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Is Exchange Rate Stabilization an Appropriate Cure for the Dutch Disease?

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Is Exchange Rate Stabilization an Appropriate Cure for the Dutch Disease?

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Abstract

This paper evaluates how successful is a policy of exchange rate stabilization to counteract the negative effects of a Dutch Disease episode. We consider a small open economy model that incorporates nominal rigidities and a learning-by-doing externality in the tradable sector. The paper shows that leaning against an appreciated exchange rate can prevent an inefficient loss of tradable output but at the cost of generating a misallocation of resources in other sectors of the economy. The paper also finds that welfare is a decreasing function of exchange rate intervention. These results suggest that stabilizing the nominal exchange rate in response to a Dutch Disease episode is highly distortionary.

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Contents **Page**

I. Introduction

Small open economies experience recurrent episodes of exchange rate appreciation in response to different types of shocks.[1] When an appreciation induces a contraction of the exporting manufacturing sector, then an economy usually is diagnosed as having a Dutch Disease.[2] The Dutch Disease phenomenon is a source of concern for policymakers to the extent that a smaller tradable sector might undermine future possibilities of growth and employment creation. In this context, policymakers face a key question: What type of policy intervention can counteract the negative effects of a Dutch Disease episode? In this paper we evaluate the merits of one of the policy options commonly implemented by governments: exchange rate stabilization.

One way to prevent tradable output from falling below the efficient level is to depreciate the real exchange rate through monetary injections. A policy of exchange rate depreciation can be successful to prevent a contraction of tradable output, but it will have allocative effects in the economy. In this paper we evaluate in a dynamic stochastic general equilibrium (DSGE) model what are the cost and benefits of this policy intervention in terms of macroeconomic stability and welfare.

Figures 1 and 2 illustrate a Dutch Disease episode experienced in Canada in recent years. In the period 2002-07 the terms of trade improved 25 per cent. This increase in the terms of trade was driven by a worldwide boom in commodity prices, in particular a surge in oil and gas prices. Consistent with the empirical evidence of commodity currencies, the real effective exchange rate also appreciated around 25 percent.[3] These changes in relative prices had an impact in the reallocation of resources across sectors in the economy. Figure 2 shows the share of manufacturing production over GDP for Canada.

[1]For instance, if an economy faces a demand shock such as a discovery of natural resources or a supply shock such as higher productivity relative to the main trade partners, then the real exchange rate will appreciate.

[2]The term "Dutch Disease" was introduced to describe the situation experienced in the Netherlands in 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.

[3]For a reference on commodity currencies see Chen and Rogoff (2003).

The period of exchange rate appreciation coincides with a contraction of 3 percentage points of GDP in the share of manufacturing production. Notice that this reallocation process is unprecedented in the Canadian economy in terms of the size and the timing of the contraction. In the last 20 years Canada experienced a maximum contraction of 2 percentage points of GDP every time it enters into a recession, which coincides with a recession in the United States. The most recent episode of exchange rate appreciation shows a larger decline in manufacturing production that is unrelated to the U.S. business cycle pointing out to some Dutch Disease effects in the economy. We consider Canada an interesting case study to the extent that is an economy with a sizable manufacturing export sector and at the same time with business cycles sensitive to variations in commodity prices. These two features makes the potential costs of a Dutch Disease episode larger compared to other small open economies.

In a standard frictionless two-sector real business cycle model, the reallocation between the tradable and non-tradable sector, such as the one observed in Canada, is the efficient response to an increase in the terms of trade. Higher terms of trade will increase the demand for tradable and non-tradable goods, and as a consequence wages will be higher in the economy. Taken international prices as given, higher wages will reduce the production of tradable goods, and the demand will be satisfied with imports from the rest of the world. In this situation there is no rationale for government intervention, and protecting the tradable sector will reduce overall welfare. However, if we consider a market failure, the adjustment of the economy to higher terms of trade can generate an inefficient outcome. One market failure commonly discussed in the Dutch Disease literature is the learning-by-doing externality in the tradable sector. Considering a learning-by-doing mechanism, a reduction in output will lead to lower productivity and a decrease of future production. If this mechanism is not internalized by the firms, then there will be an inefficient loss of tradable production.

One policy option commonly used to influence tradable production is stabilizing the exchange rate. Intervening in the foreign exchange rate market can prevent a fall of tradable production below the efficient level. However, if we consider nominal rigidities in alternative sectors of the economy, as the empirical evidence suggests, then an intervention in the foreign exchange rate market could also induce a misallocation of resources.[4][5] Policymakers face a trade-off between correcting the learning-by-doing externality in the tradable sector and ensuring an efficient allocation of resources across productive sectors. In the paper we evaluate this trade-off, and analyze how successful is a policy of exchange rate stabilization to prevent a misallocation of resources during a Dutch Disease.[6]

The main result of the paper is that exchange rate intervention is a welfare-reducing policy to counteract the effects of the Dutch Disease. On the one hand, a policy of exchange rate stabilization can prevent a contraction of tradable production below the efficient level. On the other hand, stabilizing the exchange rate exacerbates the effects on aggregate demand generated by an improvement of the terms of trade and hence increases macroeconomic volatility. In a calibrated version of the model to the Canadian economy we find that the costs in terms of macroeconomic volatility and misallocation of resources far exceed any benefits obtained from a depreciated exchange rate. The intuition for this result is that exchange rate intervention through monetary policy is a blunt instrument to correct the learning-by-doing externality. Stabilizing the exchange rate not only expands tradable output, but also stimulates all sectors in the economy in tandem, which turns to be highly distortionary in a context of higher terms of trade.

This paper is related to an extensive Dutch-Disease Literature. Van Wijnbergen (1984), Krugman (1987), and Caballero and Lorenzoni (2009) evaluate alternative policy interventions in the context of the Dutch Disease. These authors differ regarding which friction generates a misallocation of resources in response to an appreciated exchange rate. The first two authors consider a learning-by-doing externality in the tradable sector, while Caballero and

[4]For a reference of sticky prices in alternative sectors of the economy see Bils and Klenow (2004).

[5]If we assume that prices in some sectors of the economy are sticky and the nominal exchange rate is stabilized, then the real exchange rate adjustment is going to come partially from an increase in domestic inflation. Either if we assume a pricing behavior as in Rotemberg (1982) or Calvo (1983), the higher inflation induced in the sticky sectors due to the exchange rate stabilization will generate a loss of resources in those sectors, and hence a misallocation of resources.

[6]Central banks typically can stabilize the exchange rate through interventions in the foreign exchange market or through domestic open-market operations that affect the short-term interest rate. In this paper we adopt the assumption of *perfect asset substitutability* which generates equivalent effects for these two options.

Lorenzoni analyze the case of financial frictions in the exportable sector. This paper also conducts a policy evaluation in response to a Dutch Disease considering as the starting point a New Keynesian small open economy model. Our framework is similar to the work of Lubik and Schorfheide (2007), Adolfson et al. (2007), and Justiniano and Preston (2008), who estimate and evaluate different versions of the New Keynesian model for small open economies. We depart from these models introducing a learning-by-doing mechanism in the manufacturing exportable sector. Cooper and Johri (2002) and Chang et al. (2002) provide empirical evidence regarding the quantitative importance of the learning-by-doing mechanism. This paper contributes to the Dutch Disease literature performing a quantitative evaluation on the merits of exchange rate intervention to correct the learning-by-doing externality.

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 main findings of the paper. Section 5 shows the welfare analysis. Section 6 presents a sensitivity analysis. Section 7 concludes. The Appendix contains all the equilibrium conditions of the model.

II. A Small Open Economy with Learning-by-Doing

In this section we present a multi-sector small open economy model with nominal rigidities and a learning-by-doing externality in the tradable sector. The model is built along the lines of Christiano et al. (2005), Smet and Wouters (2007), Adolfson et al. (2007), Chang et al. (2002) and Cooper and Johri (2002). The model captures two features of economies that can be exposed to a Dutch Disease: a large commodity sector, and a learning-by-doing externality in the manufacturing sector. This last feature generates a misallocation of resources during a boom of commodity prices, and calls for government intervention.

The model considers three sectors. One produces a manufactured tradable good (H). The second one, a non-tradable good (N). A third sector produces a commodity good, which is exported entirely at a given international price. Consumer preferences are defined over final consumption good and leisure. The model considers sticky prices in the tradable and non-tradable sector which generate real effects for changes in monetary policy. The key innovation with respect to standard New Keynesian models is the introduction of a learning-by-doing externality in the manufacturing tradable sector.

A. Households

The household's preferences are defined over consumption and leisure:

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

where L_t is labor effort, C_t is its total consumption, and the external habit component is defined by $\mathcal{H}_{t+i} = C_{t+i-1}$. Households have access to three types of assets: money $\mathcal{M}_t$, one-period non-contingent foreign bonds B_t^*, and one-period domestic contingent bonds $\mathcal{D}_{t+1}$ which pay out one unit of domestic currency in a particular state. The household budget constraint is given by:

$$\begin{aligned} &P_t^C C_t + E_t \left\{ d_{t,t+1} \mathcal{D}_{t+1} \right\} + \mathcal{E}_t B_t^* + \mathcal{M}_t = \\ &\qquad W_t l_t + \Pi_t - \mathcal{T}_t + \mathcal{D}_t + \mathcal{E}_t B_{t-1}^* \left(1 + i_{t-1}^*\right) \Theta((\mathcal{B}_{t-1})) + \mathcal{M}_{t-1}. \end{aligned}$$

where Π_t are profits received from domestic firms, W_t is the nominal wage, $\mathcal{T}_t$ is the per-capita lump-sum tax, and $\mathcal{E}_t$ is the nominal exchange rate. $d_{t,t+1}$ is the period t price of one-period domestic contingent bonds normalized by the probability of the occurrence of the state. The financial costs of the foreign bond B_t^* is defined by the foreign interest rate i_t^* and the risk premium $\Theta(.)$. [7]

[7] This premium is a function of the net foreign asset positions relative to GDP, $\mathcal{B}_t = \frac{\mathcal{E}_t B_t^*}{P_{Y,t} Y_t}$ where $P_{Y,t} Y_t$ is nominal GDP and B_t^* is the aggregate net asset position of the economy. This premium is introduced as a technical device to ensure stationarity (see Schmitt-Grohé and Uribe, 2003).

B. Firms

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

1. Final Good Producers

The final good producers Y_t^F combine home produced inputs Y_t^{DH}, imports Y_t^M, and non-tradable inputs Y_t^{DN} according to a constant elasticity of substitution production function:

$$Y_t^F = \left[\alpha_Y^{1/\eta_Y}(Y_t^T)^{\frac{\eta_Y-1}{\eta_Y}} + (1-\alpha_Y)^{1/\eta_Y}(Y_t^{DN})^{\frac{\eta_Y-1}{\eta_Y}}\right]^{\frac{\eta_Y}{\eta_Y-1}}, \tag{2}$$

$$Y_t^T = \left[\gamma_Y^{1/\omega_Y}(Y_t^{DH})^{\frac{\omega_Y-1}{\omega_Y}} + (1-\gamma_Y)^{1/\omega_Y}(Y_t^{M})^{\frac{\omega_Y-1}{\omega_Y}}\right]^{\frac{\omega_Y}{\omega_Y-1}}. \tag{3}$$

where Y_t^T denotes the production of tradable inputs.

2. Retailers

We assume that firms in the retail sector sell home goods Y_t^H and non-tradable goods Y_t^N in two separate stages. First, there is an assembler that combines the differentiated intermediate good indexed by $j \in [0,1]$ in each sector $J = H, N$ to produce Y_t^J. The technology is a constant elasticity of substitution aggregator given by:

$$Y_t^J = \left(\int_0^1 Y_t^J(j)^{\frac{\epsilon_J-1}{\epsilon_J}} dj\right)^{\frac{\epsilon_J}{\epsilon_J-1}}, \tag{4}$$

where ϵ_J is the elasticity of substitution between variety of goods. The optimal choice for each assembler yields a demand function for intermediate goods:

$$Y_t^J(j) = \left(\frac{P_t^J(j)}{P_t^J} \right)^{-\epsilon_J} Y_t^J, \tag{5}$$

$$P_t^J = \left(\int_0^1 P_t^J(j)^{1-\epsilon_J} dj \right)^{\frac{1}{1-\epsilon_J}} . \tag{6}$$

Second, retailers of each intermediate good have monopolistic power and set their prices according to the Calvo (1983) framework. Every period a fraction $(1 - \theta_J)$ of retailers in sector $J = H, N$ set their prices optimally. The optimal price $P_t^{J*}(j)$ chosen by each retailer maximizes the expected present value of profits:

$$E_t \left[\sum_{i=0}^{\infty} (\theta_J)^i \Lambda_{t,t+i} \left(\frac{P_t^{J*}(j) - P_{t+i}^{WJ}}{P_{t+i}^J} \right) Y_{t+i}^J(j) \right], \tag{7}$$

where $\Lambda_{t,t+i}$ is the stochastic discount factor, and P_t^{WJ} is the wholesale price of the intermediate good of sector $J = H, N$.

3. Intermediate Good Producers

There is a continuum of firms in the non-tradable sector. Each firm $n \in [0, 1]$ produces output $Y_t^N(n)$ using capital and labor, $K_t^N(n)$ and $L_t(n)$, respectively. The production function is given by:

$$Y_t^N(n) = A_t^N \left[L_t^N(n) \right]^{\eta_N} \left[K_t^N(n) \right]^{1-\eta_N}, \tag{8}$$

where $A_{N,t}$ denotes an aggregate productivity shock in the sector.

The tradable sector is subject to a learning-by-doing externality. The production function of each representative firm $h \in [0, 1]$ in this sector is given by:

$$Y_t^H(h) = A_t^H \left[H_t(h) \right]^{\lambda_H} \left[L_t^N(h) \right]^{\eta_H} \left[K_t^H(h) \right]^{\gamma_H}, \tag{9}$$

where A_t^H, $K_t^H(h)$, and $L_t(h)$, denotes an aggregate productivity shock, capital and labor. $H_t(h)$ is the level of organizational capital in the home-goods sector, and we assume that it evolves according to the following law of motion:

$$H_{t+1}(h) = [H_t(h)]^{\phi_H} \left[\overline{Y}_t^H\right]^{\mu_H}. \tag{10}$$

where $\overline{Y}_t^H$ is the production at the industry level, $(1-\phi_H)$ is the depreciation rate of organizational capital, and μ_H is the elasticity of organizational capital with respect to current output. This is the same specification as in Cooper and Johri (2002). These authors found empirical evidence for this specification of learning-by-doing using plant-level and national income and product accounts data. In a more recent paper Clarke (2008) found evidence of learning-by-doing for Canada. In this paper we follows the same interpretation of organizational capital as in Lev and Radharkrishnan (2003): "Organizational 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, higher production in the tradable sector leads to an increase in organizational capital which improves the efficiency of the sector and generates further production in the future.

4. Capital Producers

Capital producers $J = H, N$ own and rent sector-specific capital to firms in the home and non-tradable goods sector. The aggregate investment of each type of capital is a composite of home, foreign and non-tradable goods as in the case of the final good. The representative firm of each type of capital J solves the following problem:

$$V_t^J = \max_{K_{t+i}^J, I_{t+i}^J} E_t \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \frac{Z_{t+i}^J K_{t+i}^J - P_{t+i}^C I_{t+i}^J}{P_{t+i}^C} \right\},$$

subject to the law of motion of physical capital:

$$K_{t+1}^{J} = (1-\delta)K_{t}^{J} + S\left(\frac{I_{t}^{J}}{I_{t-1}^{J}}\right) I_{t}^{J}, \tag{11}$$

where Z_t^J the rental rate of physical capital, δ is the depreciation rate of capital in sector J. $S(.)$ characterizes the adjustment cost for investment.[8]

C. Commodity Sector

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

$$X_t = [X_{t-1}]^{\rho_x} [X_0]^{1-\rho_x} \exp\left(\varepsilon_t^x\right), \tag{12}$$

where $\varepsilon_t^x \sim N(0, \sigma_x^2)$ is a stochastic shock and ρ_x measures the persistency of the process. [9] We assume that the commodity price P_t^x follows the stochastic process:

$$P_t^x = \left[P_{t-1}^x\right]^{\rho_{px}} \left[P_0^x\right]^{1-\rho_{px}} \exp\left(\varepsilon_t^{px}\right). \tag{13}$$

where $\varepsilon_t^{px} \sim N(0, \sigma_{px}^2)$ is a stochastic shock and ρ_{px} measures the persistency of the commodity prices.

[8] We follow Christiano et al. (2005) and specify an investment adjustment cost that satisfies the following conditions: $S(1) = 1$, $S'(1) = 0$, $S''(1) = -\mu_S < 0$. This assumption generates an inertia in investment that is consistent with a time-to-build specification.

[9] We assume an exogenous process for commodity exports to simplify the model. Considering a more realistic setup in which the commodity sector hires physical capital and labor would not change the qualitative results of the model. For instance, in Canada the commodity sector (mining, gas, and oil) only hires about 2 percent of the labor force. Taking into account this feature of the data does not affect the main policy implications of the model.

D. Monetary policy rule

The monetary policy is characterized by a Taylor-type rule:

$$\left(\frac{1+i_t}{1+i}\right) = \left(\frac{1+i_{t-1}}{1+i}\right)^{\psi_i} \left(\frac{Y_t}{\overline{\overline{Y}}_t}\right)^{(1-\psi_i)\psi_y} \left(\frac{\pi_{C,t}}{\overline{\pi}}\right)^{(1-\psi_i)\psi_\pi} \left(\frac{s_t}{\overline{s}}\right)^{(1-\psi_i)\psi_s} \tag{14}$$

where i_t, Y_t, $\pi_{C,t}$, s_t, are the nominal interest rate, GDP, CPI inflation, and the depreciation rate, respectively. The parameters ψ_y, ψ_π, and ψ_s, are the weights assigned in the Taylor rule to stabilize deviations of output, inflation and depreciation rate, with respect to their equilibrium values. The parameter ψ_i indicates the degree of interest rate smoothing in the Taylor-type rule.

E. Market Clearing Conditions

In every period markets clear for labor, capital, intermediate home and non-tradable goods, the final good, and international bonds. The market clearing condition for labor and capital are given by:

$$L_t = \left(\int_0^1 L_t^N(n)dn\right) + \left(\int_0^1 L_t^H(h)dh\right), \tag{15}$$

$$K_t^J = \left(\int_0^1 K_t^J(j)dj\right), J = H, N. \tag{16}$$

The market clearing conditions for home and non-tradable intermediate goods are:

$$Y_t^{DN} = Y_t^N, \tag{17}$$

$$Y_t^{DH} + C_t^{H*} = Y_t^H. \tag{18}$$

where $C_t^{H*} = \gamma^* \left(\frac{P_{H,t}}{\mathcal{E}_t P_{F,t}^*}\right)^{-\eta^*} C_t^*$ is the foreign demand for home goods, and C_t^* is the aggregate foreign consumption. Finally, the equilibrium conditions in the final good production and international bonds are given by:

$$Y_t^F = C_t + I_t^H + I_t^N \tag{19}$$

$$\begin{aligned} \mathcal{E}_t B_t^* &= (1+i_{t-1}^*)\Theta\left(\mathcal{B}_{t-1}\right)\mathcal{E}_t B_{t-1}^* + P_t^M Y_t^M \\ &\quad - P_t^H C_t^{H*} - P_t^x X_t \end{aligned} \tag{20}$$

III. Calibration

Table 1 describes the parameter values used in the calibration of the model. Most of the parameters for the real block of the model are obtained from the Bank of Canada Quarterly Projection Model (Murchison and Rennison, 2006) and are in line with the literature of monetary policy in open economies.[10] We calibrate the model so each time period is one quarter. The utility function is logarithmic in consumption with a constant labor supply elasticity:

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

Consistent with the evidence of Taylor (1999) and Nakamura and Steinsson (2008) we set the frequency of price adjustment to four quarters. In the baseline calibration we assume that nominal rigidities are present in the home goods and non-tradable goods sectors. In the sensitivity analysis we also consider the case of incomplete pass-through, where the importers have the ability to set prices in the domestic market.

The Taylor-type rule parameters are obtained from Lubik and Schorfheide (2007). These authors use Bayesian techniques to estimate a specification of the Taylor rule for Canada in which the nominal interest rate responds

[10] For the elasticity of the investment adjustment cost we chose the value $\mu_S = 2.5$ taken from Christiano et al. (2005).

to variations of GDP, inflation, and exchange rate depreciation, and has a smoothing component. Finally, the learning-by-doing parameters are obtained from Cooper and Johri (2002). The share of organizational capital in the production function is $\lambda_H = 0.25$ which corresponds to a learning rate of 20 percent found in the literature. Consistent with the empirical evidence, the depreciation rate of organizational capital is $1 - \phi_H = 0.37$. Following Schmitt-Grohé and Uribe (2001), we assume that the elasticity of the risk premium with respect to debt is close to zero $(\Theta'/\Theta)\mathcal{B}_t = 0.001$, which induces stationarity without affecting the quantitative properties of the model.

Using data for Canada for the period 1980:Q1 - 2008:Q4 we estimate the following processes for the shocks affecting the economy:

$$a_t^H = 0.96\ a_{t-1}^T + \epsilon_t^H,\ \ \epsilon_t^H \sim N(0, \sigma_H^2), \sigma_H = 0.015, \tag{21}$$

$$a_t^N = 0.97\ a_{t-1}^N + \epsilon_t^N,\ \ \epsilon_t^N \sim N(0, \sigma_N^2),\ \sigma_N = 0.005, \tag{22}$$

$$x_t = 0.86\ x_{t-1} + \epsilon_t^X,\ \ \epsilon_t^X \sim N(0, \sigma_X^2),\ \sigma_X = 0.017. \tag{23}$$

where a_t^H, a_t^N, and x_t are the log-deviations of home goods sector productivity, non-tradable sector productivity, and production in the commodity sector (mining, gas and oil). The commodity price shock and the external demand shock are estimated using data on oil prices and U.S. consumption:

$$p_t^X = 0.94\ p_{t-1}^X + \epsilon_t^{PX},\ \ \epsilon_t^{PX} \sim N(0, \sigma_{PX}^2),\ \sigma_{PX} = 0.15. \tag{24}$$

$$c_t^* = 0.99\ c_{t-1}^* + \epsilon_t^*,\ \epsilon_t^* \sim N(0, \sigma_{C^*}^2), \sigma_{C^*} = 0.006, \tag{25}$$

where p_t^X and c_t^* are the log-deviations of commodity prices and foreign consumption.

Table 1: Baseline Parameter Values

Description	**Symbol**	**Value**
Discount Factor	β	0.99
Habit Persistence	h	0.65
Labor Supply Elasticity	$1/\varphi$	0.60
Share of Tradable Inputs - Final Good Sector	α_Y	0.50
Elasticity of Substitution - Final Good Sector	η_Y	0.50
Share of Home Inputs - Tradable Good Sector	γ_Y	0.50
Elasticity of Substitution - Tradable Good Sector	ω_Y	0.50
Depreciation Rate	δ	0.02
Capital Share - Non-tradable Sector	η_N	0.30
Labor Share - Non-tradable Sector	$1-\eta_N$	0.70
Capital Share - Home Goods Sector	η_H	0.20
Labor Share - Home Goods Sector	$1-\eta_H$	0.55
Calvo Parameter - Home Goods Sector	θ_H	0.75
Calvo Parameter - Non-tradable Sector	θ_N	0.75
Elasticity of Substitution - Home Goods Sector	ε_H	6
Elasticity of Substitution - Non-tradable Sector	ε_N	6
Foreign Interest Rate Elasticity	$(\Theta'/\Theta)\mathcal{B}_t$	0.001
Foreign Demand Elasticity	η^*	0.50
Depreciation Rate - Organizational Capital	$1-\phi_H$	0.37
Output Elasticity - Organizational Capital	μ_H	0.37
Learning Rate	λ_H	0.25
Interest Rate Smoothing Coefficient - Taylor Rule	ψ_i	0.70
Inflation Coefficient - Taylor Rule	ψ_π	1.30
Output Coefficient - Taylor Rule	ψ_y	0.23
Depreciation Coefficient - Taylor Rule	ψ_s	0.14

IV. Findings

A. Effects of Learning-by-doing

This section reports the quantitative effects of learning-by-doing in the economy. Figure 3 shows the impulse response function when the economy is affected by an increase of one standard deviation of commodity prices. The solid line represents the dynamics of the New Keynesian model without the learning-by-doing externality and the dashed line represents the dynamics of the model laid out in Section 2 with external learning-by-doing. To gain intuition about how shocks are propagated in the model, first we explain the dynamics of the small open economy without learning by doing, and then the dynamics with this externality.

The solid line in figure 3 shows the reallocation process experienced in the economy in response to an increase of one standard deviation of commodity prices. Consistent with standard two-sector model, the commodity shock induces a reallocation from the tradable sector to the non-tradable sector. In response to higher commodity prices there is a higher demand for tradable and non-tradable goods. Considering that international prices are given, this higher demand for non-tradable goods will induce a real exchange rate appreciation and a reallocation of resources from the tradable to the non-tradable sector. At the same time, a higher demand for tradable goods is satisfied with imports from the rest of the world. In terms of the main macroeconomic variables, figure 4 depicts how an increase in commodity prices generates an expansion of GDP, consumption, investment and a higher trade balance deficit.[11]

The dashed lines in figures 3 and 4 describe the dynamics of the model with learning-by-doing. Two effects are operating in the model with learning by doing. First, in response to a decline in home goods production, the amount of organizational capital decreases through the law of motion (10). A lower organizational capital reduces the overall productivity of the home goods sector, which exacerbates the initial contraction in production. The second effect is an appreciation of the real exchange rate. Lower productivity

[11] In the impulse response function we show the trade balance excluding the commodity exports, to better assess the effects of higher commodity prices.

in the home goods sector increases the price level in the small open economy, which leads to a higher value of the real exchange rate. In figure 4 we can appreciate the aggregate effects of the learning-by-doing distortion. First, there is a gradual decline of GDP over time which is driven by a lower production in the manufacturing sector. Second, the fact that there is lower tradable production and higher imports, there is a deterioration of the trade balance.

Overall the main effects of learning–by-doing in the model are a decline of tradable production, GDP, and the trade balance. Clearly this externality reduces welfare of households. In the next sections we evaluate how successful is a policy of exchange rate stabilization to correct this externality.

B. Learning-by-doing and Exchange Rate Intervention

In this section we evaluate the impact of alternative policy rules to correct the frictions associated with price rigidities and the learning-by-doing externality. We consider four types of monetary policy rules which differ in their degree of exchange rate intervention: a Taylor-type rule, an empirical monetary policy rule, a fixed exchange rate policy, and an optimized rule that maximizes welfare.

We compare the dynamics of these rules with the allocations of a benchmark model with flexible prices and internalized learning-by-doing.[12] When learning by doing is internalized, there is a price for organizational capital that allows firms and households in the economy to decide the efficient amount of employment, capital and production for the sector. The real allocation of the benchmark model indicates the best outcome a policy intervention can achieve at a business cycle frequency.[13]

[12] See Appendix B for the first-order conditions with internalized learning-by-doing.

[13] An additional friction we consider in the model is monopolistic competition which generates a misallocation of resources at the steady state. Goodfriend and King (2001) showed that monetary policy is not effective to remove the markup of monopolistic competition at the steady state. If we additionally consider a subsidy on employment, then it is possible to achieve the first-best allocation with the combination of fiscal and monetary policy.

Any discrepancy or deviation from the benchmark model indicates a misallocation of resources in the economy. We gauge if a monetary policy is welfare improving if it is able to close the discrepancies or gaps with the benchmark model. In the limit, the optimal policy will generate an allocation that exactly coincides with the one from the benchmark model.[14][15]

Figures 5 and 6 show the impulse response function for the benchmark model and three rules: a Taylor-type rule, the empirical rule, and a fixed exchange rate. For the calibrated parameter values we observe that in the benchmark model there is a reallocation of resources from the home goods sector to the non-tradable sector. In the real model we also observe an appreciation of the real exchange rate, and an expansion of consumption, investment and GDP. To evaluate the success of alternative policy rules we have to measure how far from this benchmark are the allocations generated by the alternative monetary policies rules.

First we analyze the behavior of the Taylor-type rule. We calibrate the rule with the estimated parameter values for Canada imposing the restriction $\psi_s = 0$. In figure 5 we observe that under the Taylor-type rule, home goods production goes below the efficient level of output. In terms of the New Keynesian literature, under this rule there is a negative output gap in the home goods production. In principle, it is possible to close this gap by engineering a monetary expansion that depreciates the exchange rate and stimulates tradable output. However, it is important for policymakers to evaluate what are the implications of an exchange rate depreciation in other sectors of the economy. Next we show how a policy of exchange rate intervention stimulates non-tradable production and imports beyond the efficient level.

Now we consider the empirical rule which considers some exchange rate intervention. For this case we set $\psi_s = 0.15$. This parameter reduces the appreciation of the real exchange rate in response to the commodity price shock. The empirical rule allows the production of home goods to be closer to the efficient level; however the rest of the sectors are going to expand more

[14] See Correia et al. (2008).

[15] If we evaluate a variable such as a production, a deviation with respect to the benchmark model is consistent with the definition of output gap in a standard New Keynesian model.

than in the benchmark model. Figure 5 shows how non-tradable production and imports are larger than the efficient level, while the real exchange rate is going to be more depreciated. In terms of macroeconomic variables, figure 6 depicts how this policy generates an increase in GDP, consumption, and investment.

The third rule is a fixed exchange rate. This policy is equivalent to set the parameter of exchange rate depreciation in the Taylor-rule close to infinity, that is $\psi_s \rightarrow \infty$. Given that we consider sticky prices in the model economy, this policy is extremely successful to limit the magnitude of exchange rate appreciation. Nevertheless, all the quantities in the small open economy overshoot the allocations from the benchmark model, which reflects higher distortions. In sum, this policy generates higher macroeconomic volatility compared to other rules.

Figures 7 and 8 compare the dynamics of optimized policy rule with the empirical rule and the benchmark model. The specification of the optimized rule is the same as (14). However, as opposed to the empirical rule, the parameters are such that maximize the unconditional welfare measured by (1).[16] Compared to the alternative rules, the allocation under the optimized rule remains very close to the one of the benchmark model. More importantly, the optimized rule allows for an appreciation of the exchange rate and the reallocation process from the tradable to the non-tradable sector.

Two are the main results from this section. First, monetary policy is a very potent instrument to increase tradable production and to prevent an inefficient outcome in this sector. Second, leaning against an appreciated exchange rate generates greater macroeconomic volatility. The initial impulse of higher commodity prices triggers an expansion of aggregate demand in a commodity-exporting economy like Canada. In this situation, a policy of exchange rate stabilization generates a further expansion of aggregate demand and greater volatility over the business cycle. To evaluate whether or not this is an appropriate policy we need to compare the benefits of higher tradable production against the costs of larger macroeconomic volatility. In the

[16] In Schmitt-Grohé and Uribe (2007) it is shown that an optimized rule of this form generate dynamics that approximate the Ramsey policy. In the model the parameters of the optimized Taylor-type rule are given by $\psi_\pi = 2.23, \psi_i = 0.56, \psi_y = -0.76$, and $\psi_s = -0.25$.

next section we conduct a welfare analysis of alternative policy rules to compare properly the costs and benefits of stabilizing the exchange rate during a Dutch Disease episode.

V. Welfare Calculations

This section quantifies the welfare costs of alternative monetary policy rules. The welfare costs are calculated as in Lucas (1987) and is measured as a fraction of consumption that agents are willing to give up to eliminate the excess volatility of a specific policy. The welfare of the benchmark model, denoted by B, and the welfare of a monetary regime, denoted by R, are given by:

$$U^B = E\left[\sum_{t=0}^{\infty} \beta^t u(C_t^B - hC_{t-1}^B, 1 - L_t^B)\right], \tag{26}$$

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

typically (26) is going to be greater than (27) since the benchmark model does not incorporate frictions such as price stickiness or the learning-by-doing externality. In order to evaluate how costly is a specific policy we solve for the welfare cost, denoted by λ, in the following equation:

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

The welfare cost is computed as in Schmitt-Grohé (2005) from the second order approximation of equation (28). If a specific policy generates welfare costs then $\lambda > 0$, while if it is successful to correct nominal rigidities and the learning-by-doing externality then $\lambda = 0$. To have a meaningful estimation of the welfare costs first we ensure that the model is able to reproduce some of the moments in the data. Table 2 describes the second moments from the data and the model, and the welfare costs of monetary policy rules.

Table 2: Simulated Business Cycles and Welfare Costs

	Std. Dev.		Std. Dev. x/ Std. Dev. GDP				Welfare
	GDP	NX/GDP	C	INV	L	RER	λ
Canadian Data (1980-2008)	1.51	0.89	0.57	2.73	0.71	2.46	-
Empirical Rule	1.49	0.93	0.78	2.65	0.76	2.81	0.04
Taylor-Type Rule	1.58	1.32	0.77	2.70	0.79	2.97	0.04
Fixed Exchange Rate	2.52	1.22	0.79	2.49	0.98	1.50	0.19
Optimized Rule	1.49	1.33	0.78	2.70	0.48	3.30	0.00

The first row in table 2 reports some moments observed in the Canadian data. We observe that consumption and employment are less volatile than GDP, while investment and the real exchange rate are more than twice as volatile as output. The fact that consumption is less volatile than GDP is not specific to Canada but is a feature common to industrialized countries. [17] On the other hand, investment tends to be more volatile than output in most small open economies, both industrialized and emerging. [18] One feature that is also common to open economies is the exchange rate disconnect puzzle, or the fact that the real exchange rate is more volatile than macroeconomic quantities such as consumption or output.

The second row in table 2 shows the results from simulating the model with the estimated empirical rule subject to the five shocks described in section 3. Overall, the model with the empirical rule matches the main features of the data. In the model consumption tends to be more volatile than in the data, but still is the case than consumption is less volatile than

[17] See Neumeyer and Perri (2005) and Aguiar and Gopinath (2007).
[18] See Schmitt-Grohé (1998).

GDP, as is observed in developed small open economies. The last column in the second row shows the welfare cost as a fraction of the steady-consumption. The empirical rule generates a welfare cost equivalent to 0.04 percent of life time consumption.

The third row shows the second moments and welfare calculation of the Taylor-type without exchange rate intervention. The results of this policy are very close to the empirical rule. The Taylor-type rule allows for greater real exchange rate volatility. This volatility spills over the trade balance, which has a standard deviation 50 percent larger than in the case of the empirical rule.

The fourth row shows the fixed exchange rate policy. This rule increases the volatility of GDP by 60 percent, and the volatility of labor by 25 percent, while at the same reduces real exchange rate volatility by 50 percent.[19] The intuition for higher output volatility is that a fixed exchange rate policy exacerbates the business cycle in the presence of sticky prices.

As we analyzed in the previous section, stabilizing the nominal exchange rate in response to an increase in commodity prices can be achieved by increasing the money supply, which provides a further stimulus to the economy in addition to an increase in commodity prices. This policy generates a welfare cost equivalent to 0.19 percent of the stream of lifetime consumption. This number is about two times the measure of costs of business cycles estimated by Lucas (1987). This welfare loss is generated mainly by the increase in labor supply volatility by 25 percent.

The fifth row describes the results of the optimized rule. By construction, this rule does not generate substantial welfare costs compared to the benchmark model. This rule brings the allocation of the economy close the one with flexible prices and internalized learning-by-doing. Interestingly, the optimized rule generates a relatively low volatility of output and labor and a higher volatility of real exchange rate. This result is consistent with the view of Friedman (1953) in favor of flexible exchange rates. In presence of nominal rigidities, a flexible exchange rate is capable of insulating the economy from external shocks by generating a faster adjustment of relative prices.

[19] Notice that since investment responds sluggishly owing to the investment adjustment costs, most of the variation of production in the short-run is generated by fluctuations in the labor supply.

Figure 9 depicts the welfare costs as a function of the exchange rate intervention parameter ψ_s. The horizontal axis shows the depreciation rate coefficient in the Taylor rule, and the vertical axis the relative value of the welfare costs.[20] The graph describes how welfare costs are an increasing function of exchange rate intervention. As a central bank intervenes in the foreign exchange rate market, the allocation in the economy tends to move away from the efficient equilibrium which is costly in terms of welfare. In particular, a policy of exchange rate stabilization increases macroeconomic volatility, which affects negatively the households' welfare.

The main result in this section is that a policy of exchange rate intervention results in welfare losses. In spite of being an effective instrument to correct inefficiencies in the home goods sector, it is costly in terms of macroeconomic volatility. This result suggests that correcting the learning-by-doing externality with monetary policy is highly distortionary. During a Dutch disease episode there are welfare gains if the monetary authority allows a real exchange rate appreciation to ensure a reallocation of resources across sectors.

VI. Sensitivity Analysis

Now we consider alternative specifications of the model to assess the robustness of our results. There are several dimensions in which we could add more layers of realism to the model. In this section we explore four modifications to the benchmark model: larger learning-by-doing externalities, learning-by-doing in the non-tradable sector, incomplete pass-through for imported goods, and financial autarky. All of these frictions are commonly discussed in the literature and potentially can improve the fit of the model to the data.

Figure 10 describes the impulse response functions of home production and the real exchange rate under alternative specifications of the model. The first row shows the results under the assumption of high organizational capital. We raised the share of organizational capital to $\lambda_H = 0.5$, which

[20] This is the ratio of λ for a rule with exchange rate intervention such as equation (13) compared with the λ with no exchange rate intervention. For $\psi_s = 0$ this ratio is equal to 1.

implies a learning rate of 40 percent, two times the empirical estimate.[21] The main difference with the baseline model is that home goods production is going to be more sensitive to exchange rate appreciations due to the higher externality. As we can notice in panel 10.A., with the empirical rule the contraction of output is below the efficient level of production, while in the baseline case the reverse is true. This result indicates that for a given policy rule, higher learning-by-doing rate generates greater costs during a boom in commodity prices. Also in this case if the externality is corrected with a currency depreciation then all macroeconomic variables overshoot their efficient levels.

Panels C and D in figure 10 show a more realistic case in which the learning-by-doing externality is present in both sectors of the economy. We assume the same parameters values of learning-by-doing in the home goods and non-tradable sector. With this additional externality the reallocation process from the tradable to the non-tradable sector is exacerbated. A real exchange rate appreciation stimulates non-tradable output, and through the LBD mechanism there is a further increase of future non-tradable production. The additional output comes at expense of reallocating factors from the production of tradable goods. With the externality in the non-tradable sector there are welfare gains from appreciating the currency. As we can observe in the impulse response functions, a greater exchange rate intervention induces deviations from the efficient allocation.

Panels 10.E. and 10.F. show an economy with limited pass-through from exchange rate to imported prices. In this extension we assume that importers set their prices according to a Calvo mechanism every four quarters. The result of this additional assumption is that the expenditure switching effect is going to be weaker in this economy. Since the price of imported goods is less sensitive to exchange rate fluctuations, a depreciation of the currency is going to generate a lower substitution between imported and home goods. As shown in the graphs, it is still the case that leaning against an appreciated exchange rate is distortionary.

Finally panels 10.G. and 10.H. show some results under the assumption of financial autarky. We model this financial imperfection assuming an extremely high value for the elasticity of risk premium with respect to bonds.

[21] See Cooper and Johri (2002).

In particular, we set $(\Theta'/\Theta)\mathcal{B}_t = 100$. Under this assumption, the small open economy finds it extremely costly to issue foreign debt, and hence is limited in its ability to intertemporally smooth consumption. However, it is still engaged in trade of goods with the rest of the world. The impulse response functions show that the effects of a shock in commodity prices are much larger under financial autarky. Since households are not able to smooth consumption, the greater resources from commodities are translated into a higher aggregate demand. The final effect is greater reallocation of factors across sectors, and a larger contraction of home goods production. Even though, in this case the effects of the externalities are larger, monetary policy continues to be an inefficient instrument to correct this distortion. The allocation under exchange rate stabilization generates significant deviations from the outcome in the benchmark real model.

In this section we introduced alternative assumptions about the frictions operating in the baseline model. The main conclusion of the sensitivity analysis is that the results of the model remain valid under these alternative frictions. Introducing more realistic features into the model does not change the basic trade-off for exchange rate intervention. Despite the fact that learning-by-doing affects negatively the economy during a commodity boom, correcting this externality with exchange rate stabilization is highly distortionary.

VII. Conclusions

In this paper we evaluated the consequences of stabilizing the nominal exchange rate in response to a Dutch Disease episode. In order to evaluate this policy intervention we considered a New Keynesian small open economy model that exhibits a learning-by-doing externality in the tradable sector. This type market failure introduces a trade-off for monetary policy. The learning-by-doing externality calls for a policy of exchange rate stabilization which brings tradable production close to the efficient level. On the other hand, in a standard New Keynesian model higher terms of trade calls for an appreciation of the real exchange rate to ensure and efficient allocation of resources across sectors.

Under a calibration consistent with the Canadian data, we find that the trade-off is resolved in favor of allowing a real exchange rate appreciation. This result indicates that stabilizing the nominal exchange rate with monetary policy is a blunt instrument to correct the learning-by-doing externality. Any attempt to correct LBD leaning against an appreciated exchange rate will result in a misallocation of resources and a reduction in welfare. If a government is interested in tackling the problems associated with learning-by-doing in a Dutch Disease episode, it should used alternative policy instruments. In this model the role of monetary policy should be focused on stabilizing prices subject to nominal rigidities in order to ensure a smooth adjustment toward a situation of higher commodity prices.

One of the arguments for exchange rate intervention is that a real exchange appreciation undermines the competitiveness of a country and can have a lasting negative impact on growth and employment creation. The results from a calibrated model indicate that the government can achieve a better outcome by allowing the economy to adjust to higher commodity prices through a real exchange rate appreciation. This paper provides theoretical support for the current policy of the Bank of Canada of not intervening in the foreign exchange market. In fact, this central bank has not intervened in the foreign exchange rate market in the last ten years.

There are several interesting extensions for future research. We could evaluate the effectiveness of alternative instruments to correct the learning-by-doing externality such as fiscal policy, the adoption of a commodity fund in case the government owns a natural resource, or alternative structural reforms in goods and factor markets that facilitate the reallocation process across sectors. We could also explore alternative frictions affecting the tradable sector, which can be operating during a commodity boom. For instance Caballero and Lorenzoni (2009) evaluate the welfare gains of influencing the real exchange rate when the tradable sector is subject to financial frictions. Finally, it is important to conduct a similar quantitative exercise for a developing small open economy. In a situation in which the monetary authority may lack credibility, stabilizing the exchange rate could be a better alternative to stabilize prices and anchor inflation expectations, as is shown empirically in Rogoff et al. (2004).

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Appendix A: Equilibrium Conditions

Households

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

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

$$\left(C_t-hC_{t-1}\right)\zeta_L l_t^{\varphi}=\frac{W_t}{P_t^C}. \tag{31}$$

Equations (29) and (30) define the Euler equations for domestic bonds and international bonds, respectively. Labor supply is determined by (31).

Final Good Producers

$$P_t^C F_{Y^{DH},t}=P_t^H, \tag{32}$$

$$P_t^C F_{Y^{M},t}=P_t^M, \tag{33}$$

$$P_t^C F_{Y^{DN},t}=P_t^N, \tag{34}$$

where $Y_t^F=F(Y_t^{DH},Y_t^M,Y_t^{DN})$ is the production function for final goods. Equations (32) - (34) describe the demand for home, imported, and non-tradable inputs, respectively.

Retailers

The first-order conditions for the retailers in sector $J=H,N$ are:

$$E_t\left[\sum_{i=0}^{\infty}(\theta_J)^i\Lambda_{t,t+i}\left(\frac{P_t^{J*}(j)}{P_{t+i}^J}\right)^{-\epsilon_J}Y_t^J(j)\left[\frac{P_t^{J*}(j)}{P_{t+i}^J}-\frac{\epsilon_J}{\epsilon_{J-1}}\frac{P_{t+i}^{WJ}}{P_{t+i}^J}\right]\right]=0, \tag{35}$$

where $P_t^J = (\theta_J (P_{t-1}^J)^{1-\epsilon_J} + (1-\theta_J)(P_t^{J*})^{1-\epsilon_J})^{1/(1-\epsilon_J)}$

Intermediate Good Producers

The first order conditions for the home and non-tradable sectors are:

$$F^N_{L^N,t} = \frac{W_t}{P_t^N}, \tag{36}$$

$$F^N_{K^N,t} = \frac{Z_t^N}{P_t^N}, \tag{37}$$

$$F^H_{L^H,t} = \frac{W_t}{P_t^H}, \tag{38}$$

$$F^H_{K^H,t} = \frac{Z_t^H}{P_t^H}. \tag{39}$$

where $Y_t^N(n) = F^N(A_t^N, L_t^N(n), K_t^N(n))$ and $Y_t^H(h) = F^H(A_t^H, H_t(h), L_t^H(h), K_t^H(h))$ are the production function for home and non-tradable goods, respectively.

Capital Producers

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

$$\begin{aligned} 1 \quad = \quad & \frac{Q_t^J}{P_t^C}\left[S\left(\frac{I_t^J}{I_{t-1}^J}\right) + S'\left(\frac{I_t^J}{I_{t-1}^J}\right)\frac{I_t^J}{I_{t-1}^J}\right] - \\ & E_t\left[\Lambda_{t,t+1}\frac{Q_{t+1}^J}{P_{t+1}^C}\left[S'\left(\frac{I_{t+1}^J}{I_t^J}\right)\left(\frac{I_{t+1}^J}{I_t^J}\right)^2\right]\right], \end{aligned} \tag{40}$$

$$\frac{Q_t^J}{P_t^C} = E_t\left[\Lambda_{t,t+1}\left[\frac{Z_t^J}{P_t^C} + \frac{Q_{t+1}^J}{P_{t+1}^C}(1-\delta)\right]\right]. \tag{41}$$

Equations (40) and (41) determine the evolution of investment I_t^J and the real price of capital $\frac{Q_t^J}{P_t^C}$ in each sector.

Market Clearing Conditions

$$L_t = \left(\int_0^1 L_t^N(n)dn \right) + \left(\int_0^1 L_t^H(h)dh \right), \tag{42}$$

$$K_t^J = \left(\int_0^1 K_t^J(j)dj \right), J = H, N, \tag{43}$$

$$Y_t^{DN} = Y_t^N, \tag{44}$$

$$Y_t^{DH} + C_t^{H*} = Y_t^H, \tag{45}$$

$$Y_t^F = C_t + I_t^H + I_t^N, \tag{46}$$

$$\begin{aligned} \mathcal{E}_t B_t^* \quad = \quad & (1 + i_{t-1}^*)\Theta\left(\mathcal{B}_{t-1}\right)\mathcal{E}_t B_{t-1}^* + P_t^M Y_t^M \\ & -P_t^H C_t^{H*} - P_t^x X_t. \end{aligned} \tag{47}$$

Equations (42) and (43) are the market clearing conditions in the labor and capital markets. Equations (44) - (46) define the market clearing conditions for the non-tradable, home, and final goods, respectively. (47) describes the law of motion for international bonds, where $C_t^{H*} = \gamma^* \left(\frac{P_{H,t}}{\mathcal{E}_t P_t^{M*}} \right)^{-\eta^*} C_t^*$ is the foreign demand for home goods.

Appendix B: Internalization of Learning-by-Doing

When the learning-by-doing mechanism is internalized, the problem of firms in the home goods sector is the following:

$$\Pi_t = \max_{H_{t+i}, L^H_{t+i}, K^H_{t+i}} E_t \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \frac{P^{WH}_{t+i} Y^H_{t+i}(h) - W_{t+i} L^H_{t+i}(h) - Z^H_{t+i} K^H_{t+i}(h)}{P^C_{t+i}} \right\},$$

subject to the law of motion of organizational capital:

$$H_{t+1}(h) = [H_t(h)]^{\phi_H} \left[Y^H_t(h) \right]^{\mu_H}. \tag{48}$$

where $\Lambda_{t,t+i}$ is the stochastic discount factor. The first order conditions of the firm are given by:

$$\frac{W_t}{P^C_t} = \frac{P^{WH}_t}{P^C_t} F^H_{L^H,t} + \frac{Q^O_t}{P^C_t} G_{L^H,t}, \tag{49}$$

$$\frac{Z^H_t}{P^C_t} = \frac{P^{WH}_t}{P^C_t} F^H_{K^H,t} + \frac{Q^O_t}{P^C_t} G_{K^H,t}, \tag{50}$$

$$\frac{Q^O_t}{P^C_t} = E_t \left[\Lambda_{t,t+1} \left[\frac{P^{WH}_{t+1}}{P^C_{t+1}} F^H_{H,t+1} + \frac{Q^O_{t+1}}{P^C_{t+1}} G_{K^H,t+1} \right] \right] \tag{51}$$

where $Y^H_t(h) = F^H(A^H_t, H_t(h), L^H_t(h), K^H_t(h))$ is the production function of home goods, $H_{t+1}(h) = G(A^H_t, H_t(h), L^H_t(h), K^H_t(h))$ is the law of motion for organizational capital, and $\frac{Q^O_t}{P^C_t}$ is the real price of organizational capital. When we consider a model with internalization of learning-by-doing the first-order conditions (38) - (39) are replaced by (49) - (51).

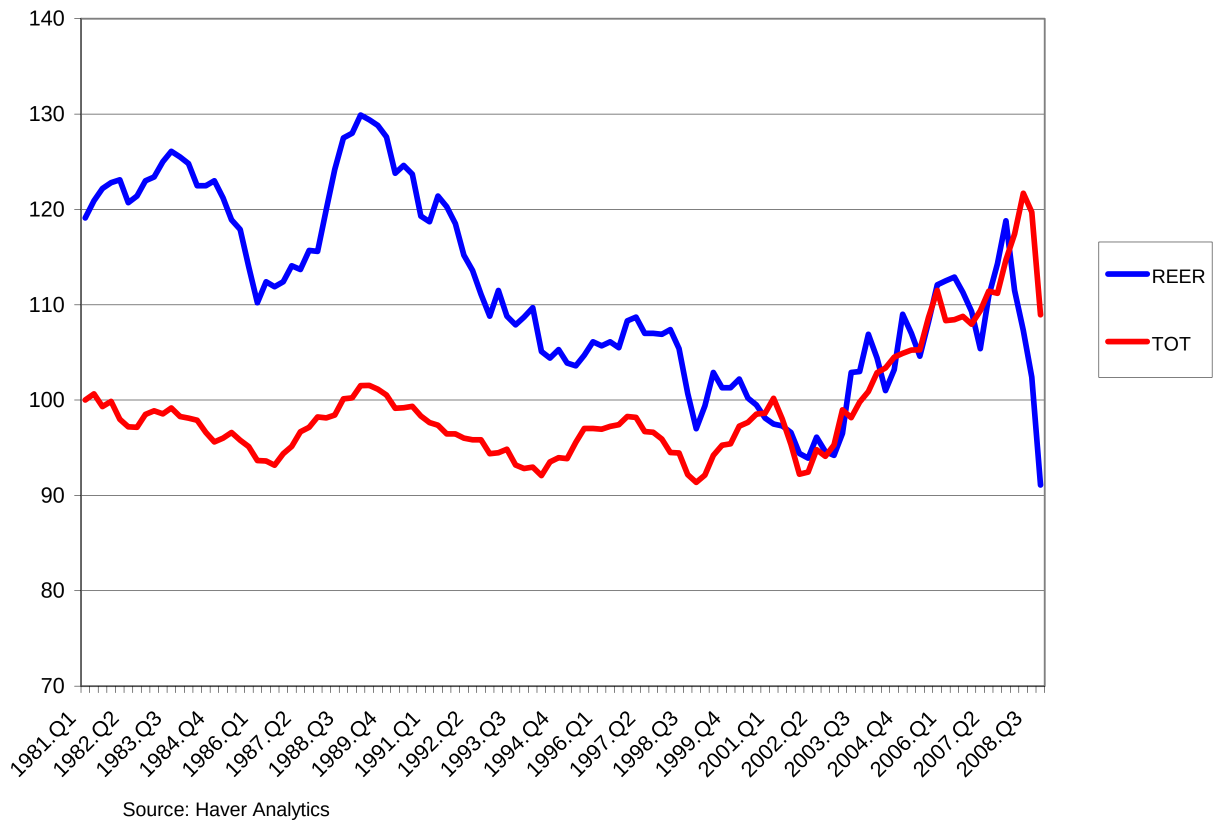

Figure 1: Real Effective Exchange Rate and Terms of Trade in Canada (1981 - 2008)

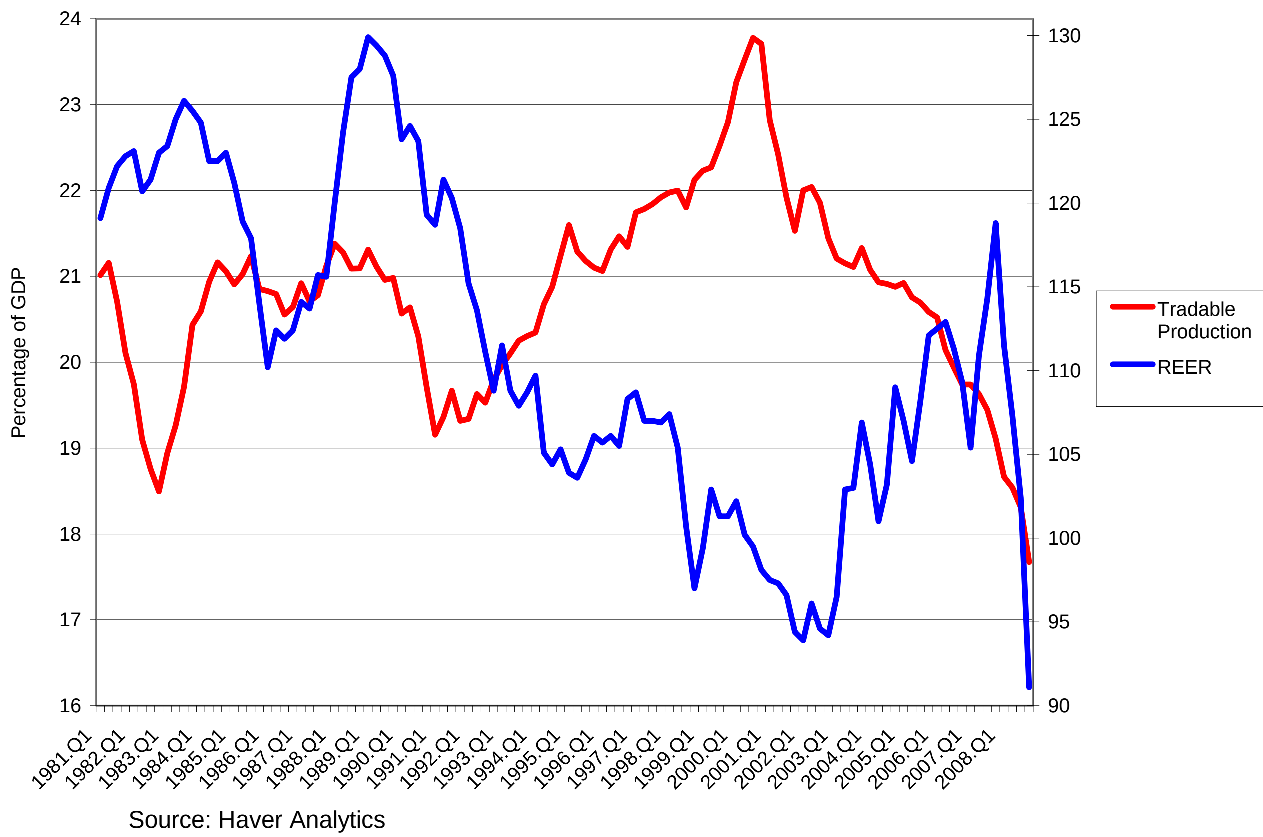

Figure 2: Real Effective Exchange Rate and Share of Tradable Production in Canada (1981 - 2008)

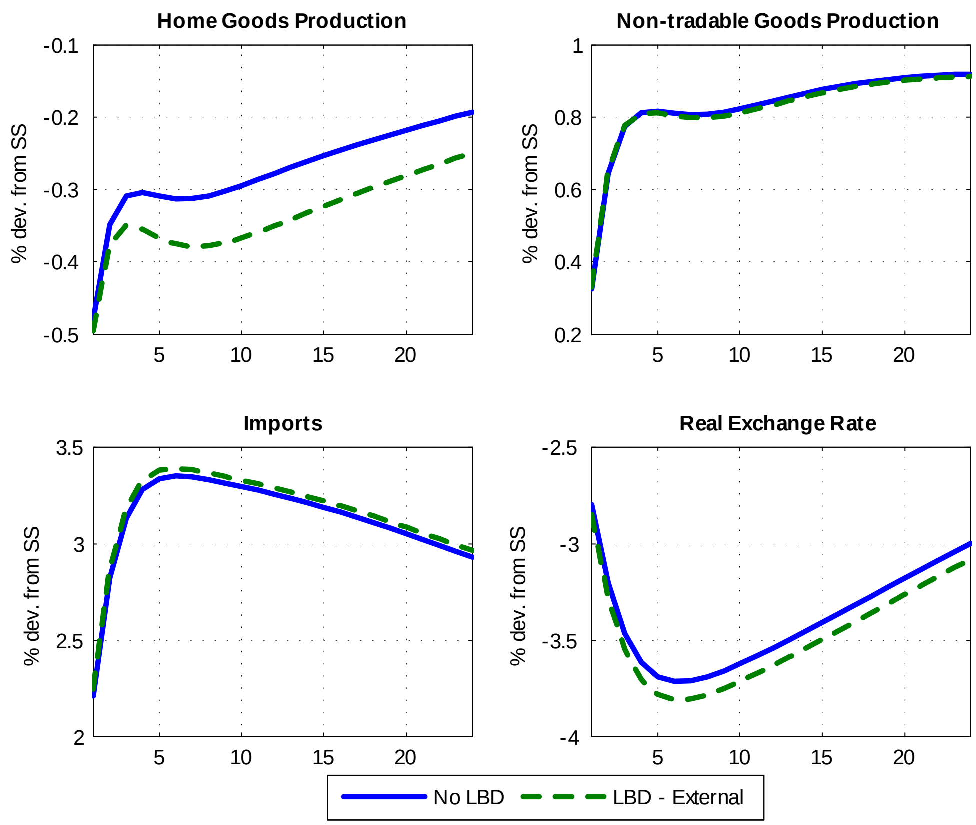

Figure 3: Effects of Learning-by-Doing

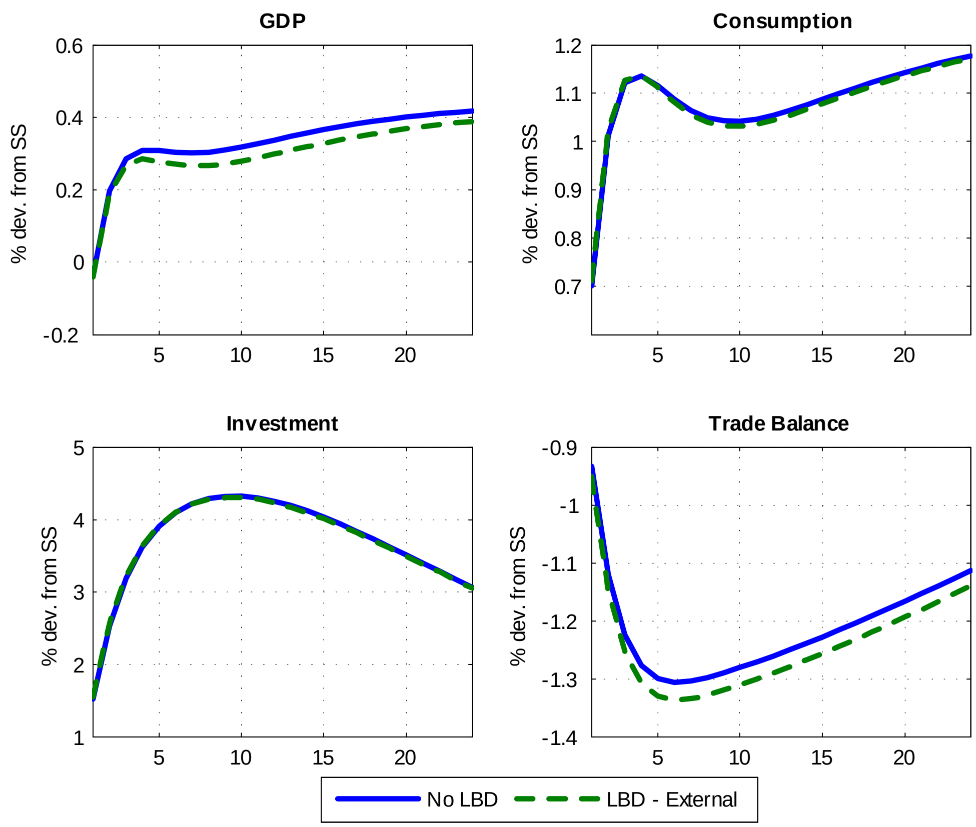

Figure 4: Effects of Learning-by-Doing

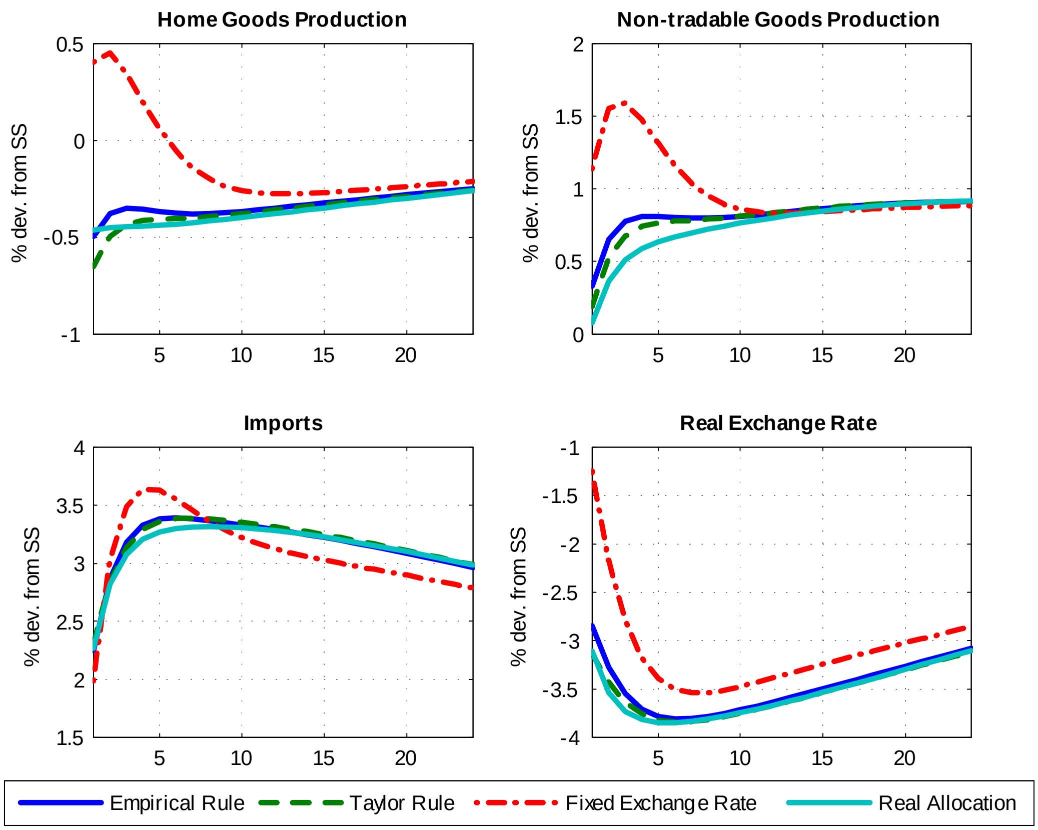

Figure 5: Learning-by-Doing and Exchange Rate Intervention

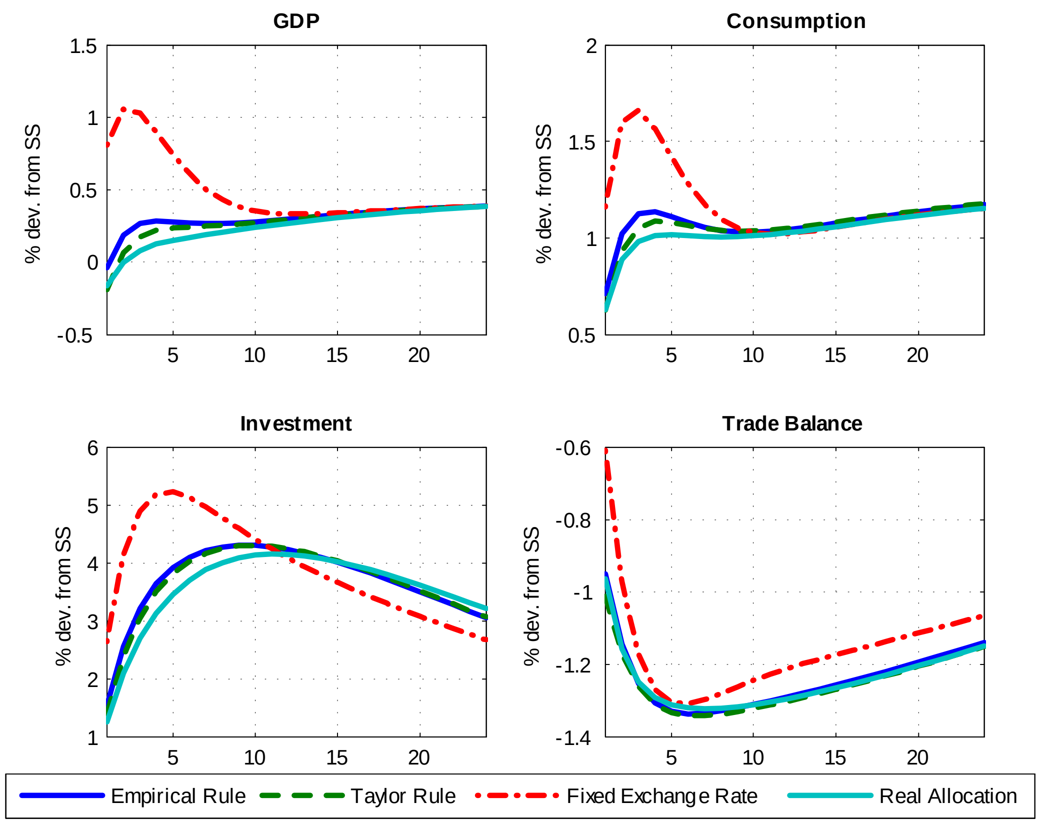

Figure 6: Learning-by-Doing and Exchange Rate Intervention

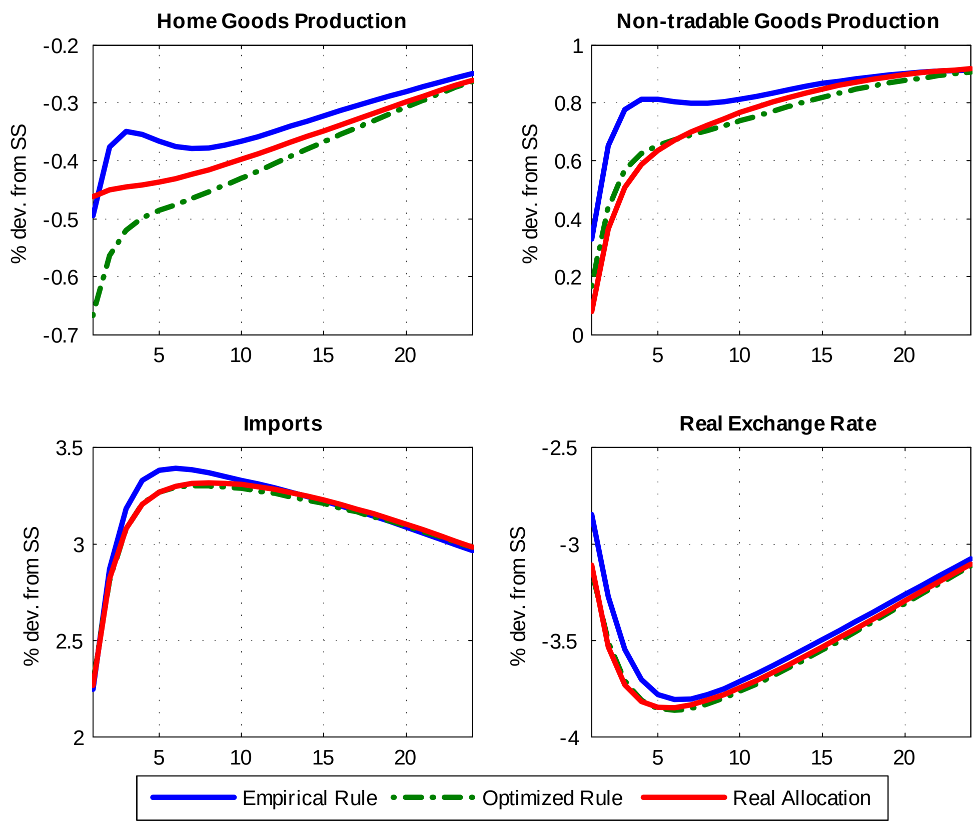

Figure 7: Learning-by-Doing and Exchange Rate Intervention

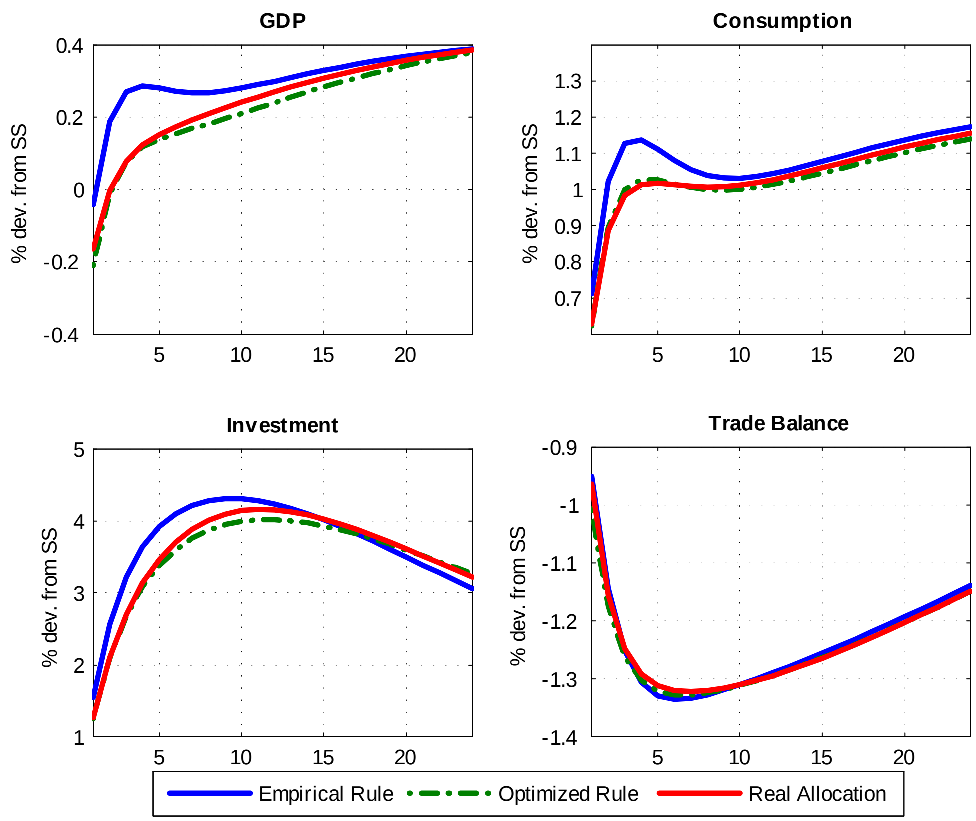

Figure 8: Learning-by-Doing and Exchange Rate Intervention

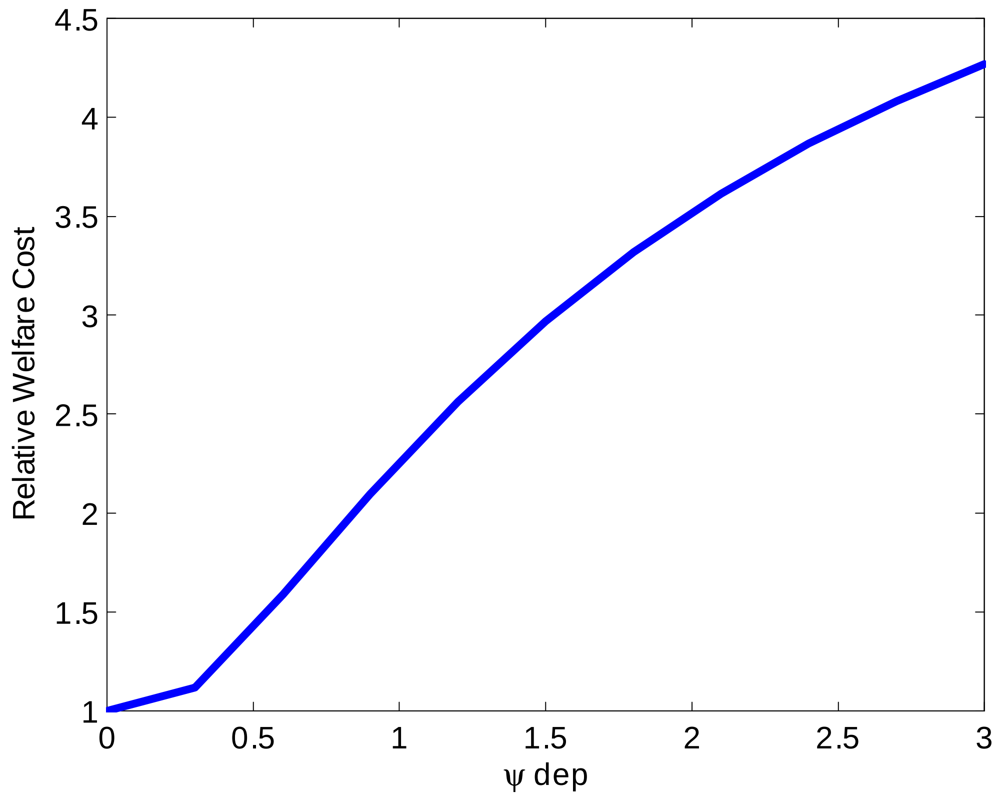

Figure 9: Relative Welfare Costs and Exchange Rate Intervention

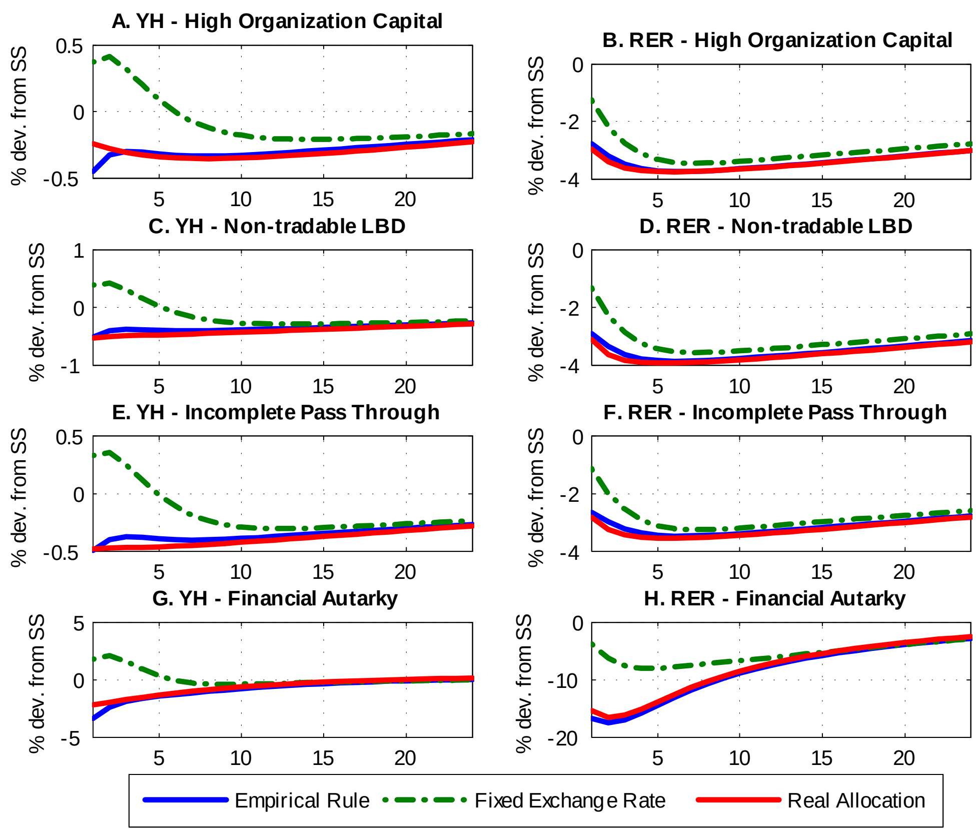

Figure 10: Sensitivity Analysis