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Foreign Exchange Intervention and the Dutch Disease

by Julia Faltermeier, Ruy Lama, and Juan Pablo Medina

I N T E R N A T I O N A L M O N E T A R Y F U N D

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Foreign Exchange Intervention and the Dutch Disease

Prepared by Julia Faltermeier, Ruy Lama, and Juan Pablo Medina¹

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Abstract

We study the optimal foreign exchange (FX) intervention policy in response to a positive terms of trade shock and associated Dutch disease episode in a small open economy model. We find that during a Dutch disease episode tradable production drops below the socially optimal level, resulting in lower welfare under learning-by-doing (LBD) externalities. FX reserves accumulation improves welfare by preventing a large appreciation of the real exchange rate and by inducing an efficient reallocation between the tradable and non-tradable sectors. For an empirically plausible parametrization of LBD externalities, the model predicts that in response to a 10 percent increase in commodity prices FX reserves should increase by 1.5 percent of GDP. We also find that the welfare gains from optimally using FX reserves are twice as high as the gains from relying only on monetary policy. These results suggest that FX intervention is a beneficial policy to counteract the loss of competitiveness during a Dutch disease episode.

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Author's E-Mail Address: julia.faltermeier@upf.edu; rlama@imf.org; juan.medina@uai.cl.

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1. Introduction

Small open economies face recurrent fluctuations in their terms of trade. During episodes of positive terms of trade shocks, the equilibrium response of the economy is a real exchange rate appreciation. When this appreciation induces a contraction of the manufacturing sector, an economy is usually diagnosed as experiencing a Dutch disease.¹ By itself, the reduction in manufacturing production does not necessarily reduce welfare, as it reflects the natural adjustment of an economy to higher wealth and the optimal response of the economy is to shift resources from the tradable to the non-tradable sector. However, policymakers typically are concerned about this adjustment process to the extent that the decline of manufacturing production might be more persistent than what is warranted by higher commodity prices. This could be the case, for instance, when learning-by-doing externalities (LBD) are present in the production process of manufactured goods. In this context, one of the key questions policymakers face is: What is the optimal policy response to a Dutch disease episode? In this paper, we analyze the macroeconomic benefits from relying on Foreign Exchange (FX) intervention to cope with the Dutch disease symptoms during a boom in commodity prices. We also compare the welfare gains from conducting optimal FX intervention policy against the benefits from relying only on monetary policy.

Figure 1 illustrates the most recent episode of a boom in commodity prices in six Latin American economies. Most of these economies responded to higher commodity prices in a way predicted by the standard textbook model. As a result of an improvement in the terms of trade, and higher export revenue, the exchange rate appreciated in most economies. With a stronger currency, there was a loss of competitiveness and a decline in manufacturing production as a share of Gross Value Added (GVA). Interestingly, most of these economies accumulated FX reserves during this episode, in part due to precautionary motives, but also to counteract the adverse effects of large exchange rate movements on tradable output. A relevant policy question related to this episode is if the observed accumulation of FX reserves was a

¹The term "Dutch Disease" was introduced to describe the situation experienced in the Netherlands in the 1960s after the discovery of gas deposits in the North Sea. The discovery of natural resources was followed by an appreciation of the real exchange rate and a crowding out of the manufacturing exports. More recently, the term is also used to describe the negative effects on exports induced by foreign aid, remittances, capital inflows or an improvement in the terms of trade.

welfare-improving policy for these economies, or if alternatively, the central bank in these economies should have refrained from intervening in the FX market, and allowed the exchange rate to absorb the positive terms of trade shock.

To study the optimal FX intervention policy in a Dutch disease environment, we develop a multi-sector small open economy model with nominal rigidities and learning-by-doing externalities. The learning-by-doing externalities generate an inefficient decline in tradable production in response to a boom in commodity prices. In the model, the central bank relies on two instruments to stabilize the economy during the commodity boom: the policy rate and FX reserves. We evaluate the welfare gains derived from using each of these instruments, and the optimal combination of both of them. To illustrate the mechanisms operating in our model, we calibrate the model parameters to the Brazilian economy, which in the same way as other Latin American economies, experienced a loss of competitiveness during the boom in commodity prices.

In our quantitative simulations we find that during a boom in commodity prices, the optimal policy consists of a large and sustained accumulation of FX reserves.² In particular, for an empirically plausible calibration of learning-by-doing externalities, the central bank accumulates FX reserves by 1.5 percent of GDP in response to a 10 percent increase in commodity prices. We also find that the welfare gains from optimally relying on FX reserves during a commodity boom are about 0.04 percent of lifetime consumption, about half of the cost of business cycles calculated by Lucas (1987), whereas the gains from relying exclusively on using the policy rate are about 0.02 percent of lifetime consumption. Consistent with the literature on FX reserves (Ostry et al., 2016), our paper finds that FX reserves are a valuable policy instrument for macroeconomic stabilization purposes.

Our paper is related to two lines of research: the work on Dutch disease and FX intervention. Related to the first one, we follow the work of Van Wijnbergen (1984), Krugman (1987), and Caballero and Lorenzoni (2014) and evaluate alternative policy interventions to cope with the Dutch disease.

²In our model we assume a persistent but transitory commodity terms of trade shock and temporary effects of the learning-by-doing externality on tradable output. Hence, we rely on a rational expectations solution method of a first-order approximation of the equilibrium conditions around a well-defined steady state. For Dutch disease episodes with permanent effects on the real side of the economy, we would need to rely on global methods in order to evaluate the optimal policy responses.

Related to the second one, we follow Ostry et al. (2016), Benes et al. (2015), Canzoneri and Cumby (2014), and Liu and Spiegel (2015), by developing a small open economy model where FX intervention plays an important role as a macroeconomic stabilization tool. This paper contributes to the literature by analyzing the role of FX intervention in insulating a small open economy from Dutch disease effects during a boom in commodity prices.

The rest of the paper is organized as follows. Section 2 describes the small open economy model. Section 3 discusses the calibration strategy for the model. Section 4 presents the quantitative findings of the paper and a sensitivity analysis of key parameters in the model. Finally, section 5 concludes.

2. A Small Open Economy Model

We develop a small open economy model with nominal rigidities and LBD externalities. The model is built along the lines of Christiano et al. (2005), Smets and Wouters (2007), and Adolfson et al. (2007). We depart from these models by introducing LBD externalities in the tradable sector as in Cooper and Johri (2002) and Lama and Medina (2012), and by introducing FX intervention as in Liu and Spiegel (2015). The model captures two features of economies that can be exposed to a Dutch disease: a large commodity sector and LBD externalities in the manufacturing sector. This last feature generates a misallocation of resources during a boom of commodity prices. The central bank can stabilize the economy during a boom in commodity prices by relying on FX intervention and the policy rate. In the appendix we described the model's equilibrium conditions.

2.1. Households

There is a continuum of households indexed $h \in [0, 1]$, and the preferences of each household are defined over consumption and labor:

$$U_t(h) = E_t \left[\sum_{i=0}^{\infty} \beta^i u(C_{t+i}(h), L_{t+i}(h)) \right], \quad (1)$$

where $\beta \in [0, 1]$ is the discount factor, $C_t(h)$ is consumption of the final

good and $L_t(h)$ is the labor supply of household h . The household budget constraint is given by:

$$P_t C_t(h) + E_t \{d_{t,t+1} \mathcal{D}_{t+1}(h)\} + B_t(h) + \mathcal{E}_t B_t^*(h) =$$

$$W_t(h) L_t(h) + \Pi_t + T_t + \mathcal{D}_t(h) + (1 + i_{t-1}) B_{t-1}(h) + \mathcal{E}_t B_{t-1}^*(h) (1 + i_{t-1}^*) \Theta(B_{t-1}^*)$$
(2)

where $\mathcal{D}_{t+1}(h)$ is a state-contingent domestic bond, $B_t(h)$ a non-contingent domestic bond, and $B_t^*(h)$ a non-contingent foreign bond. $d_{t,t+1}$ is the price of one-period domestic contingent bonds divided by the probability of the occurrence of the state, and i_t is the short-term domestic interest rate. The state-contingent domestic bond allows full insurance against income fluctuations across households, which implies that the marginal utility of income, and consumption, are exactly the same across households. Households receive income from working at the wage rate $W_t(h)$, profits Π_t from firms, and lump sum transfers T_t from the central bank profits/losses. \mathcal{E}_t denotes the nominal exchange rate, P_t the price of final consumption goods, i_t^* the foreign interest rate, and $\Theta(B_{t-1}^*)$ an endogenous risk premium, which depends on the lagged aggregate stock of foreign debt B_{t-1}^* . As in Schmitt-Grohé and Uribe (2003), the role of the risk premium is to induce stationarity in the model.

2.2. Wage Setting Process

As in Erceg et al. (2000), we assume that each household supplies a differentiated labor service $L_t(h)$. A representative firm (or "employment agency") combines the differentiated labor inputs according to a Dixit-Stiglitz aggregator:

$$L_t = \left[\int_0^1 (L_t(h))^{\frac{\epsilon_L - 1}{\epsilon_L}} dh \right]^{\frac{\epsilon_L}{\epsilon_L - 1}}$$

where L_t is the aggregate labor supply. As shown by Erceg et al. (2000), the demand curve for each type of labor is given by:

$$L_t(h) = \left(\frac{W_t(h)}{W_t} \right)^{-\epsilon_L} L_t$$
(3)

$$W_t = \left[\int_0^1 (W_t(h))^{1-\epsilon_L} dh \right]^{\frac{1}{1-\epsilon_L}}$$

Households set wages in a staggered fashion as in Calvo (1983). In each period, a fraction $(1 - \theta_W)$ of households renegotiate their wage contract. The household will set the optimal wage W_t^* such that it maximizes the expected lifetime utility subject to the budget constraint (2) and the labor demand schedule (3), while W_t^* remains in place:

$$\text{Max } E_t \left\{ \sum_{i=0}^{\infty} (\beta\theta_W)^i u(C_{t+i|t}, L_{t+i|t}) \right\},$$

where $x_{t+i|t}$ is the variable x in period $t + i$ for households that choose wages optimally in period t .

2.3. Firms

There are four types of firms in the economy: final good producers, intermediate good producers, retailers and capital producers. Next, we describe the structure of these firms.

2.3.1. Final Good Producers

Producers of the final good Y_t^F combine a tradable intermediate input (Y_t^{DT}) and non-tradable intermediate input (Y_t^{DN}) according to a constant elasticity of substitution (CES) production function:

$$Y_t^F = \left[\alpha_Y^{1/\eta_Y} (Y_t^{DT})^{\frac{\eta_Y-1}{\eta_Y}} + (1 - \alpha_Y)^{1/\eta_Y} (Y_t^{DN})^{\frac{\eta_Y-1}{\eta_Y}} \right]^{\frac{\eta_Y}{\eta_Y-1}}, \quad (4)$$

where α_Y and η_Y are the share of tradable inputs and the elasticity of substitution between tradable and non-tradable inputs, respectively. The price of the final good is given by:

$$P_t = \left[\alpha_Y (P_t^T)^{1-\eta_Y} + (1 - \alpha_Y) (P_t^N)^{1-\eta_Y} \right]^{\frac{1}{1-\eta_Y}}, \quad (5)$$

where P_t^T and P_t^N are the price of tradable and non-tradable inputs, respectively.

2.3.2. Intermediate Good Producers

A representative firm produces intermediate non-tradable goods Y_t^N , according to a Cobb-Douglas production function in a competitive market:

$$Y_t^N = A_t^N [K_t^N]^{\alpha_N} [L_t^N]^{1-\alpha_N}, \quad (6)$$

where A_t^N , K_t^N , L_t^N , denote aggregate productivity, capital, and labor inputs, respectively.

The tradable sector is subject to LBD externalities as in Cooper and Johri (2002). The production function of the representative firm is given by:

$$Y_t^T = A_t^T H_t^{\lambda_T} ([K_t^T]^{\alpha_T} [L_t^T]^{1-\alpha_T})^{1-\lambda_T}, \quad (7)$$

where A_t^T , K_t^T , and L_t^T , denote aggregate productivity, capital, and labor. H_t is the level of organizational capital in the tradable sector which evolves according to the following law of motion:

$$H_{t+1} = [H_t]^{\phi_T} [Y_t^T]^{\mu_T}, \quad (8)$$

where $(1 - \phi_T)$ is the depreciation rate of organizational capital, and μ_T is the elasticity of organizational capital with respect to tradable output. We restrict the exponents of the law of motion to the case of constant returns to scale, that is $\phi_T + \mu_T = 1$. Notice that in equation (8), the representative firm takes as given the aggregate tradable production, which is the source of the externality. In this paper we follow the same interpretation of organizational capital as in Lev and Radharkrishnan (2003): "Organization capital is thus an agglomeration of technologies -business practices, processes and designs, including incentive and compensation systems- that enable some firms to consistently extract out of a given level of resources a higher level of product and a lower cost than other firms". Hence in the model, lower production leads to a decline in organizational capital which reduces the efficiency of the tradable sector.

2.3.3. Retailers in the Non-Tradable Sector

Firms in the retail sector sell non-tradable goods (Y_t^{DN}) in two separate stages. First, there is an assembler that combines the differentiated intermediate non-tradable goods $Y_t^{DN}(j)$, where $j \in [0, 1]$. The technology is a constant elasticity of substitution function given by:

$$Y_t^{DN} = \left(\int_0^1 Y_t^{DN}(j)^{\frac{\epsilon_N-1}{\epsilon_N}} dj \right)^{\frac{\epsilon_N}{\epsilon_N-1}}, \quad (9)$$

where ϵ_N is the elasticity of substitution between varieties of goods. The resulting demand for the j th intermediate non-tradable good is:

$$Y_t^{DN}(j) = \left(\frac{P_t^N(j)}{P_t^N} \right)^{-\epsilon_N} Y_t^{DN}, \quad (10)$$

$$P_t^N = \left(\int_0^1 P_t^N(j)^{1-\epsilon_N} dj \right)^{\frac{1}{1-\epsilon_N}}.$$

Second, retailers purchase the homogenous intermediate good and differentiate it into a continuum of goods. Each retailer sets her price on a staggered basis as in Calvo (1983). In each period, a fraction $(1 - \theta_N)$ of retailers set their prices optimally while the remaining fraction do not change their prices. The optimal price P_t^{N*} chosen by each retailer maximizes the expected present value of profits:

$$E_t \left[\sum_{i=0}^{\infty} (\theta_N)^i \Lambda_{t,t+i} (P_t^{N*} - P_{t+i}^{WN}) Y_{t+i}^{DN}(j) \right], \quad (11)$$

where $\Lambda_{t,t+i}$ is the stochastic discount factor defined as $\Lambda_{t,t+i} = \beta^i (C_t - hC_{t-1}) / (C_{t+i} - hC_{t+i-1}) (P_t / P_{t+i})$ and P_t^{WN} is the wholesale price of the non-tradable intermediate good. The aggregate price of non-tradable goods evolves according to:

$$P_t^N = \left[\theta_N (P_{t-1}^N)^{1-\epsilon_N} + (1 - \theta_N) (P_t^{N*})^{1-\epsilon_N} \right]^{\frac{1}{1-\epsilon_N}}. \quad (12)$$

2.3.4. Capital Producers

Firms in this sector produce and rent sector-specific capital to producers in the tradable and non-tradable sectors. The aggregate investment good is defined in terms of the final good. The representative capital-producer firm solves the following problem for each sector $J = T, N$:

$$V_t^J = \max_{K_{t+i}^J, I_{t+i}^J} E_t \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} (R_{K,t+i}^J K_{t+i}^J - P_{t+i}^F I_{t+i}^J) \right\},$$

subject to the law of motion of physical capital:

$$K_{t+1}^J = (1 - \delta)K_t^J + S\left(\frac{I_t^J}{I_{t-1}^J}\right)I_t^J, \quad (13)$$

where V_t^J the present discounted value of profits, δ is the depreciation rate of capital in sector J , $R_{K,t}^J$ is the rental rate of capital in sector J , and $S(\cdot)$ characterizes the adjustment cost for investment.³ The optimal allocation of capital across sectors will be determined by two Euler equations (See appendix).

2.4. Commodity sector

We assume that the exports of commodities X_t in this economy evolve exogenously according to the following stochastic process:

$$X_t = [X_{t-1}]^{\rho_x} [X_0]^{1-\rho_x} \exp(\varepsilon_t^x), \quad (14)$$

where $\varepsilon_t^x \sim N(0, \sigma_x^2)$ is a stochastic shock and ρ_x measures the persistency of the process. We assume that the commodity price P_t^x follows the stochastic process:

$$P_t^x = [P_{t-1}^x]^{\rho_{px}} [P_0^x]^{1-\rho_{px}} \exp(\varepsilon_t^{px}). \quad (15)$$

where $\varepsilon_t^{px} \sim N(0, \sigma_{px}^2)$ is a stochastic shock and ρ_{px} measures the persistency of commodity prices.⁴ Income from the commodity sector is given by $P_t^x X_t$, which is fully transferred to households.

2.5. Monetary Policy and Foreign Exchange Intervention

Monetary policy is characterized by a Taylor-type rule:

³Investment adjustment costs, as in Christiano et al. (2005), satisfy the following conditions: $S(1) = 1$, $S'(1) = 0$, $S''(1) = -\mu_S < 0$. This assumption generates inertia in investment that is consistent with a time-to-build specification.

⁴In our model a Dutch disease can be generated by either an increase in the quantity of exported commodities X_t or alternatively an increase in the price of commodities P_t . Both shocks will generate identical results. For simplicity we focus our analysis on price shocks, and assume that the quantity of commodity exports is constant.

$$\left(\frac{1+i_t}{1+\bar{i}}\right) = \left(\frac{Y_t}{\bar{Y}}\right)^{\psi_y} \left(\frac{\pi_t^N}{\bar{\pi}}\right)^{\psi_{\pi^N}} \left(\frac{e_t}{\bar{e}}\right)^{\psi_e}, \quad (16)$$

where i_t , Y_t , $\pi_t^N = P_t^N/P_{t-1}^N$, and $e_t = \mathcal{E}_t/\mathcal{E}_{t-1}$ are the nominal interest rate, GDP, the non-tradable inflation rate, and the depreciation rate, respectively. \bar{Y} , $\bar{\pi}$, \bar{e} , and \bar{i} are the steady state values of GDP, inflation, nominal depreciation, and the nominal interest rate, respectively.⁵ The parameters ψ_y , ψ_{π^N} , and ψ_e , denote the weights for output, non-tradable inflation, and the nominal depreciation in the policy rule, respectively.

FX intervention is conducted with a policy rule with the following specification:

$$\left(\frac{F_t^*}{\bar{F}^*}\right) = \left(\frac{Y_t}{\bar{Y}}\right)^{\theta_y} \left(\frac{\pi_t^N}{\bar{\pi}}\right)^{\theta_{\pi^N}} \left(\frac{e_t}{\bar{e}}\right)^{\theta_e}, \quad (17)$$

where F_t^* is the stock of foreign exchange reserves. The parameters θ_y , θ_{π^N} , and θ_e , denote the weights for output, non-tradable inflation, and nominal depreciation in the FX intervention rule, respectively. \bar{F}^* is the steady state stock of foreign exchange reserves. We assume that FX intervention is conducted in a sterilized fashion. For every $\mathcal{E}_t \Delta F_t^*$ units of foreign bonds purchased, the central bank issues ΔB_t units of domestic bonds ($\mathcal{E}_t \Delta F_t^* = \Delta B$). Also, in each period the central bank earns interest income $\mathcal{E}_t F_{t-1}^* (1 + i_{t-1}^*)$ on the stock of reserves from the previous period, and pays $B_{t-1} (1 + i_{t-1})$ to domestic bond holders. Profits or losses from FX intervention are rebated to the households through lump-sum transfers T_t . The asset transactions and financial income from sterilized FX intervention are summarized in the central bank's budget constraint:

$$\mathcal{E}_t F_t^* - B_t = \mathcal{E}_t F_{t-1}^* (1 + i_{t-1}^*) - B_{t-1} (1 + i_{t-1}) - T_t. \quad (18)$$

In the baseline scenario we assume $\theta_y = \theta_{\pi^N} = \theta_e = 0$, that is, the central bank does not intervene in the FX market. We then choose these coefficients optimally and quantify the welfare gains from conducting FX intervention during a Dutch disease episode.

⁵We assume a zero inflation target, implying that $\bar{\pi} = \bar{e} = 1$.

2.6. Market Clearing Conditions

In each period, markets for labor, capital, domestic and international bonds, intermediate and final goods clear. The market clearing condition for labor is given by:

$$L_t = L_t^N + L_t^T. \quad (19)$$

The market clearing condition for non-tradable goods is:

$$Y_t^{DN} \Xi_t^N = Y_t^N, \quad (20)$$

where Ξ_t^N captures a term of price dispersion of retailers in the non-tradable sector.

The aggregate domestic demand for final goods satisfies:

$$Y_t^F = C_t + I_t^T + I_t^N. \quad (21)$$

Total real GDP is defined as:

$$Y_t \equiv P_0^N Y_t^N + P_0^T Y_t^T + P_0^x X_t \quad (22)$$

where P_0^N and P_0^T are the steady state prices for the non-tradable and tradable inputs.

The law of one price holds for tradable goods:

$$P_t^T = \mathcal{E}_t P_t^*. \quad (23)$$

where P_t^* is the price of the tradable goods in foreign currency.

Combining the households and government budget constraints, we obtain the balance of payment identity:

$$B_t^* + F_t^* = (1 + i_{t-1}^*) (\Theta (B_{t-1}^*) B_{t-1}^* + F_{t-1}^*) + P_t^* (Y_t^T - Y_t^{DT}) + P_t^x X_t. \quad (24)$$

2.7. Calibration

The model is calibrated to the Brazilian economy as an example of a small open economy exposed to commodity shocks. Table 1 summarizes the key parameters from the calibration. Most of the parameters are obtained from the Central Bank of Brazil DSGE macroeconomic model (de Castro et al.,

2011) and are in line with the literature on open economy models. We calibrate the model so each period is one quarter. Household preferences are represented by the following utility function:

$$u(C_t - h\mathcal{H}_t, L_t) = \log(C_t - h\mathcal{H}_t) - \zeta_L \frac{L_t^{1+v}}{1+v}$$

where L_t is labor effort, C_t is its total consumption, and the external habit component is defined by $\mathcal{H}_t = C_{t-1}$. The habit formation parameter is set to $h = 0.74$ and the inverse of the Frisch elasticity of labor supply is set to $v = 1$.

The LBD parameters are obtained from Cooper and Johri (2002) and are consistent with the evidence for emerging economies from García-Cicco and Kawamura (2015). The share of organizational capital in the production function is $\lambda_T = 0.25$ which corresponds to a learning rate of 20 percent found in the literature.⁶ Consistent with the empirical evidence, the depreciation rate of organizational capital is $1 - \phi_T = 0.37$. We calibrate the elasticity of the risk premium with respect to debt to $\varrho = (\Theta'/\Theta)B_t^* = 0.4$, so that the current account increases by 0.4 percent of GDP in response to a scaling up of FX reserves of one percent of GDP as in Bayoumi et al. (2015). We set the steady value of foreign debt at 60 percent of GDP ($B_t^*/Y = 0.6$).

The commodity price and exports stochastic processes are estimated using data on commodity terms of trade from Gruss (2014) and data on commodity exports from the central bank of Brazil. We estimated the AR(1) processes for the sample period 1990:Q1-2014:Q4:

$$p_t^X = 0.95 p_{t-1}^X + \epsilon_t^{PX}, \quad \epsilon_t^{PX} \sim N(0, \sigma_{PX}^2), \quad \sigma_{PX} = 0.06. \quad (25)$$

$$x_t = 0.97 x_{t-1} + \epsilon_t^X, \quad \epsilon_t^X \sim N(0, \sigma_X^2), \quad \sigma_X = 0.13. \quad (26)$$

where p_t^X and x_t are the log-deviations of commodity prices and production in the commodity sector. Consistent with national accounts, the commodity sector represents 10 percent of GDP.

⁶Notice that a doubling of organizational capital, increases production by 2^{λ_T} . Following Cooper and Johri (2002), the learning rate is calculated as $2^{\lambda_T} - 1$. For our calibration, the learning rate is approximately 20 percent, consistent with the empirical evidence in micro-studies.

Table 1: Baseline Calibration

Parameter	Value	Description
β	0.99	Discount Factor
h	0.74	Habit Formation
$1/\nu$	1	Labor Supply Elasticity
α_Y	0.30	Share of Tradable Inputs - Final Good Sector
η_Y	1	Elasticity of Substitution - Final Good Sector
ϵ_N	11	Elasticity of Substitution - Non-tradable Sector
ϵ_L	11	Elasticity of Substitution - Employment Agency
θ_N	0.75	Calvo Parameter - Non-tradable Sector
θ_W	0.75	Calvo Parameter - Wages
α_N	0.30	Capital Share - Non-tradable Sector
α_T	0.30	Capital Share - Tradable Sector
δ	0.02	Depreciation Rate
μ_S	3.4	Investment Adjustment Cost
λ_T	0.25	Share of Organizational Capital
$1 - \phi_T$	0.37	Depreciation Rate of Organizational Capital
ψ_y	0.2	Output Coefficient - Taylor Rule
ψ_π	1.7	Inflation Coefficient - Taylor Rule
ψ_e	0.7	Depreciation Coefficient - Taylor Rule
θ_y	0	Output Coefficient - FXI Rule
θ_π	0	Inflation Coefficient - FXI Rule
θ_e	0	Depreciation Coefficient - FXI Rule
ϱ	0.4	Foreign Risk Premium Elasticity

3. Foreign Exchange Intervention and the Dutch Disease

3.1. Dutch Disease and Learning-by-Doing Externalities

Figure 2 shows the impulse response functions (IRFs) when the small open economy experiences a 10 percent increase in commodity prices, which corresponds to, approximately, two standard deviations shock. The solid line represents the model dynamics in the absence of LBD externalities (constant organizational capital), and the dashed line corresponds to the model dy-

namics when the LBD externalities are operating. The difference between the models shed light on the propagation mechanism of LBD externalities during a Dutch disease episode. Next we explain the model dynamics for each of these cases.

The solid lines illustrate the reallocation process experienced in response to a transitory increase in commodity prices. Consistent with a standard multi-sector model, higher commodity prices increase the demand for both tradable and non-tradable goods. Taking into account that the international price of tradable goods is given for a small open economy, the increase in demand for non-tradable goods will generate higher prices in that sector and hence a real exchange rate appreciation. As a result of this change in relative prices there is a reallocation of resources from the tradable to the non-tradable sector. The demand for tradable goods is satisfied with imports from the rest of the world, which leads to a deterioration of the trade balance. While the theoretical effect on GDP is ambiguous, since the increase in non-tradable production is offset by a decline in tradable production, for our parametrization we observe a decline in output.

The dashed lines now show how the model dynamics change when we take into account the effects of LBD externalities. To better understand the effects of the externalities, it is important to revisit equations (7-8). In response to lower production of tradable goods, the stock of organizational capital declines, which exacerbates the initial negative impact on tradable production. This endogenous decline in organizational capital is isomorphic to a decline in tradable sector productivity. There are two main effects derived from the LBD externalities. First, there is a real exchange depreciation in response to a lower productivity in the tradable sector. This response is akin to the Balassa-Samuelson effect. In response to lower tradable productivity, there is an increase in the relative price of tradable goods. Since the price of non-tradable goods is sticky, the equilibrium response of the economy is a nominal and real exchange rate depreciation. Second, there is a further decline in tradable production which reduces aggregate demand and induces a deterioration of the tradable balance. In sum, LBD externalities amplify the decline of the tradable sector with negative spillovers to the rest of the economy. Next we evaluate the role of policy in correcting this externality.

3.2. Dutch Disease and Optimal Policy Rules

In this section we evaluate the performance of a set of policy rules implemented during a boom in commodity prices. While our main focus is analyzing the welfare gains from conducting FX intervention during a Dutch disease episode, we also evaluate the implications of alternative policy rules (i.e. monetary policy rules).

We choose the policy rule coefficients that maximize the welfare of the representative agent. We follow Lucas (1987) and Schmitt-Grohé and Uribe (2007) and measure the welfare gains in terms of the fraction of lifetime consumption (λ). The welfare in the baseline calibration, denoted by B, and the welfare under alternative policy rules, denoted by A, are given by:

$$U^J = E \left[\sum_{t=0}^{\infty} \beta^t u(C_t^J - hC_{t-1}^J, L_t^J) \right], \quad J = A, B. \quad (27)$$

Notice that in the baseline calibration the central bank follows a Taylor rule according to the estimated coefficients in de Castro et al. (2011) and does not intervene in the FX market. We compute the welfare gains of alternative policy rules (λ) by solving the following equation:

$$\begin{aligned} & E \left[\sum_{t=0}^{\infty} \beta^t u(C_t^B - hC_{t-1}^B, L_t^B) \right] \\ &= E \left[\sum_{t=0}^{\infty} \beta^t u((1 - \lambda)(C_t^A - hC_{t-1}^A), L_t^A) \right] \end{aligned} \quad (28)$$

Figure 3 shows the model dynamics under the alternative monetary and FX intervention rules. The blue line represents the dynamics under the baseline calibration, that is, when the central bank follows the empirical Taylor-type rule and does not conduct FX intervention. The dynamics are the same as in the case of figure 2.

The red line shows the case of an exchange rate peg. The peg regime is simulated as in Schmitt-Grohé and Uribe (2001) where the exchange rate is fully stabilized with the use of the monetary policy rate. Under this regime, there is a smaller real exchange rate appreciation than in the baseline, which is achieved through a reduction in the policy rate. Under this policy regime, tradable production is stabilized at the expense of more volatility in the non-tradable sector. While the policy rate is able to contain the appreciation of

the real exchange rate and partially insulate the tradable sector from a Dutch disease, it also stimulates aggregate demand resulting in an increase in non-tradable production. Overall, the procyclical monetary policy implemented to stabilize the nominal exchange rate increases macroeconomic volatility as found in Lama and Medina (2012).

The pink line shows the dynamics under the optimized monetary policy rule. Relative to the baseline calibration, the optimal policy rule generates a real exchange rate depreciation and stimulates both the production of tradable and non-tradable goods. This policy rule not only stabilizes tradable output but also reduces GDP volatility.

Next we analyze the case where the central bank conducts FX intervention optimally but follows the estimated Taylor-type monetary policy rule. Interestingly, when a second instrument is deployed, there are significant macroeconomic stabilization gains. First, the real exchange rate is largely stabilized, which implies a smooth adjustment of tradable output and the trade balance to the shock in commodity prices. In addition, both domestic demand and inflation are stabilized. Following the Tinbergen (1952) principle, with the additional instrument, FX reserves, is it possible to largely stabilize simultaneously two targets, the tradable and non-tradable sector.

On the contrary, when there is one instrument, the monetary policy rule, there is always a trade-off. For instance, a reduction in the policy rate can stabilize tradable output at the expense of increasing the volatility of non-tradable output, as illustrated in the extreme case of the exchange rate peg.

Finally, we analyze the case where both the monetary and FX intervention rules are optimized. Quantitatively the results are very similar to the previous case when only the FX intervention rule is optimized. The main difference with the previous case is that when the central bank adopts optimal FX intervention and monetary policy rules, the magnitude of FX intervention is smaller, as the policy rate plays a greater role in stabilizing the business cycle.

Table 2 summarizes the welfare gains and losses from the different rules, as well as the volatility of consumption and labor. Consistent with model dynamics shown in IRFs, the policy rules that reduce macroeconomic volatility the most, provide the highest welfare gains. Notice that the exchange rate peg generates a very large welfare loss, since the exchange rate peg is sustained with a procyclical monetary policy which exacerbates the business cycle during a boom in commodity prices. The optimal monetary policy rule increases welfare by 0.02 percent of permanent consumption relative to

the baseline model. The optimal FX intervention rule yields a much larger welfare gain of 0.04 percent of permanent consumption, almost half of the welfare gain from eliminating business cycle fluctuations calculated by Lucas (1987). Finally, the largest welfare gain, 0.05 percent, is from the combined implementation of optimized monetary and FX intervention rules.

Table 2: Welfare Analysis

	Std. C	Std. L	Welfare
Baseline Model	2.14	1.99	
Fixed Exchange Rate	5.64	5.74	-0.55
Optimal Monetary Policy Rule	2.66	1.11	0.02
Optimal FXI Policy Rule	2.21	0.94	0.04
Optimal Monetary and FXI Policy Rule	2.01	0.11	0.05

3.3. Sensitivity Analysis

In this section we evaluate the robustness of our results to alternative values of key parameters. We assess how different values of the share of organizational capital (λ_T), price stickiness (θ_N), wage stickiness (θ_W), and the degree of imperfect asset substitution (ρ) influence the model dynamics and welfare.

Figure 4 shows the response of the stock of FX reserves and the tradable balance relative to GDP. Qualitatively our results are robust to a wide range of parameter values. It is always the case that in response to a commodity shock there is a deterioration of the tradable balance and it is optimal to accumulate FX reserves to smooth the external adjustment. However, the precise magnitude of adjustment of these two variables will change depending on the parameter values. For the case of the intensity of LBD externality, we observe that the larger the share of organizational capital, the larger is the accumulation of FX reserves. As there are more gains from stimulating the tradable sector, it becomes optimal for the central bank to increase the stock of FX reserves. Interestingly, even in the absence of LBD, it is optimal to accumulate FX reserves, although the magnitude is much smaller than in the baseline calibration. In this situation, the role of FX intervention is to stabilize the business cycle rather than correcting the externalities in the tradable sector. In the presence of two nominal frictions (price and wage

rigidities), the divine coincidence breaks down (Blanchard and Galí, 2007) and monetary policy alone is insufficient to reach the first-best outcome. In that situation a second instrument, which in our model corresponds to FX reserves, is necessary to correct these two frictions.

For the parameters related to nominal rigidities (sticky prices and sticky wages), when their magnitude is reduced, it is optimal for the central bank to accumulate more FX reserves. These two frictions amplify the welfare costs of FX interventions (for a given level of FX reserves) as they amplify the volatility of consumption and labor. When we reduce the magnitude of these frictions, the central bank optimally increases the stock of FX reserves in order to correct the LBD externalities and its impact on welfare. Put it other terms, the reduction of nominal rigidities increase the relative importance of LBD, which calls for an optimal increase in the stock of FX reserves. For the parameter that governs the degree of imperfect asset substitution (ρ), we find that when it is reduced, the optimal accumulation of FX reserves is larger. As a lower value of ρ reduces the effectiveness of FXI, it is necessary to a larger accumulation of FX reserves in order to achieve the same welfare levels.

Figure 5 reports the welfare gains from implementing an optimal FX intervention rule given a calibrated Taylor-type rule for different parameter values. For all cases, the welfare gains are in the range of 0.02 to 0.06 percent of lifetime consumption. Moreover, the welfare gains are increasing in the magnitude of the distortions present in the economy. The larger the size of LBD externalities, sticky prices and wages, and imperfect asset substitutability, the larger the gains from using FX reserves to stabilize the economy in response to a commodity price shock. This analysis confirms that there gains from conducting FX intervention during a Dutch disease episode.

4. Conclusions

In this paper we studied the optimal FX intervention policy in response to a Dutch disease episode. For a calibrated version of our small open economy model, we find an important role for FX intervention in smoothing the external adjustment during a boom in commodity prices. We obtain three key results from our analysis. First, under LBD externalities, the optimal response of the central bank is a large and persistent accumulation of FX reserves such that externalities in the tradable sector are corrected. Second, in

the absence of learning-by-doing, still there is an important role for FX, albeit with a more modest pace of accumulation. In this case, FX reserves represent a policy instrument that contributes effectively to the smoothing of the commodity cycle by saving in good times. Third, the choice of instruments matters when dealing with a Dutch disease episode. While monetary policy can play an important role in counteracting the learning-by-doing externalities by generating a depreciation of the exchange rate, our welfare analysis shows that its contribution is limited. Our calculations indicate that FX reserves are a superior instrument that can effectively counteract the effects of a Dutch disease.

There are important avenues for future research. For instance, we could evaluate the role of fiscal instruments or the adoption of a sovereign wealth fund for dealing with a boom in commodity prices. In addition, it would be useful to conduct a similar exercise in a multi-country model, in order to assess both the spillovers from learning-by-doing externalities and from the use of FX reserves in dealing with a Dutch disease episode.

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Appendix: Equilibrium conditions

In this appendix we present the equilibrium conditions that characterize the small open economy model.

Households

$$\beta E_t \left[(1 + i_t) \frac{P_t}{P_{t+1}} \left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t} \right) \right] = 1, \quad (29)$$

$$\beta E_t \left[(1 + i_t^*) \Theta(B_t^*) \frac{P_t}{P_{t+1}} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \left(\frac{C_t - hC_{t-1}}{C_{t+1} - hC_t} \right) \right] = 1. \quad (30)$$

Equations (29) and (30) define the Euler equations for domestic bonds and international bonds, respectively.

Labor supply and wage setting

The optimal wage in period t , W_t^* , satisfies

$$E_t \left[\sum_{i=0}^{\infty} (\beta \theta_W)^i \left[\frac{(C_{t+i|t} - hC_{t+i-1|t})^{-1}}{P_{t+i}} L_{t+i|t} W_t^* - \frac{\epsilon_L}{\epsilon_L - 1} \zeta_L (L_{t+i|t})^{1+\nu} \right] \right] = 0, \quad (31)$$

where $C_{t+i|t}$ is the consumption in period $t+i$, $\bar{\pi}$ is the inflation target, and $L_{t+i|t}$ is the labor supplied in period $t+i$ by the households that choose wages optimally in period t .

The aggregate wage rate is given by:

$$(W_t)^{1-\epsilon_L} = \theta_W (W_{t-1})^{1-\epsilon_L} + (1 - \theta_W) (W_t^*)^{1-\epsilon_L} \quad (32)$$

Final Good Producers

$$P_t \left(\frac{\alpha_Y Y_t^F}{Y_t^{DT}} \right)^{1/\eta_Y} = P_t^T, \quad (33)$$

$$P_t \left(\frac{(1 - \alpha_Y) Y_t^F}{Y_t^{DN}} \right)^{1/\eta_Y} = P_t^N, \quad (34)$$

where Y_t^F is the production function for final goods given in equation (4). Equations (33) and (34) describe the demand for tradable and non-tradable inputs, respectively.

Intermediate Good Producers

The first order conditions for factor demand in the non-tradable sector are:

$$(1 - \alpha_N)A_t^N \left[\frac{K_t^N}{L_t^N} \right]^{\alpha_N} = \frac{W_t}{P_t^{WN}}, \quad (35)$$

$$\alpha_N A_t^N \left[\frac{L_t^N}{K_t^N} \right]^{1-\alpha_N} = \frac{R_{K,t}^N}{P_t^{WN}}, \quad (36)$$

Likewise, the conditions for the optimal factor demand in the tradable sector are given by:

$$(1 - \lambda_T)(1 - \alpha_T)A_t^T \left[\frac{H_t}{L_t^T} \right]^{\lambda_T} \left[\frac{K_t^T}{L_t^T} \right]^{\alpha_T(1-\lambda_T)} = \frac{W_t}{P_t^T}, \quad (37)$$

$$(1 - \lambda_T)\alpha_T A_t^T \left[\frac{H_t}{K_t^T} \right]^{\lambda_T} \left[\frac{L_t^T}{K_t^T} \right]^{(1-\alpha_T)(1-\lambda_T)} = \frac{R_{K,t}^T}{P_t^T}. \quad (38)$$

Retailers

The first-order conditions for the retailers in the non-tradable sector is:

$$E_t \left[\sum_{i=0}^{\infty} (\beta\theta_N)^i \frac{(C_t - hC_{t-1})}{(C_{t+i} - hC_{t+i-1})} \frac{P_t}{P_{t+i}} Y_t^{DN}(j) \left[P_t^{N*} - \frac{\epsilon_N}{\epsilon_N - 1} P_{t+i}^{WN} \right] \right] = 0, \quad (39)$$

where:

$$P_t^N = (\theta_N(P_{t-1}^N)^{1-\epsilon_N} + (1 - \theta_N)(P_t^{N*})^{1-\epsilon_N})^{1/(1-\epsilon_N)} \quad (40)$$

Capital Producers

For each sector-specific capital producer $J = H, N$ the first order conditions are:

$$1 = \frac{Q_t^J}{P_t} \left[S \left(\frac{I_t^J}{I_{t-1}^J} \right) + S' \left(\frac{I_t^J}{I_{t-1}^J} \right) \frac{I_t^J}{I_{t-1}^J} \right] - E_t \left[\frac{(C_t - hC_{t-1}) Q_{t+1}^J}{(C_{t+1} - hC_t) P_{t+1}} \left[S' \left(\frac{I_{t+1}^J}{I_t^J} \right) \left(\frac{I_{t+1}^J}{I_t^J} \right)^2 \right] \right], \quad (41)$$

$$\frac{Q_t^J}{P_t} = E_t \left[\frac{(C_t - hC_{t-1})}{(C_{t+1} - hC_t)} \left[\frac{R_{K,t+1}^J}{P_{t+1}} + \frac{Q_{t+1}^J}{P_{t+1}} (1 - \delta) \right] \right]. \quad (42)$$

Equations (41) and (42) determine the evolution of investment I_t^J and the real price of capital $\frac{Q_t^J}{P_t}$ in sector $J = T, N$.

Monetary Policy and the Foreign Exchange Intervention

Monetary policy is characterized by a Taylor-type rule:

$$\left(\frac{1 + i_t}{1 + i} \right) = \left(\frac{Y_t}{\bar{Y}} \right)^{\psi_y} \left(\frac{\pi_t^N}{\bar{\pi}} \right)^{\psi_{\pi^N}} \left(\frac{e_t}{\bar{e}} \right)^{\psi_e} \quad (43)$$

where i_t , Y_t , $\pi_t^N = P_t^N/P_{t-1}^N$, $e_t = \mathcal{E}_t/\mathcal{E}_{t-1}$, are the nominal interest rate, GDP, non-tradable inflation, and the depreciation rate, respectively.

Similarly, FX intervention is also conducted with the following policy rule:

$$\left(\frac{F_t^*}{\bar{F}^*} \right) = \left(\frac{Y_t}{\bar{Y}} \right)^{\theta_y} \left(\frac{\pi_t^N}{\bar{\pi}} \right)^{\theta_{\pi^N}} \left(\frac{e_t}{\bar{e}} \right)^{\theta_e}. \quad (44)$$

Market Clearing Conditions

$$L_t^N + L_t^T = L_t = \int_0^1 L_t(h) dh \frac{1}{\Xi_t^W}, \quad (45)$$

$$Y_t^{DN} \Xi_t^N = Y_t^N, \quad (46)$$

$$Y_t^F = C_t + I_t^T + I_t^N, \quad (47)$$

Ξ_t^W and Ξ_t^N are the wage and non-tradable price dispersions, respectively. These terms are defined as:

$$\Xi_t^W = \theta_W \left(\frac{W_{t-1}}{W_t} \right)^{-\epsilon_L} \Xi_{t-1}^W + (1 - \theta_W) \left(\frac{W_t^*}{W_t} \right)^{-\epsilon_L} \quad (48)$$

$$\Xi_t^N = \theta_N \left(\frac{P_{t-1}^N}{P_t^N} \right)^{-\epsilon_N} \Xi_{t-1}^N + (1 - \theta_N) \left(\frac{P_t^{N*}}{P_t^N} \right)^{-\epsilon_N} \quad (49)$$

The law of one price holds for tradable goods:

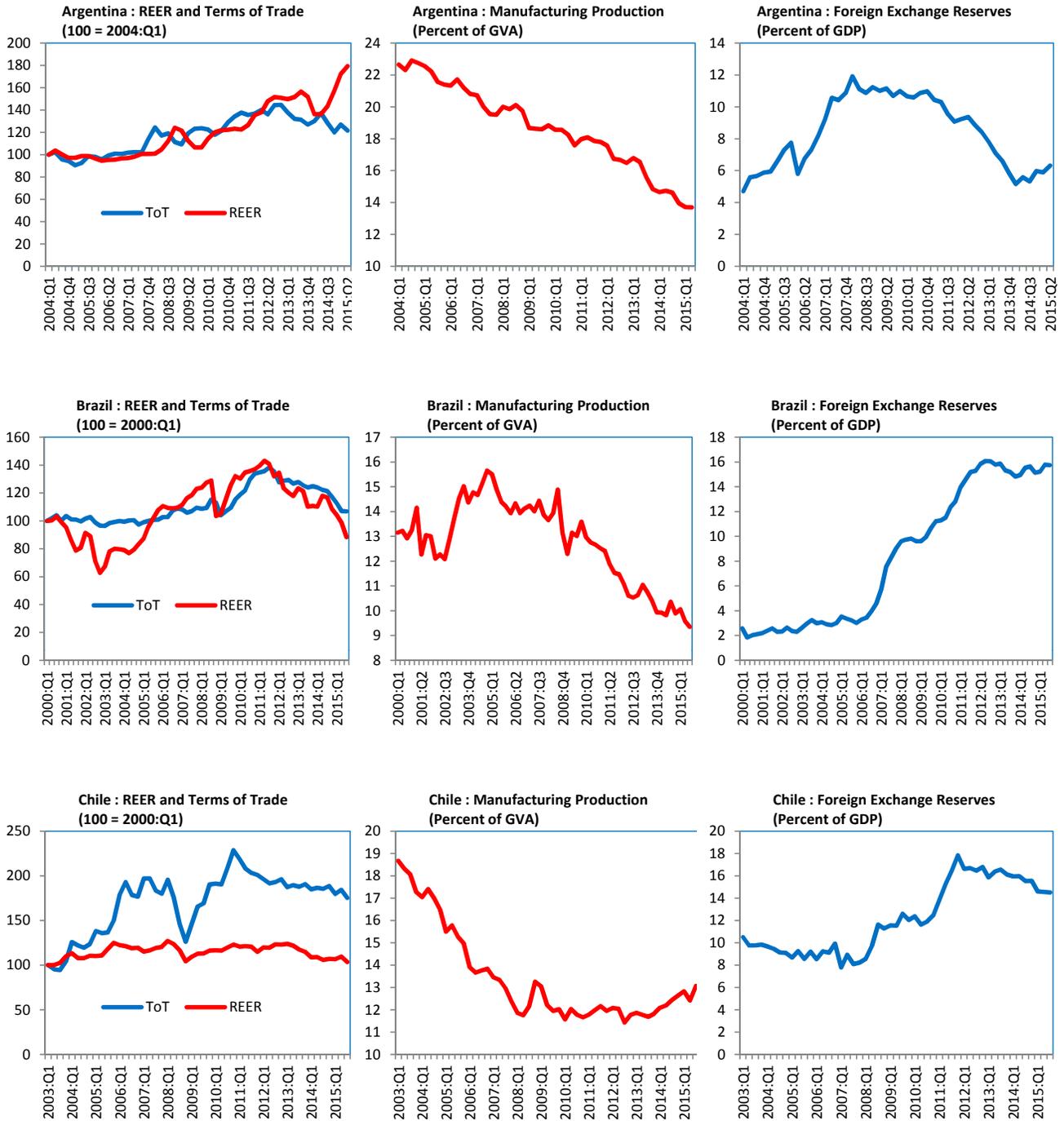
$$P_t^T = \mathcal{E}_t P_t^*. \quad (50)$$

$$\mathcal{E}_t (B_t^* + F_t^*) = (1 + i_{t-1}^*) (\Theta (B_{t-1}^*) \mathcal{E}_t B_{t-1}^* + \mathcal{E}_t F_{t-1}^*) + P_t^T Y_t^T - P_t^T Y_t^{DT}. \quad (51)$$

Equations (45), (46), and (47) are the market clearing conditions for the labor, the non-tradable sector, and the final goods, respectively. (51) is the balance of payment identity. Finally, real GDP is defined as:

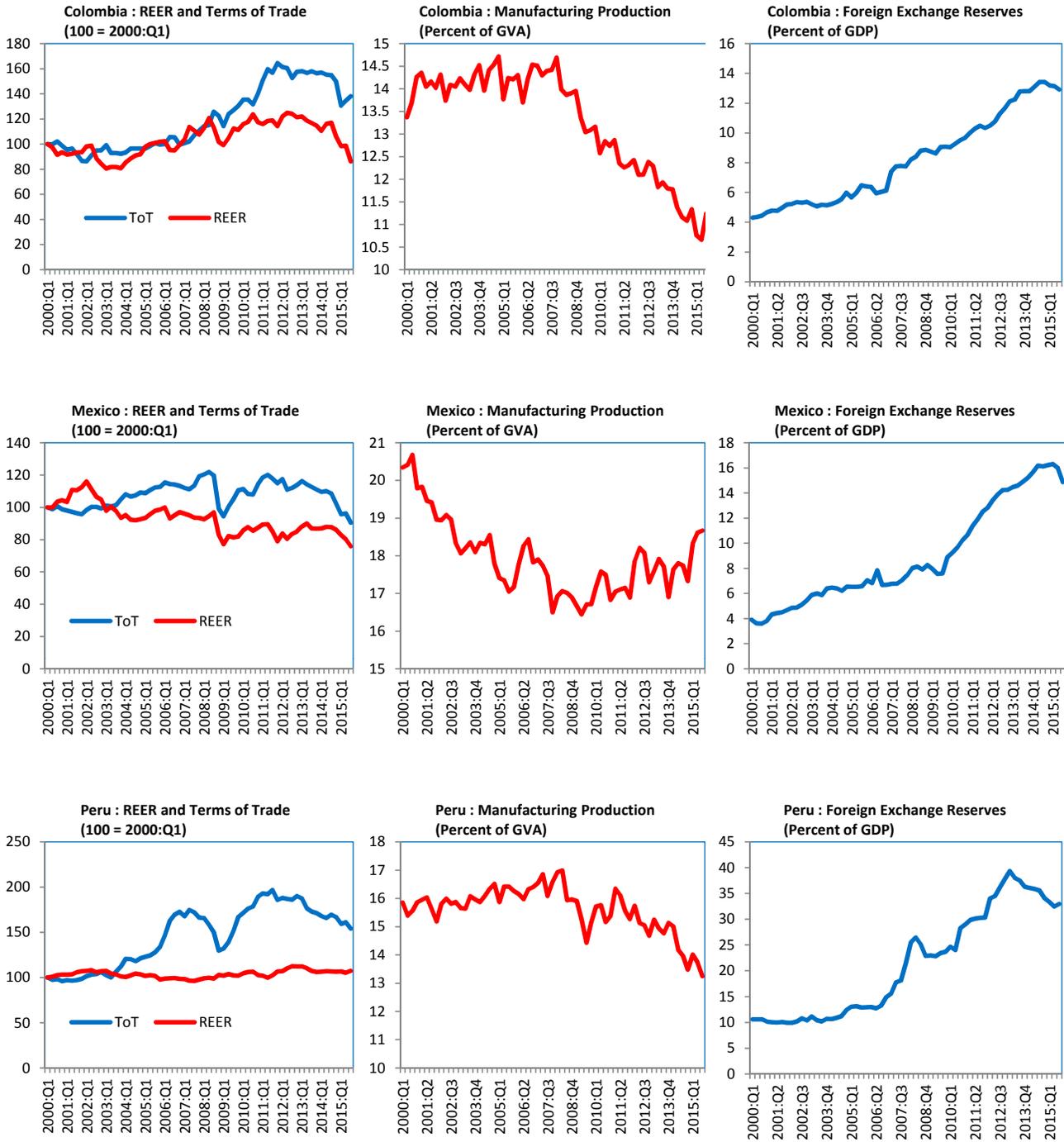
$$Y_t \equiv P_0^N Y_t^N + P_0^T Y_t^T + P_0^x X_t \quad (52)$$

Figure 1. Commodity Cycle and Foreign Exchange Intervention



Source: Haver Analytics

Figure 1 (Continued). Commodity Cycle and Foreign Exchange Intervention



Source: Haver Analytics.

Figure 2. Effects of Learning-by-Doing

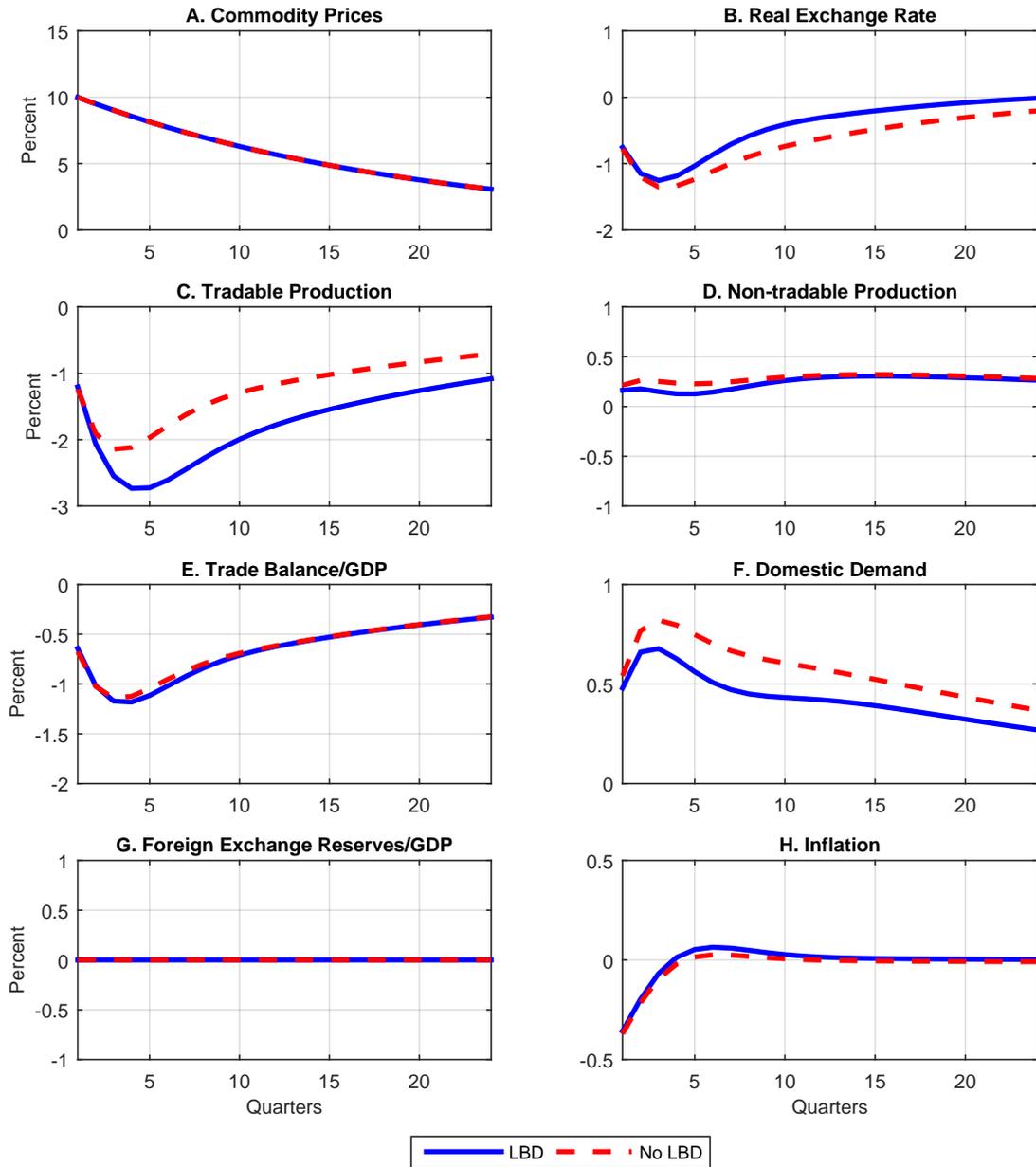


Figure 2 (Continued). Effects of Learning-by-Doing

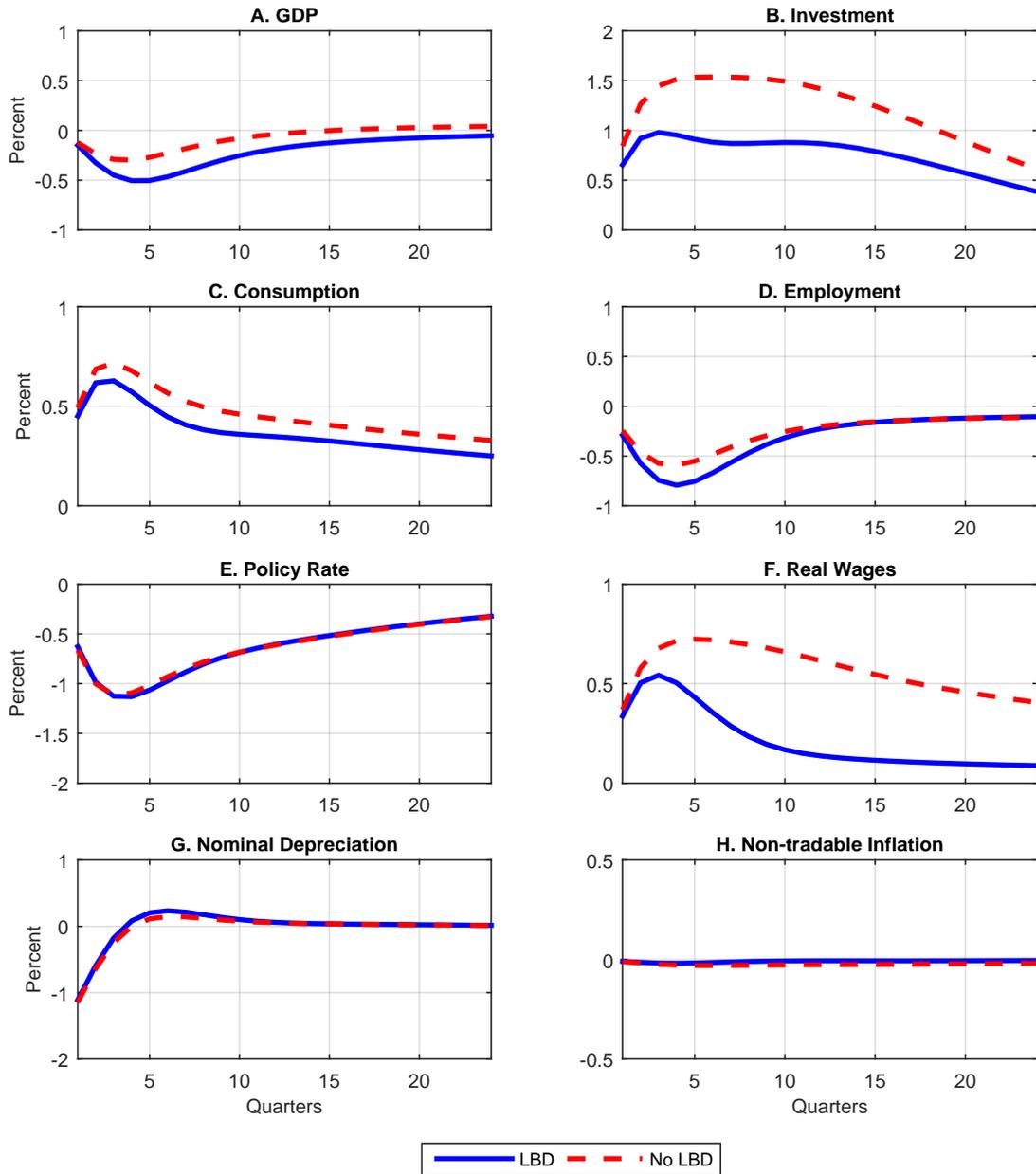


Figure 3. Dutch Disease and Policy Rules

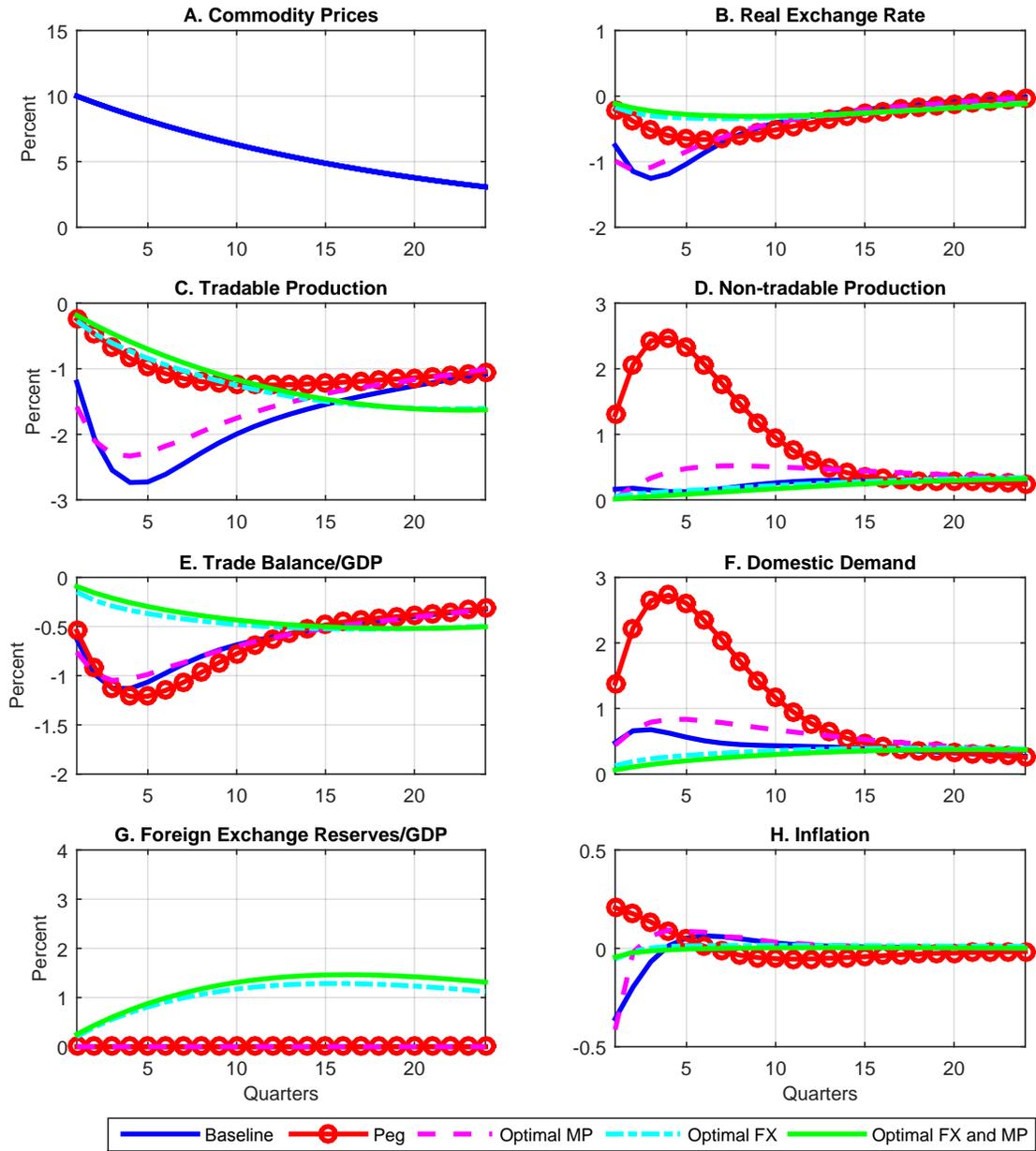


Figure 3 (Continued). Dutch Disease and Policy Rules

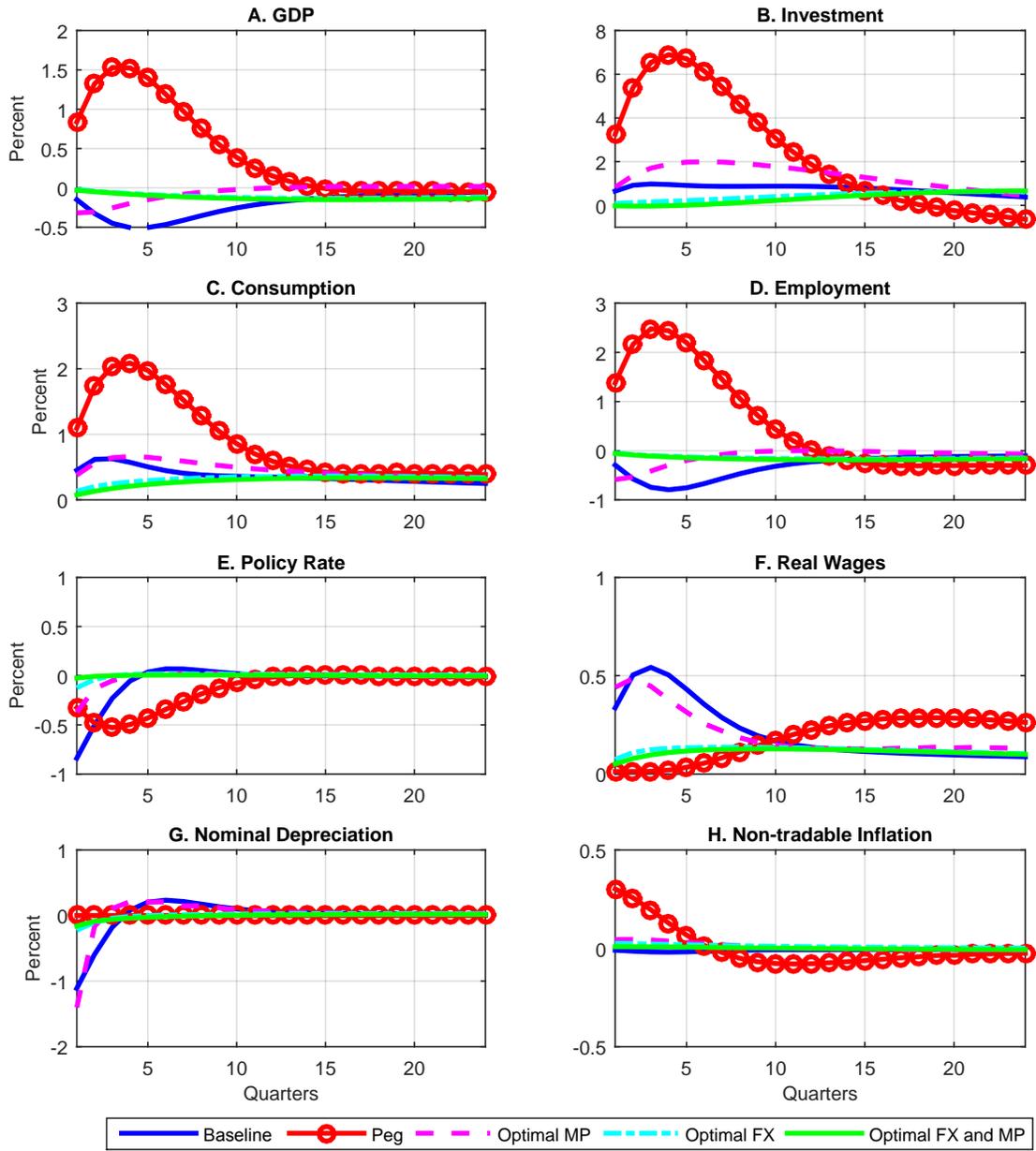


Figure 4. Sensitivity Analysis

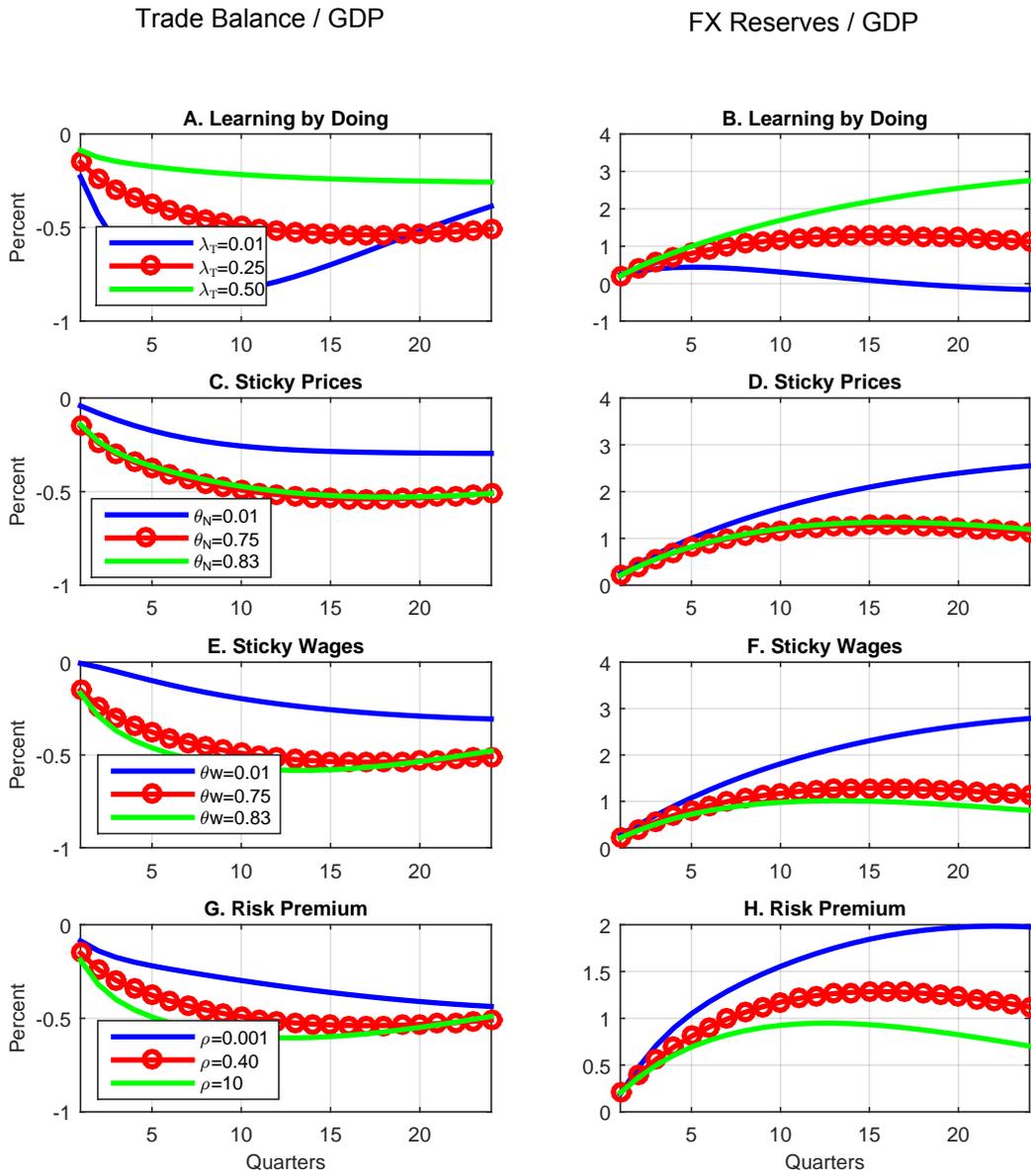


Figure 5. Welfare Gains and Sensitivity Analysis

