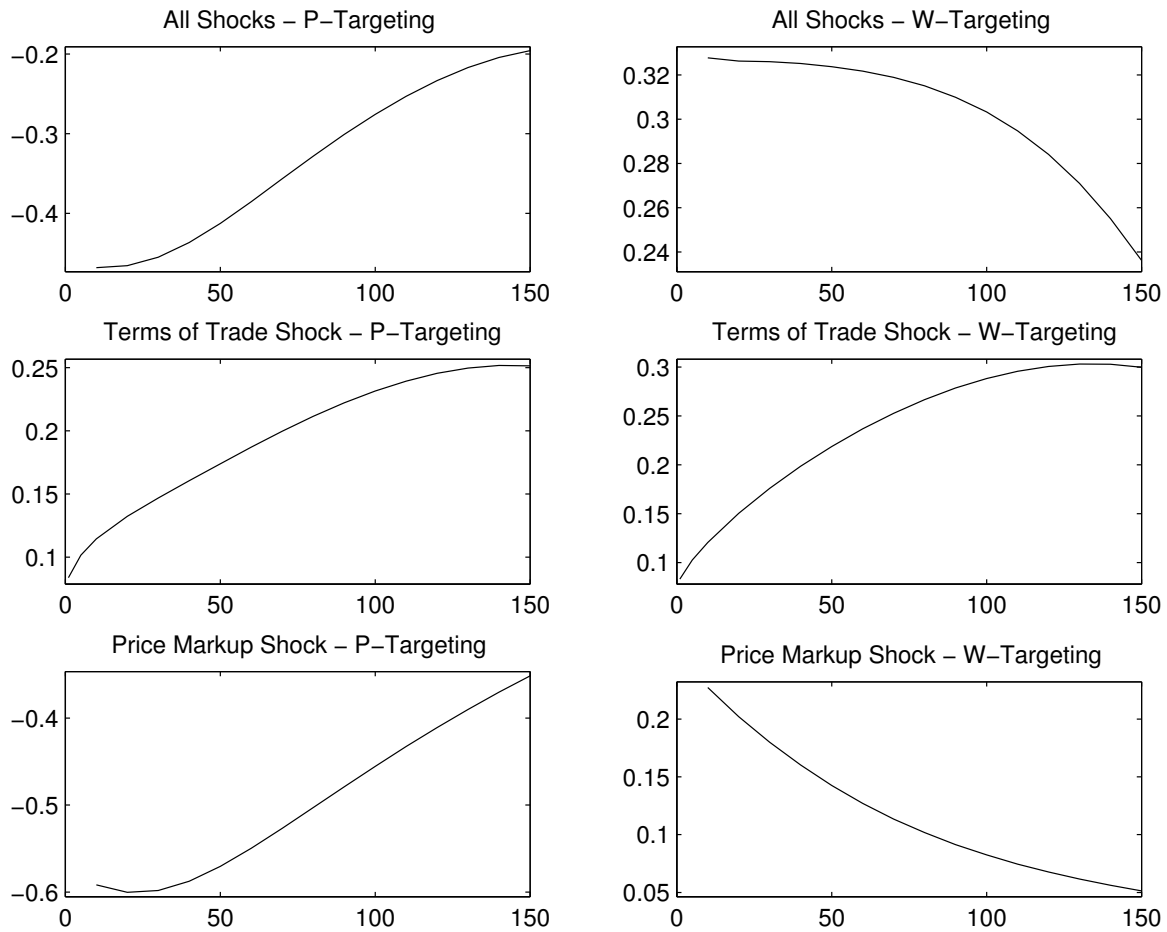


Figure 10: Welfare Results - Price Inflation Targeting versus Wage Inflation Targeting