# Dutch Disease in a Dynamic International Trade Model of an Small Open Economy

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**Abstract**

In this paper, we model a dynamic small open economy which produces and trades final goods and a commodity. The commodity is modeled as an homogeneous good and it is employed as intermediate input by monopolistic competitive firms in the home economy as well as in the rest of the world. The dynamic system developed in this paper relies on key parameters that characterize the small open economy. These parameters are the elasticity of substitution across final goods and the shape parameter of the Pareto distribution of productivities. In order to compute the steady-state of the economy and study the dynamics implied by the model, we estimate both the elasticity of substitution and the shape parameter of the Pareto distribution considering data for the Chilean economy, which satisfies the small open economy assumption as well as the commodity production.

We study the impulse response of the endogenous variables to different shocks within the stochastic dynamic system developed in the paper. We first implement an aggregated productivity shock. This type of shock increases welfare over time and it is very persistent. Secondly, we implement a shock to the commodity price. This shock illustrates the effect of the so called "Dutch disease", since the domestic small open economy, that produces and trade the commodity, faces a decrease in welfare.

We also study the effect of commonly used government policies on the Dutch disease. Our findings show that government policies interact with the Dutch disease in such a way that commonly used policies may aggravate the effect of the Dutch disease.

## 1 Introduction

The literature on the Dutch disease suggests that a bonanza in natural resource exports will lead to a contraction in production of tradables. In a first view, the idea behind the Dutch disease is that the extra wealth generated by the sales of natural resources induces appreciation of the real exchange rate, which makes domestic goods more expensive and less attractive, and thus, a contraction of the traded sector follows (Corden and Neary, 1982; Corden, 1984).

It seems intuitively that the market response to a resource windfall is the decline in the traded sector. However, the Dutch disease phenomenon is perceived as a negative issue. This is because a problem takes place when the traded sector is an important determinant of growth and, for example, it benefits from learning by doing. If human capital spillovers in production are generated by employment in the traded sector and it induces endogenous growth, then the negative effect of the natural resource exports on employment in the traded sector slows down learning by doing and thus it restricts growth (van der Ploeg, 2011).

Sach and Warner (1995) show that resource rich countries grow on average about one percent point less during the period 1970-89. Even after taking into account traditional growth determinants, there is a strong negative effect of resource dependence on growth[1].

Recent empirical evidence, for 135 countries during the period 1975-2007, indicates that in response to a natural resource bonanza nonresource exports decrease by 35-70 percent and nonresource imports increase by 0-35 percent (Harding and Venables, 2010). These findings hold in pure cross-sections of countries, and in panel estimations including dynamics and country fixed effects. Ismail (2010) uses detailed disaggregated sectorial data for manufacturing and obtains similar results: a ten percent resource windfall is on average associated with a 3.4 percent fall in value added across manufacturing.

Beine et al (2012) find a negative relationship between natural resource windfalls and employment for the Canadian manufacturing sector.

Quasi-experimental evidence within country from Brazil shown in Caselli and Michaels (2009) offers support for the Dutch disease hypothesis, but also shows evidence of wasteful local government and corruption.

Thus, macroeconomic and sectorial evidence seems to offer support for the Dutch disease effect.

A second face of the Dutch disease is associated with corruption. Resource wealth may worsen the quality of institutions (Ishan et al, 2005). Sala-i-Martin and Subramanian (2003) argue that corruption seems to be why oil resources have ruined growth performance in the Nigerian economy.

Acemoglu et al (2004) argue that resource wealth makes it easier for incumbent politicians to buy off political challengers. Resource wealth raise the value of being in power and induce politicians to expand public sectors, bribe voters, create unproductive jobs, inefficient subsidies, etc. (Robinson et al, 2006).

Mauro (1995) shows, using a sample of fifty five countries, that resource dependence is indeed strongly positively associated with corruption perceptions which in turn is associated with lower growth.

A third face of the Dutch disease is associated to volatility. Resource revenues are highly volatile. Thus, the Dutch disease can also induce real exchange volatility and thus less investment in physical capital, worsening the contraction of the traded sector. Estimates in Van der Ploeg and Poelhekke (2009, 2010) suggest a strong negative and significant effect of macroeconomic volatility on growth and a strong and positive effect of exports of especially point-source resources on macroeconomic volatility. They also show that with commodity price volatility liquidity constraints are more likely to happen and thus growth would fall.

In this paper we want to study the dynamic effects of a commodity price boom from the perspective of a small open economy. In order to do so, we model a dynamic small open economy which produces and trades final goods and a commodity. The commodity is modeled as an homogeneous good and it is employed as a factor input by monopolistic competitive firms in the home economy as well as in the rest of the world.

We tune the model estimating the elasticity of substitution across final goods and the shape parameter of the Pareto distribution of productivities considering Chilean data which satisfies the small open economy assumption as well as the commodity production.

[1]Even though, these results have been criticized on the econometric grounds.

The main commodity exported from Chile is Copper. Figure (1) shows the historical evolution of the copper price since 1960. The copper price boom can be seen starting around 2004.

Figure 1: Copper Price evolucion since 1960


As discussed before in this section, there is empirical evidence that a boom in natural resources brings along a contraction in the traded sector. In particular, Ruehle and Kulkarni (2011) find evidence in support of the Dutch disease for the Chilean economy.

In this paper we want to build a theoretical model consistent with such findings in which we can explore the effect of the resource bonanza on the manufacture sector.

Our model considers firm heterogeneity as in Melitz (2003), in a dynamic setting as in Ghironi and Melitz (2005), in a small open economy as in Demidova and Rodriguez-Clare (2009 and 2013).

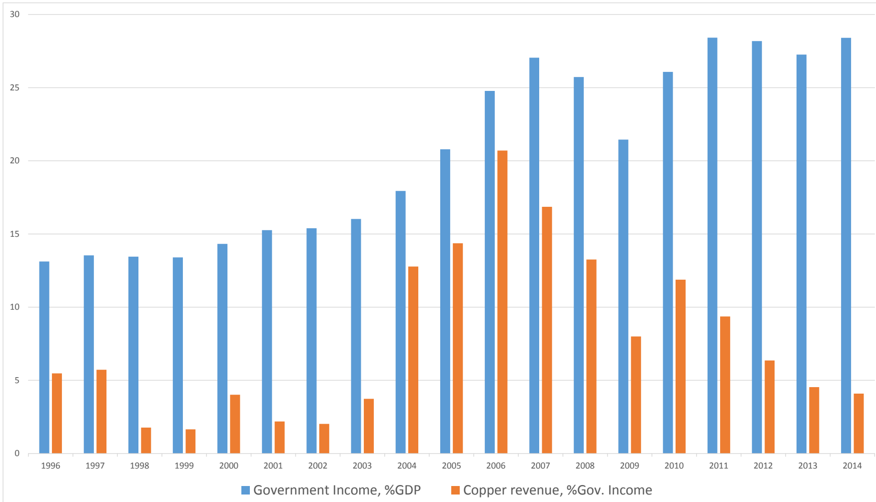
Besides the direct or traditional effect of the Dutch disease, the extra resources associated with the copper boom may bring along potential problems regarding the efficient use of such resources. Figure (2) shows the evolution of government income from copper as a percentage of GDP and government revenues from copper as a percentage of total government income.

Both measures shown in Figure (2) illustrate the effect of the commodity boom on the government budget. As discussed earlier in this section, the commodity boom could trigger undesired effect in an economy inducing politicians to expand public sectors, bribe voters, create unproductive jobs, inefficient subsidies, etc.

Employing the model developed in this paper, we will explore the impact of the commodity price boom in the manufacture sector as the direct or traditional effect of the Dutch disease, and the effect induced by the interaction of the commodity price boom and different government policies.

The rest of the paper is organized as follows: Section 2 describes de model. In section 3, we delineate the macro dynamics of the model. In section 4, the data employed in this paper and the estimation of the parameters that describe the model are presented. Section 5 shows the steady state while section 6 describes the impulse responses of our model. Section 7 studies the effect of the Dutch disease interacted with government policies. Finally, section 8 offers some conclusions.

Figure 2: Evolution of government revenue




## 2 Model

Our model combines three distinctive characteristics. First, we consider a model of trade for a small open economy as in Demidova and Rodriguez-Clare (2009 and 2013) (DRC). Their model relies on the traditional Melitz (2003) model, as it considers a monopolistic competition environment and firm heterogeneity. Second, we include in the DRC setting a homogeneous good which is produced and traded by the small open economy. We use this homogeneous good to model a commodity which is produced in the small open economy and is used as input to produce final goods in the home economy as well as in the rest of the world. Third, we develop a dynamic version of the small open economy with heterogeneous firms shown in DRC in which we include the commodity market.

### 2.1 Household Problem

Let's consider a small country populated by $L$ identical individuals, each of which has a unit of labor that is supplied inelastically and earns a wage $w_t$. Each agent spends his income on a continuum of domestic and imported goods indexed $\omega$ and $\omega'$, respectively. The consumption of domestic and imported goods are given by $q_t(\omega)$ and $q^*_{x,t}(\omega')$.

A representative household maximizes expected intertemporal utility from consumption:

$$E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\frac{(C_s)^{1-\gamma}}{1-\gamma}\right]$$

where $\beta \in (0,1)$ is the subjective discount factor and $\gamma > 0$ is the inverse of the intertemporal elasticity of substitution. At time $t$, the household consumes a basket of goods $C_t$ composed by domestically produced goods $q_t(\omega)$ and foreign produced goods $q^*_{x,t}(\omega')$ of the form:

$$C_t = \left[ \int_{\omega \in \Omega} \left( q_t\left(\omega\right) \right)^{\frac{\sigma-1}{\sigma}} d\omega + \int_{\omega' \in \Omega'} \left( q^*_{x,t}\left(\omega'\right) \right)^{\frac{\sigma-1}{\sigma}} d\omega' \right]^{\frac{\sigma}{\sigma-1}}$$

where $\sigma > 1$ is the elasticity of substitution across goods.

The budget constraint faced by the representative agent at prices $p_t\left(\omega\right)$ and $p^*_{x,t}\left(\omega'\right)$ for domestic and foreign goods, respectively, is as follows:

$$\int p_t\left(\omega\right) q_t\left(\omega\right) d\omega + \int p^*_{x,t}\left(\omega'\right) q^*_{x,t}\left(\omega'\right) d\omega' = I_t$$

where $I_t$ corresponds to the income at time $t$.

The solutions to the household problem is given by equations shown in (1).

$$\begin{aligned} Q_t\left(\omega\right) &= \left(\frac{p_t(\omega)}{P_t}\right)^{-\sigma} C_t \\ Q^*_{x,t}\left(\omega'\right) &= \left(\frac{p^*_{x,t}(\omega')}{P_t}\right)^{-\sigma} C_t \end{aligned} \tag{1}$$

In this paper we assume a small open economy as in Demidova and Rodriguez-Clare (2009 and 2013). This translates into the following functional form for the amount produced of a variety $\omega$ for the foreign market,

$$Q_{x,t} = A_t \cdot p_{x,t}\left(\omega\right)^{-\sigma} \tag{2}$$

where $A_t$ is exogenous and $p_{x,t}\left(\omega\right)$ is the price charged by a domestic exporter of a variety $\omega$.

The price index in the home economy associated to the consumer problem is as follows:

$$P_t = \left[ \int p_t\left(\omega\right)^{1-\sigma} d\omega + \int p^*_{x,t}\left(\omega'\right)^{1-\sigma} d\omega' \right]^{\frac{1}{1-\sigma}}$$

### 2.2 Firm Problem

Firms are embedded in a monopolistic competition environment as in Melitz (2003). Firms pay a sunk cost $f_E$ to draw a productivity level $z$. Depending on the level of $z$, a firm will serve the domestic economy exclusively (relatively low $z$ with respect to a threshold), or it could serve both the domestic economy and the foreign economy (relatively high $z$ with respect to a threshold).

The production scheme for a domestic firm $z$ is given in (3). Where $Q_t\left(\omega\right)$ is the amount of goods, of a variety $\omega$, domestically demanded, and $Q_{x,t}\left(\omega\right)$ is the amount of goods, of a variety $\omega$, foreign demanded. $\tau$ corresponds to the traditional iceberg type of transport cost. The fix costs of production are shown in (4). Then, a firm that exclusively serves the domestic economy will produce $Q_t\left(\omega\right)$ with no fix cost of production.

$$\bar{Q}_t = \begin{cases} Q_t\left(\omega\right) + \tau \cdot Q_{x,t}\left(\omega\right) & \text{if firm is exporting} \\ Q_t\left(\omega\right) & \text{otherwise} \end{cases} \tag{3}$$

Also, a firm that serves the domestic economy and the foreign economy will produce an amount equal to $Q_t\left(\omega\right) + \tau \cdot Q_{x,t}\left(\omega\right)$ incurring in fix costs of production $f_x$. The fix cost $f_x$ is measured in effective units of labor which translates into $\frac{w_t f_x}{Z_t}$ units of consumption.

$$f_{\bar{Q}} = \begin{cases} f_x & \text{when exporting} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

Monopolistic firms produce final goods employing a production technology, shown in (5), which corresponds to a Cobb-Douglas production function that depends on labor $l_t$, and an homogeneous good $q_{o,t}$. The Hicks-neutral productivity $Z_t z$ is the product between an aggregated productivity shock $Z_t$ and the firm's productivity draw $z$.

$$Q_t = (Z_t z) \cdot l_t^{\alpha} \cdot q_{o,t}^{1-\alpha} \tag{5}$$

The conditional factor demand for a firm $z$ is given in (6) .The amount of inputs demanded by a firm $z$ depends on the exporting status of the firm, the productivity level, and the input bundle cost, which is determined by the wage rate $w_t$, and the commodity price $p_{o,t}$.

$$\begin{aligned} l_t(z) &= \tfrac{\alpha}{w_t}\left(\tfrac{(w_t)^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\theta \cdot (Z_t z)}\right) \cdot \bar{Q}_t + f_Q \\ q_{o,t}(z) &= \tfrac{1-\alpha}{p_{o,t}}\left(\tfrac{(w_t)^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\theta \cdot (Z_t z)}\right) \cdot \bar{Q}_t \end{aligned} \tag{6}$$

The price of the domestically produced non-traded goods, $p_t(z)$, and the price of the domestically produced traded goods, $p_{x,t}(z)$, are shown in (7). It is customary to say that the price charged by the domestic competitive firms correspond to a constant mark-up, $(1/\rho)$, over the marginal cost of production.

$$p_t(z) = \left(\tfrac{\sigma}{\sigma-1}\right)\left(\tfrac{(w_t)^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\theta \cdot (Z_t z)}\right) = \left(\tfrac{(w_t)^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\rho\theta \cdot (Z_t z)}\right), \qquad p_{x,t}(z) = \tau \cdot p_t(z) \tag{7}$$

where $\rho = \frac{\sigma-1}{\sigma}$ and $\theta = \alpha^{\alpha} \cdot (1-\alpha)^{1-\alpha}$.

As mentioned before, the production scheme faced by a domestic firm $z$ depends on its productivity level respect to an endogenous threshold $z_{x,t}$. For instance, a firm $z$ which satisfies $z \geq z_{x,t}$, will serve both the domestic economy and the foreign economy, and its production scheme will be given by $\bar{Q}_t = Q_t + \tau \cdot Q_{x,t}$. On the other hand, whenever $z < z_{x,t}$, such firm will serve only the domestic economy and $\bar{Q}_t = Q_t$.

The productivity threshold for exporting firms corresponds to the productivity level for which profits are equal to zero. This productivity threshold is shown in equation (8).

$$(z_{x,t})^{1-\sigma} = \frac{Z_t}{\sigma w_t f_x}\left(\frac{(w_t)^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\rho\theta \cdot (Z_t)}\tau\right)^{1-\sigma} A_t \tag{8}$$

Total profits for a monopolistic firm $z$, at time $t$, are given by $d_t(z) = d_{D,t}(z) + d_{x,t}(z)$. Where $d_{D,t}(z)$ corresponds to the profits earned by firm $z$ from serving the domestic economy at time $t$, while $d_{x,t}(z)$ represents the profits earned by a firm $z$ from serving the foreign market at time $t$.

$$d_{D,t}(z) = \tfrac{p_t(z)^{1-\sigma}}{\sigma}\tfrac{C_t}{(P_t)^{-\sigma}} \quad , \quad d_{x,t}(z) = \begin{cases} \tfrac{p_{x,t}^{1-\sigma}(z)}{\sigma} A_t - \tfrac{w_t f_x}{Z_t} & \text{if firm } z \text{ exports,} \\ 0 & \text{otherwise} \end{cases}$$

Using (8), we can write $d_{x,t}(z)$ as in (9).

$$d_{x,t}(z) = \frac{w_t \cdot f_x}{Z_t}\left[\left(\frac{z_{x,t}}{z}\right)^{1-\sigma} - 1\right] \tag{9}$$

The definition of the small open economy employed in this paper considers three main characteristics. First, $A_t$ is exogenous as shown in equation (2). Second, the bundle cost for the foreign firms is unaffected by the small open economy. Thus, foreign salary $w_t^*$ is exogenous. Third, there is an exogenous number of total firms in the rest of the world $M_t^*$. However, a fraction of such number is going to export to the small open economy ($M_{x,t}^*$) and that fraction is defined by the endogenous foreign productivity threshold $\bar{z}_{x,t}^*$. Thus, $M_{x,t}^*$ is endogenous while $M_t^*$ is not.

### 2.2.1 Commodity Production

In this model we have an intermediate sector in the home economy which produces inputs for the final good's production. The production of the homogeneous good is performed using a technology of the form:

$$\bar{Q}_{o,t} = \psi \cdot \bar{K}^{1-\zeta} \cdot l_{o,t}^{\zeta} = \Psi \cdot l_{o,t}^{\zeta}$$

The firm problem in the commodity market is to choose labor, which is priced at $w_t$, to produce the homogeneous good, which is traded at an exogenous price $p_{o,t}$, in order to maximize profits. Where $\psi$ is the productivity of the sector, $\zeta$ is the labor share, and $\bar{K}$ is the long-run capital associated to the sector.

The operating profits generated in this sector have the form $IC_t = (1-\zeta)p_{o,t}\bar{Q}_{o,t}$. Where $\bar{Q}_{o,t}$ represents the total demand of the homogeneous good.

### 2.2.2 Average Productivity

Firms, in the final market, draw their productivity level, after paying a sunk cost $f_E$, from a Pareto distribution of the form $G(z) = 1 - \left(\frac{z_{\min}}{z}\right)^{\kappa}$. The sunk cost, $f_E$, is measured in effective units of labor which translates into $\frac{w_t f_E}{Z_t}$ units of consumption.

Let's define the aggregated (or average) productivity of domestically produced non-traded goods, $\widetilde{z}_D$, and the average productivity of domestically produced traded goods, $\widetilde{z}_{x,t}$, as in (10). Where $z_{\min}$ is the minimum productivity level in the support of the distribution $G$.

$$\widetilde{z}_D = \left[\int_{z_{\min}}^{\infty} z^{\sigma-1} dG(z)\right]^{\frac{1}{\sigma-1}} = \nu \cdot z_{\min} \quad , \quad \widetilde{z}_{x,t} = \frac{1}{1-G(z_{x,t})}\left[\int_{z_{x,t}}^{\infty} z^{\sigma-1} dG(z)\right]^{\frac{1}{\sigma-1}} = \nu \cdot z_{x,t} \tag{10}$$

where $\nu = \left(\frac{\kappa}{\kappa+1-\sigma}\right)^{1-\sigma}$, and it is required that $k > \sigma - 1$.

Using (10) we can write the price of varieties and the price index as a function of aggregated productivity. Thus, the price index becomes a function of the number of home monopolistic firms $M_t$, the average price for non-traded domestic goods $\widetilde{p}_t$, the fraction of foreign monopolistic firms which are productive enough to be exporters $M_{x,t}^*$, as well as the average price of imported final goods $\widetilde{p}_{x,t}^*$; where:

$$\widetilde{p}_t = p_t\left(\widetilde{z}_D\right) \quad , \quad \widetilde{p}_{x,t}^* = p_{x,t}^*\left(\widetilde{z}_{x,t}\right)$$

$$P_t = \left[M_t \cdot \left(\widetilde{p}_t\right)^{1-\sigma} + M_{x,t}^* \cdot \left(\widetilde{p}_{x,t}^*\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

In a similar way we can write average profits as function of average productivity as in (11). Where $\tilde{d}_t$ corresponds to the average profits obtained by a domestic firm that only serves the domestic economy. $\tilde{d}_{x,t}$ is the average profit obtained by a domestic firm from serving the foreign economy.

$$\widetilde{d}_t = d_t\left(\widetilde{z}_D\right) \quad , \quad \widetilde{d}_{x,t} = d_{x,t}\left(\widetilde{z}_{x,t}\right) \tag{11}$$

Then, a representative domestic firm generates dividends or profits, $\tilde{D}_t$, of the following form:

$$\widetilde{D}_t = \widetilde{d}_t + \frac{M_{x.t}}{M_t} \cdot \widetilde{d}_{x,t}$$

Since, $M_t$ is the total number of domestic competitive firms and $M_{x,t}$ is the number of monopolistic firms who actually export at time $t$, then, $\frac{M_{x.t}}{M_t}$ represents the proportion of home firms that export at time $t$.

$$M_{x,t} = \left(1 - G\left(z_{x,t}\right)\right) \cdot M_t$$

The small open economy assumption also imposes that the total number of foreign firm, $M_t^*$, is unaffected by the small economy. Therefore, $M_t^*$ is exogenous. The fraction of foreign firms that export to the small open economy is endogenous and depends on the foreign productivity threshold $z_{x,t}^*$.

$$M_{x,t}^* = \left(1 - G\left(z_{x,t}^*\right)\right) \cdot M_t^*$$

### 2.3 Equilibrium conditions and dynamics

In equilibrium, the free entry condition must be satisfied. This condition states that the value of the representative (average) firm $\tilde{v}_t$, at time $t$, equalizes the value of the sunk cost $f_E$ paid to obtain a productivity draw. This is shown in (12). If it were not the case, that is the free entry condition does not hold, then there would be additional firms willing to produce $\left(\text{if } \widetilde{v}_t > \frac{w_t \cdot f_E}{Z_t}\right)$ or firms willing to exit $\left(\text{if } \widetilde{v}_t < \frac{w_t \cdot f_E}{Z_t}\right)$. Thus, in equilibrium, it must be the case that:

$$\widetilde{v}_t = \frac{w_t \cdot f_E}{Z_t} \tag{12}$$

The value of a representative (average) firm at time $t$ corresponds to the expected present discounted value of future average dividends.

$$\widetilde{v}_t = E_t\left(\left\{\widetilde{D}_s\right\}_{s=t+1}^{\infty}\right)$$

In this model, firms produce in every period, until they are hit with a death shock, which occurs with probability $\delta \in (0,1)$ at the very end of each period. That is, among firms that were producing in the market at $t-1$, and new firms that are ready to produce at $t$, $M_{E,t-1}$, only a proportion $1-\delta$ of those firms will actually produce at time $t$. This exit inducing shock is independent of the firm's productivity level. Thus, $M_t$ is the sum of the firms that where already incumbent in the previous period and survived the death shock, and the firms that were "new firms" (entrants) in the previous period (at the very end of previous period) and also survived the death shock. Therefore $M_t$ represents the total number of firms producing during period $t$.

$$M_t = (1-\delta)\left(M_{t-1} + M_{E,t-1}\right)$$

The total number of firms willing to produce at time $t+1$ is shown in (13). Where $M_t$ is the number of firms already operating in the market at time $t$, and $M_{E,t}$ is the number of new entrants.

$$M_{H,t} = M_t + M_{E,t} \tag{13}$$

The total amount of the homogeneous good demanded in the home economy, at time $t$, is as follows:

$$Q_{o,t} = \int q_{o,t} \cdot M_t dG(z) + \int q_{o,x,t} \cdot M_{x,t} dG(z) \tag{14}$$

Where the first term of the right hand side of (14) represents the total demand of the commodity needed to produce non-traded goods in the home economy. Similarly, the second term of the right hand side represents the total amount of commodity required by domestic exporting firms. Equation (14) can also be written in the following form:

$$Q_{o,t} = \frac{\rho(1-\alpha)}{p_{o,t}} \left[ M_t \widetilde{p}_t^{1-\sigma} C_t + M_{x,t} \widetilde{p}_{x,t}^{1-\sigma} A_t \right]$$

Analogously, an expression for the foreign demand of the homogeneous good can be obtained from $Q^*_{o,t} = \int q^*_{o,t} \cdot M^*_t dG(z) + \int q^*_{o,x,t} \cdot M^*_{x,t} dG(z)$.

Operating profits from the commodity market, at international price $p_{o,t}$, are shown in (15).

$$IC_t = (1-\zeta) p_{o,t} \left( Q_{o,t} + Q^*_{o,t} \right) \tag{15}$$

Another important feature of the model is that profits obtained in the market for the homogeneous good are transferred to the households (households own the firm). That is, we have that $T_t = IC_t$, where $T_t$ corresponds to the amount of profits generated in the commodity market that are transferred to households. This is isomorphic to the case in which the government collects the profits from the commodity trade and then it transfers them back to the households.

Another equilibrium condition that must be satisfied is the labor market clearing condition. In this condition, the labor employed in the production of the homogeneous good and the final goods as well as the labor spent on the sunk cost $f_E$ and the fix cost of production $f_x$ must equalize the labor supply $L$. This equation is shown in (16).

$$M_t \cdot \tilde{l}_t + M_{x,t} \cdot \tilde{l}_{x,t} + \frac{1}{Z_t} \left( M_{x,t} \cdot f_x + M_{E,t} \cdot f_E \right) + l_{o,t} = L \tag{16}$$

where $M_t \cdot \tilde{l}_t$ is the amount of labor employed to satisfy the domestic demand for domestic goods and $M_{x,t} \cdot \tilde{l}_{x,t}$ is the amount of labor employed to satisfy the foreign demand for domestic goods. $\frac{M_{x,t} \cdot f_x}{Z_t}$ corresponds to the amount of labor used to cover the fix costs incurred by exporting domestic firms, while $\frac{M_{E,t} \cdot f_E}{Z_t}$ corresponds to the labor used to cover the sunk costs incurred by entering firms. $l_{o,t}$ is the amount of labor needed to produce the homogeneous good.

# 3 Aggregate Dynamic Problem

The aggregated dynamic problem solved by a representative agent corresponds to the maximization of an intertemporal utility function $U\left(\{C_s\}_{s=t}^{\infty}\right)$. In this section, we will consider an economy which is under financial autarky.

$$\underset{C_t, B_{t+1}, x_{t+1}}{Max} E_t \left[ \sum_{s=t}^{\infty} \beta^{s-t} \frac{(C_s)^{1-\gamma}}{1-\gamma} \right] \tag{17}$$

A representative household holds two type of assets: shares of stock of domestic firms and domestic risk-free bonds. $x_t$ is the share of stock of domestic firms held by the representative household entering period $t$, and $B_t$ is the bond holding in period $t$.

The shares of stocks pay dividends every period that correspond to the average total profit of domestic firms that produce in that period. During period $t$, the representative household buys $x_{t+1}$ shares of stocks of $M_{H,t}$ domestic firms. It is worth to mention that only $M_{t+1} = (1-\delta)M_{H,t}$ firms will produce and pay dividends at time $t+1$. The household buys stocks of $M_{H,t}$, because the household does not know which firms will be hit by the exogenous exit shock $\delta$ at the very end of period $t$.

The representative household enters period $t$ with bond holding $B_t$ and shares of stock holding $x_t$. Thus, the income that the representative household receives, at period $t$, comes from: labor income, bond holdings, dividends from shares of stock plus the value of selling its initial share position, and transfers from the homogeneous good sector. The period budget constraint, in units of consumption, is the following:

$$B_{t+1} + \widetilde{v}_t M_{H,t} x_{t+1} + C_t = (1 + r_t) B_t + \left( \widetilde{D}_t + \widetilde{v}_t \right) M_t x_t + w_t L + T_t \tag{18}$$

Equation (18) considers that a representative household invests in period $t$ on bonds, $B_{t+1}$, and buys $x_{t+1}$ shares in a mutual fund of $M_{H,t}$ home firms. Also, the household spends on period $t$ consumption, $C_t$. Thus the expenditure of the representative household at time $t$ (left hand side of equation (18)) is composed by bonds, shares of stock, and consumption. The right hand side of equation (18) corresponds to the household income. The household income is given by the return on bond holding $(1 + r_t) B_t$, dividends $\widetilde{D}_t$ from the share of stocks, the value of the shares of stock, the salary from labor, $w_t L$, and the transfers from de government, $T_t$.

The household problem is then given by (17) subject to (18). That is, the household allocates its resources between consumption, purchase of bonds and shares of stock to be carried into next period.

The first order conditions, of the dynamic problem described above, are as follows:

$$(C_t)^{-\gamma} = \beta (1 + r_{t+1}) E_t \left[ (C_{t+1})^{-\gamma} \right] \tag{19}$$
$$\widetilde{v}_t = \beta (1 - \delta) E_t \left[ \left( \frac{C_{t+1}}{C_t} \right)^{-\gamma} \left( \widetilde{D}_{t+1} + \widetilde{v}_{t+1} \right) \right]$$

Equations in (19) describe the traditional Euler equations for bonds and stocks.

Aggregating the budget constraint across symmetric households and imposing the equilibrium condition under financial autarky[2], we obtain the aggregate accounting equation in the domestic economy as in (20).

$$C_t = w_t L + T_t + M_t \cdot \widetilde{D}_t - M_{E,t} \cdot \widetilde{v}_t \tag{20}$$

[2] In equilibrium under financial autarky it must be the case that $B_{t+1} = B_t = 0$ and $x_t = x_{t+1} = 1$.

The aggregate accounting equation states that consumption, $C_t$, in each period must be equal to labor income $w_t L$ plus the profits from the domestic firms $M_t \tilde{D}_t$ and profits from the commodity market, $T_t$, minus the investment in new firms $M_{E,t}\tilde{v}_t$.

### 3.1 Competitive Equilibrium

Table 1 summarizes the equilibrium conditions of the model presented in previous sections. The equations in the Table 1 establish a system of 12 endogenous variables and 12 equations. That is, the endogenous variables of the model are $w_t$, $\widetilde{D}_t$, $M_{E,t}$, $\widetilde{\varphi}_{x,t}$, $\widetilde{\varphi}^*_{x,t}$, $M_t$, $M_{x,t}$, $M^*_{x,t}$, $r_t$, $\widetilde{v}_t$, $C_t$, $T_t$.

Table 1: System of Equations

| | |
|---|---|
| Price index | $1 = \left[M_t \cdot (\widetilde{p}_t)^{1-\sigma} + M^*_{x,t} \cdot \left(\widetilde{p}^*_{x,t}\right)^{1-\sigma}\right]$ |
| Profits | $\widetilde{D}_t = \widetilde{d}_t + \frac{M_{x,t}}{M_t} \cdot \widetilde{d}_{x,t}$ |
| Free entry | $\widetilde{v}_t = \frac{w_t \cdot f_E}{Z_t}$ |
| Average exports profit | $\widetilde{d}_{x,t} = \frac{w_t \cdot f_x}{Z_t}\left[\upsilon^{\sigma-1} - 1\right]$ |
| Share of exporting firms | $\frac{M_{x,t}}{M_t} = (\upsilon \cdot z_{\min})^{\kappa}\, \widetilde{z}_{x,t}^{-\kappa}$ <br> $\frac{M^*_{x,t}}{M^*_t} = (\upsilon \cdot z_{\min})^{\kappa}\left(\widetilde{z}^*_{x,t}\right)^{-\kappa}$ |
| Number of firms | $M_t = (1-\delta)\left(M_{t-1} + M_{E,t-1}\right)$ |
| Euler equations (Bonds) | $(C_t)^{-\gamma} = \beta\left(1 + r_{t+1}\right) E_t\left[(C_{t+1})^{-\gamma}\right]$ |
| Euler equations (Shares) | $\widetilde{v}_t = \beta(1-\delta) E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\widetilde{D}_{t+1} + \widetilde{v}_{t+1}\right)\right]$ |
| Aggregate accounting | $C_t = w_t L + T_t + M_t \cdot \widetilde{D}_t - M_{E,t} \cdot \widetilde{v}_t$ |
| Labor market clearing | $M_t \cdot \tilde{l}_t + M_{x,t} \cdot \tilde{l}_{x,t} + \frac{1}{Z_t}\left(M_{x,t} \cdot f_x + M_{E,t} \cdot f_E\right) + l_{o,t} = L$ |
| Transfers | $T_t = \Pi_{o,t}$ |

The system of equations developed in this section characterizes the stochastic dynamics of a small open economy in a general equilibrium context. To study the dynamics implied from our model, we need to know the parameters which are important elements to determine the dynamic of the endogenous variables. These parameters are the shape parameter of the Pareto distribution $\kappa$, and the elasticity of substitution across final goods $\sigma$. In order to know this parameters, in the next section we estimate them for a small open economy. We use Chilean data, since Chile satisfies the small open economy assumption as well as the commodity trade assumption.

## 4 Estimation of Parameters

We employ two sources of data. One is data at the plant level for Chilean firms. This data is collected by the National Institute of Statistics (INE). This data is an annual survey and it is intended to cover manufacturing firms which employ at least ten workers in the case of single-plant production firms, and all firms (with no restriction) for multi-plants production firms. The other source of data corresponds to the exports data collected by the General Direction of International Policy at the Ministry of Foreign Affairs of Chile. This data covers all exports made by Chilean firms for products at the HS-8 digits code level.

### 4.1 Plant Level Data for Chilean Manufacturers

The National Annual Industry Survey (ENIA) elaborated by INE contains data at the plant level for manufacturers firms in Chile. Each plant is individualized with an identification number which is consistent over the years. We have this data for the period between the years 1996 and 2006.

In this database, for each plant we have data on production, sales, energy consumption, labor employed, capital, etc. The data is also classified at ISIC Rev. 3. The number of plants by ISIC Rev.3 (Divisions)[3] is shown in Table (2).

Table 2: Number of Plants by ISIC Rev. 3. Period 1996-2006

| Manufacturer of: | ISIC Rev. 3 | 1996 | 1998 | 2000 | 2002 | 2004 | 2006 |
|---|---|---|---|---|---|---|---|
| Food products and beverages | 15 | 1,701 | 1,656 | 1,515 | 1,621 | 1,685 | 1,606 |
| Textiles | 17 | 344 | 294 | 269 | 276 | 268 | 232 |
| Wearing apparel | 18 | 418 | 322 | 293 | 300 | 283 | 245 |
| Tanning and dressing of leather | 19 | 241 | 199 | 162 | 158 | 145 | 115 |
| Products of wood and cork | 20 | 417 | 387 | 343 | 369 | 360 | 342 |
| Paper and paper products | 21 | 135 | 132 | 144 | 146 | 169 | 158 |
| Publishing | 22 | 236 | 217 | 222 | 253 | 281 | 265 |
| Coke, refined petroleum products | 23 | 3 | 3 | 0 | 0 | 0 | 0 |
| Chemicals and chemical products | 24 | 321 | 309 | 298 | 311 | 327 | 315 |
| Rubber and plastics products | 25 | 335 | 292 | 300 | 315 | 359 | 344 |
| Other non-metallic products | 26 | 262 | 287 | 272 | 277 | 268 | 286 |
| Basic metals | 27 | 115 | 117 | 123 | 127 | 150 | 159 |
| Fabricated metal products | 28 | 425 | 387 | 392 | 405 | 416 | 403 |
| Machinery and equipment | 29 | 303 | 297 | 290 | 330 | 335 | 315 |
| Office products | 30 | 0 | 0 | 0 | 0 | 3 | 3 |
| Electrical machinery | 31 | 99 | 94 | 104 | 90 | 91 | 73 |
| Communication equipment | 32 | 10 | 9 | 12 | 12 | 12 | 4 |
| Medical instruments | 33 | 26 | 25 | 30 | 31 | 33 | 34 |
| Motor vehicles | 34 | 91 | 84 | 76 | 75 | 34 | 88 |
| Other transport equipment | 35 | 64 | 62 | 52 | 56 | 55 | 51 |
| Furniture, manufacturing | 36 | 308 | 267 | 264 | 264 | 276 | 235 |
| Total Number of Firms | - | 5,854 | 5,440 | 5,162 | 5,416 | 5,600 | 5,273 |

### 4.2 Export Data

Export data are provided by the General Direction of International Policy at the Ministry of Foreign Affairs of Chile. This data contains information on trade between Chile and different countries of the world at the firm level. Exports by products are reported with a level of aggregation given by the harmonized system classification at the 8-digit level.

[3] ISIC Rev.3 also considers Groups and Classes. However, in Table (4.1) it is shown by divisions for the tabulation category D (Manufacturing).

This data provides information of products exported, FOB value of exports, and country of destination for each exporting firm and product.

Table (3) shows the number of firms, number of products and percentage of total exports by country of destination for selected countries. Those trading partners import 86% of the total export made from Chile.

Table 3: Number of Firms, products and percentage of total exports by country destination (Selected Countries, year 2006)

| Country | Number of Firms | Number of Products | % Total FOB |
|---|---|---|---|
| Germany | 671 | 714 | 3% |
| Argentina | 1,517 | 2,279 | 1% |
| Belgium | 332 | 300 | 1% |
| Brazil | 967 | 1,193 | 5% |
| Canada | 641 | 607 | 2% |
| China | 477 | 307 | 9% |
| South Korea | 397 | 286 | 6% |
| Spain | 797 | 804 | 2% |
| USA | 2,084 | 1,993 | 16% |
| France | 521 | 584 | 4% |
| Netherland | 615 | 355 | 7% |
| India | 108 | 122 | 3% |
| Italy | 510 | 482 | 5% |
| Japan | 567 | 463 | 11% |
| Mexico | 1,023 | 1,285 | 4% |
| Peru | 1,641 | 2,782 | 2% |
| UK | 615 | 588 | 1% |
| Taiwan | 355 | 177 | 3% |

### 4.3 Productivity Estimation

In this section we use the information contained in ENIA to estimate the productivity of Chilean manufacturing firms. There are a number of econometric problems that one encounters when trying to estimate unobserved productivity as the residual of the production function using the observed firm-level variables.

Estimating firm-level production functions is a non-trivial exercise due to simultaneity bias caused by the relationship between unobserved productivity shocks and inputs used in production. Different methods have been developed to address the simultaneity bias in production function estimation. Most of them rely on finding proxy variables for productivity shocks, which are used to invert out productivity from the regression residual in a two-step estimation. The two most popular methods in this vein were developed by Olley and Pakes (1996) (OP) and Levisohn and Petrin (2003) (LP). Wooldridge (2009) proposes a one-step estimation implemented in a generalized method of moments framework.

Let us assume a production function of the standard Cobb-Douglas form. In particular, let us consider a two-factor production function.

A simple standard estimation equation of the production function (in logs) looks as follows:

$$y_{it} = \beta_o l_{it} + \beta_k k_{it} + \zeta_{it} \tag{21}$$

where $y_{it}$ is the log of some real measure of firm $i$'s output (i.e. revenue or value added), $k_{it}$ is the log of the level of capital, $l_{it}$ is the log of labor, and $\zeta_{it}$ is an error term.

In equation (21), the error term is given by $\zeta_{it} = v_{it} + e_{it}$, where $v_{it}$ is the productivity which is observed by the firm $i$, but it is unknown for the econometrician. So, the firm is able to decide the amount of the variable input (labor) when it observes the productivity level. This means that the realization of the error term affects the choice of factor input. The unobserved productivity shock $v_{it}$ is therefore correlated with factor inputs, so that estimating (21) with ordinary least squares without controlling for $v_{it}$ yields biased parameter estimates.

In order to estimate the production function at the plant level we will use three different methodologies.

OP show how, under certain assumptions, investment can be used as a proxy variable for unobserved time-varying productivity. Specifically, OP show how to invert an investment rule to express productivity as an unknown function of capital and investment, when investment is positive. OP present a two step estimation method where, in the first stage, semiparametric methods are used to estimate the coefficients on the variable inputs. In a second step, the parameters on capital inputs can be identified under assumptions on the dynamics of the productivity process.

LP propose a modification of the OP approach to address the problem of lumpy investment. LP suggest using intermediate inputs to proxy for unobserved productivity. Similarly to OP, LP contains assumption under which productivity can be written as a function of capital input and intermediate inputs (such as electricity). LP also propose a two step method to estimate the coefficients on labor and capital.

Ackerberg et al (2006) (ACF) have highlighted a potential problem with identification of the parameters in the LP first stage estimation problem. If labor is determined by the firm as a function of the unobserved productivity and state variables, then the coefficient on labor is unidentified. Wooldridge (2009) uses GMM estimation to solve the issue pointed out by ACF.

Table (4) shows the estimates of a production function of the Cobb-Douglas form using OP, LP and Wooldridge methods[4].

Table 4: Productivity Estimation

| | | OP (1996) | LP (2003) | Wooldridge (2009) | |
|---|---|---|---|---|---|
| | | | | with exogenous $k_{it}$ | with endogenous $k_{it}$ |
| $\beta_o$ | $\beta_{BC}$ | 0.535*** | 0.552*** | 0.567*** | 0.467*** |
| | $\beta_{WC}$ | 0.143*** | 0.164*** | 0.184*** | 0.130*** |
| $\beta_k$ | | 0.137*** | 0.102*** | 0.150*** | 0.491*** |
| $N$ | | 31,877 | 29,252 | 21,081 | 17,120 |

In Table (4), the estimates of the labor parameter $\beta_o$ have been divided into the separated estimation of "blue collar" labor $\beta_{BC}$, and "white collar" labor $B_{WC}$. We do this to compare our results with the ones obtained by Levisohn and Petrin (2003) in which Chilean data (for a different period of time) is used. Our results are very similar to the findings of LP.

[4]see more details in the Appendix A.

In Table (4), it seems we find decreasing returns to scale with OP and LP but increasing returns to scale using Wooldridge with endogenous capital[5]. However, the first three measures seem to yield similar results in Tables (6) and (7).

### 4.4 Trade Estimation

In this section, we estimate trade elasticities for Chilean firms who export to the rest of the world. We consider the log of the revenue equation for a firm operating in the final market, with productivity $z$, in an industry $\varphi$, in the home country, and exporting to country $j$. Thus, the equation to estimate has the following form[6]:

$$r_{z,\varphi}^{h,j} = \lambda_h + \lambda_j + \lambda_\varphi + \beta_\sigma \ln(z) + \epsilon_{z,\varphi}^{j} \tag{22}$$

where $r_{z,\varphi}^{h,j}$ is the revenue of a firm in the home economy, $h$, with productivity, $z$, in an industry, $\varphi$, that exports to country $j$. $\lambda_h$ is the constant of the model (also home economy fix effect), $\lambda_j$ is the country of destination fix effect, $\lambda_\varphi$ is the industry fix effect, $\epsilon_{z,\varphi}^{j}\tilde{}N\left(0,\sigma_\epsilon^2\right)$, and $\beta_\sigma = \sigma - 1$ is the coefficient of interest. Equation (22) specifies an equation that suffers from sample selection. This is because firms do not export to every country and we observe exports from a firm $z$ to a country $j$ when trade happens. In order to control for sample selection, we will first employ the traditional Heckman correction.

A firm $z$, in an industry $\varphi$, exports to country $j$ if $\left(\frac{z}{z_{x,\varphi}^{j}}\right) > 1$, that is, firm $z$ exports to country $j$ if the productivity of the firm is above the industry productivity threshold. Then, we can define a latent variable $W_{z,\varphi}^{j} = \left(\frac{z}{z_{x,\varphi}^{j}}\right)$, where $\omega_{z,\varphi}^{j} = \log\left(W_{z,\varphi}^{j}\right)$. Thus, a firm $z$ in an industry $\varphi$ export to country $j$ if $\omega_{z,\varphi}^{j} > 0$.

We follow Helpman, Melitz, and Rubinstein (2008) identification approach and we consider that the latent variable has the following structure:

$$\omega_{z,\varphi}^{j} = \zeta_h + \zeta_j + \zeta_\varphi + \beta_\rho \ln(z) + \beta_\omega \phi_{z,\varphi}^{j} - \eta_{z,\varphi}^{j}$$

where $\zeta_h$ is the home economy fix effect, $\zeta_j$ is the country of destination fix effect, $\zeta_\varphi$ is the industry fix effect, and $\phi_{z,\varphi}^{j}$ is a measure that affects the probability of been an exporter.

Then, the probability of being an exporter can be written as follows:

$$\Pr\left(\omega_{z,\varphi}^{j} > 0\right) = \Pr\left(\zeta_h + \zeta_j + \zeta_\varphi + \beta_\rho \ln(z) + \beta_\omega \phi_{z,\varphi}^{j} > \eta_{z,\varphi}^{j}\right)$$

We assume that $\eta_{z,\varphi}^{j}\tilde{}N\left(0,\sigma_\eta^2\right)$, and define the indicator variable $T_{z,j}$ to equal one when firm $z$ export to country $j$ and zero when it does not. Let $\rho_{z,\varphi}^{j}$ be the probability that a firm $z$ in an industry $\varphi$ exports to country $j$. Thus we can have the following Probit equation:

$$\rho_{z,\varphi}^{j} = \Pr\left(T_{z,j} = 1 \,|\text{observed variables }\right)$$

$$\rho_{z,\varphi}^{j} = \Phi\left(\zeta_h^* + \zeta_j^* + \zeta_\varphi^* + \beta_\rho^* \ln(z) + \beta_\omega^* \phi_{z,\varphi}^{j}\right) \tag{23}$$

[5]The estimation obtained using Wooldridge method with endogenous capital differs from the results in the first three columns in Table (4). This is due to the assumptions under GMM and the lag characterization of the endogenous variable.

[6]See more details in Appendix B

Table 5: Probit Estimation

| | LP | OP | W |
|---|---|---|---|
| $\hat{\beta}^*_\rho$ | 0.256*** | 0.267*** | 0.255*** |
| | (0.009) | (0.008) | (0.008) |
| $\hat{\beta}^*_{\omega}\_[z \cdot K_\varphi \cdot CSU_j]$ | -0.221 | -0.361 | -0.589 |
| | (0.781) | (0.411) | (0.669) |
| $\hat{\beta}^*_{\omega}\_[z \cdot CSU_j]$ | -0.386* | -0.215 | -0.282 |
| | (0.229) | (0.134) | (0.200) |
| $\hat{\beta}^*_{\omega}\_[z \cdot K_\varphi]$ | -0.981*** | -0.418*** | -0.682*** |
| | (0.236) | (0.129) | (0.203) |
| $\hat{\beta}^*_{\omega}\_[K_\varphi \cdot CSU_j]$ | 0.152 | 0.216** | 0.002** |
| | (0.100) | (0.099) | (0.001) |
| $N$ | 151,524 | 151,524 | 151,524 |
| $R^2$ | 0.3102 | 0.3153 | 0.3124 |

Where $\Phi(.)$ is the cdf of the standard normal distribution, and every starred coefficient represents the original coefficient divided by $\sigma_\eta$.

The instrument we will employ in the Probit equation (23) considers the three way interaction between firm's productivity $z$, the capital intensity of the industry in which the firm $z$ produces, $K_\varphi$, and the cost of business start-up procedures in country $j$, $CSU_j$, and the three pair wise interactions between $z$, $K_\varphi$, and $CSU_j$.[7]

$$\phi^j_{z,\varphi} = [z \cdot K_\varphi \cdot CSU_j,\ z \cdot CSU_j,\ z \cdot K_\varphi,\ K_\varphi \cdot CSU_j]$$

Then, we can estimate (22), using the following specification:

$$r^{h,j}_{z,\varphi} = \lambda_h + \lambda_j + \lambda_{\varphi,j} + \beta_\sigma \ln(z) + \beta_H \hat{\mu}^j_{z,\varphi} + e^j_{z,\varphi} \tag{24}$$

where $\hat{\mu}^j_{z,\varphi} = \frac{\phi(\hat{\omega}^j_{z,\varphi})}{\Phi(\hat{\omega}^j_{z,\varphi})}$ is the traditional inverse Mills ratio.

The results of the estimation for (23) are shown in Table (5)[8].

The results for the estimation of equation (24) are shown in Table (6). The standard errors shown in the Table have been bootstrapped and clustered by industry. The first three column in Table (6) show a benchmark case in which equation (22) is estimated without considering the sample selection issue using our productivity estimates. The last three column show the result of estimates for equation (24) using Heckman correction.

We now relax the normality assumption, and hence the Mills ratio functional form for the selection correction. Thus, we drop the normality assumption and we work directly with the predicted probabilities $\hat{\rho}^j_{z,\varphi}$ as in Helpman, Melitz, and Rubinstein (2008). In order to approximate

[7] Although we implement the three way interaction and the three pair wise interactions what ultimately provides the identification is the pair wise interaction between $z$ and $K_\varphi$.

[8] ** Significat at 5%. *** Significant at 1%.
LP stands for Levinsohn and Petrin.
OP stands for Olley and Pakes.
W stands for Wooldridge.

Table 6: Estimation Results

| | Benchmark | | | Sample Selection | | |
|---|---|---|---|---|---|---|
| | LP | OP | W | LP | OP | We |
| $\hat{\beta}_\sigma$ | 0.702*** | 0.767*** | 0.745*** | 1.005*** | 1.206*** | 1.167*** |
| | (0.038) | (0.042) | (0.033) | (0.163) | (0.157) | (0.133) |
| $\hat{\beta}_H$ | | | | 1.749** | 2.389*** | 2.410*** |
| | | | | (0.942) | (0.905) | (0.803) |
| $\hat{\sigma}$ | 1.702 | 1.767 | 1.745 | 2.005 | 2.206 | 2.167 |
| $N$ | 7,519 | 7,519 | 7,519 | 7,519 | 7,519 | 7,519 |
| $R^2$ | 0.2746 | 0.2963 | 0.2893 | 0.2754 | 0.2979 | 0.2907 |

Table 7: Non-Parametric Estimation
Indicator Variables

| | 50 bins | | | 100 bins | | |
|---|---|---|---|---|---|---|
| | LP | OP | W | LP | OP | W |
| $\hat{\beta}_\sigma$ | 0.890*** | 1.123*** | 1.089*** | 1.048*** | 1.398*** | 1.298*** |
| | (0.106) | (0.107) | (0.109) | (0.127) | (0.128) | (0.130) |
| $\hat{\sigma}$ | 1.890 | 2.123 | 2.089 | 2.048 | 2.398 | 2.298 |
| $N$ | 7,519 | 7,519 | 7,519 | 7,519 | 7,519 | 7,519 |
| $R^2$ | 0.2815 | 0.3044 | 0.2958 | 0.2874 | 0.3104 | 0.3012 |

an arbitrary functional form of the predicted probabilities $\hat{\rho}^j_{z,\varphi}$, we employ a relatively large set of indicator variables. Thus, we partition the predicted probabilities from the first stage into a number of bins (we use 50 bins and 100 bins) in which each bin has the same number of observations. Then, we identify each bin with an indicator variable. Now, we are able to estimate equation (24) replacing $\hat{\mu}^j_{z,\varphi}$ with the set of indicators. The results are shown in Table (7).

# 5 Steady State

On the steady state, we consider that any variable follows $x_{t+1} = x_t = x$. In addition we consider that $\tau = \tau^*$, $f_x = f_x^*$, $Z = 1$, $p_o = 1$ , and $z_{\min} = 1$.

From the Euler equation for bonds we immediately obtain the steady state value of the return for bonds, $r = \frac{1}{\beta} - 1$.

From the definition of $\tilde{p}$ and $\widetilde{p}_x$, we can obtain:

$$\tilde{p} = \tilde{p}(w), \quad \widetilde{p}_x = \widetilde{p}_x(w, \tilde{z}_x) \tag{25}$$

Using the definition of $\widetilde{d}_x$ at the steady state, and the "Average exports profit" equation from Table (1), at the steady state, we can obtain $\tilde{p}_x^{1-\sigma} = \frac{\sigma f_x \nu^{\sigma-1}}{A} w$. Combining this expression and equation (25) we get $w = w(\tilde{z}_x)$.

Thus, we can write $w$, $\tilde{p}$, $\tilde{p}_x, \widetilde{d}_x$, and $\tilde{v}$ (from Free entry equation) as function of $\tilde{z}_x$.

Using the Euler equation for shares combined with the free entry equation we can write $\tilde{D}$ as $\tilde{D} = \tilde{D}(\tilde{z}_x)$. Employing $\widetilde{d} = \frac{\tilde{p}^{1-\sigma}}{\sigma} C$ along with the Profits equation and the Share of exporting firms equation for the domestic economy (from Table (1)), we are able to solve for $C$ as $C(\tilde{z}_x)$.

In steady state, transfers to the representative household can be written as $T = T(M, \tilde{z}_x)$. Using the Aggregate accounting equation we can solve out for $M$ as $M(\tilde{z}_x)$. Moreover, from the "Share of exporting firms" equation (Table (1)) it is also possible to write $M_x$ as $M_x(\tilde{z}_x)$.

The labor amount used to produce the homogeneous good as well as the final goods can be written as function of $M, M_x, d$, and $d_x$. Thus, labor employed in the domestic economy are of the form $\tilde{l} = \tilde{l}(\tilde{z}_x)$, $\tilde{l}_x = \tilde{l}_x(\tilde{z}_x)$, and $l_o = l_o(\tilde{z}_x)$.

Also, using the Labor market clearing equation from Table (1), we can form a nonlinear equation in $\tilde{z}_x$ of the form:

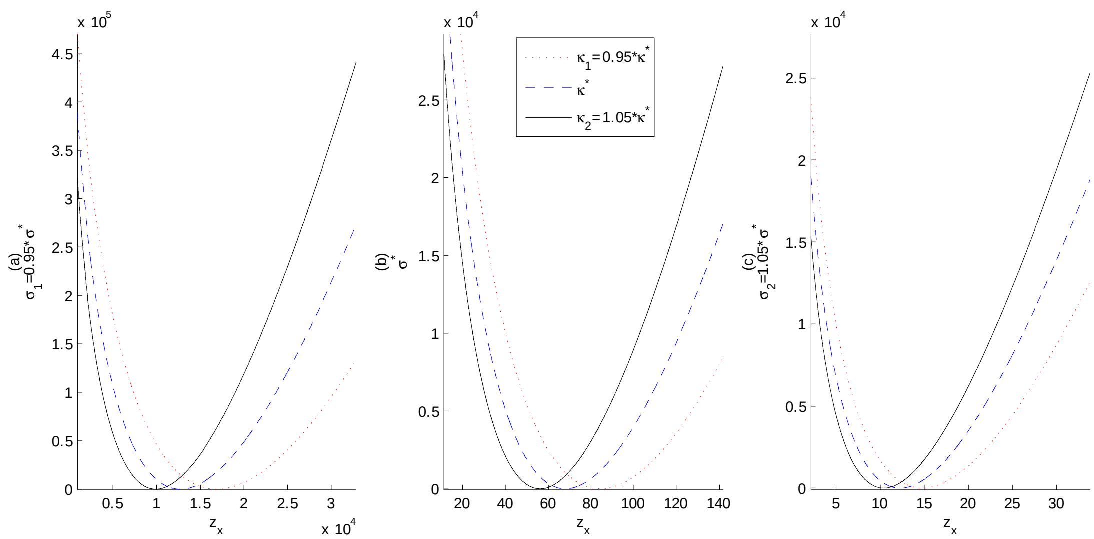
$$f(\tilde{z}_x) = \left[M(\tilde{z}_x) \cdot \tilde{l}(\tilde{z}_x) + M_x(\tilde{z}_x) \cdot \tilde{l}_x(\tilde{z}_x) + (M_x(\tilde{z}_x) \cdot f_x + M_E(\tilde{z}_x) \cdot f_E) + l_o(\tilde{z}_x) - L\right] \tag{26}$$

The solution of the non-linear equation (26) pins down the steady state values for $p$, $p_x$, $p$, $w$, $d_x$, $C$, $\tilde{d}$, $M$, $M_x$, $\tilde{D}$, $T$, $\tilde{v}$.

$\tilde{p}_x^*$ can be written as $\tilde{p}_x^* = \tilde{p}_x^*(\tilde{z}_x^*)$. Also, employing the share of exporting firms for the foreign economy allows us to write $M_x^* = M_x^*(\tilde{z}_x^*)$. Substituting these expressions into the price index equation we have $M_x^*(\tilde{z}_x^*) \cdot \tilde{p}_x^*(\tilde{z}_x^*)^{1-\sigma} = 1 - M(\tilde{z}_x) \cdot \tilde{p}(\tilde{z}_x)^{1-\sigma}$ from which we solve out for $\tilde{z}_x^*$. Knowing the steady state value of $\tilde{z}_x^*$, we can now pin down the steady state values for $p_x^*$ and $M_x^*$.

Figure (3) we plot equation (26), in the form $f(\tilde{z}_x)^2$, for the elasticity of substitution $\sigma^*$ estimated in previous section and the estimation of the shape parameter $\kappa^*$. We also consider a sensitivity analysis for values $\sigma_1$, $\sigma_2$, $\kappa_1$ and $\kappa_2$ such that $\sigma_1 < \sigma^* < \sigma_2$, and $\kappa_1 < \kappa^* < \kappa_2$.[9]

Figure 3: $f(\tilde{z}_x)^2$ for $k_1 < k^* < k_2$ and $\sigma_1 < \sigma^* < \sigma_2$.




[9]It is also necessary to consider the restriction $\kappa > \sigma - 1$.

Figure (3) shows uniqueness for the productivity threshold base on the parameters estimated in previous section. In Figure (3, a, b, and c), the productivity threshold (given by $f(\tilde{z}_x)^2 = 0$) is above $z_{\min}$ which means that a proper fraction of the monopolistic firms will export.

In our case, Figure (3) shows that the smaller is the value of the elasticity of substitution, the greater the productivity threshold for domestic exporting firms $\tilde{z}_x$. It also shows that, given a level for the elasticity of substitution, the productivity threshold for domestic exporting firms $\tilde{z}_x$ is negatively related to the value of the shape parameter $\kappa$.

# 6 International Trade and Macroeconomic Dynamics

We now analyze the full response path of key variables in response to transitory shocks to productivity, $Z_t$, and the commodity price, $p_{o,t}$. Previously, we have estimated the parameters of the model for the Chilean economy. Using these parameters, we compute the steady-state levels of endogenous variables and numerically solve for the dynamic responses to exogenous shocks.

## 6.1 Impulse responses

In this section, we now study the responses of the endogenous variables in our model to a transitory one percent increase in domestic aggregate productivity and in the commodity price. The responses are shown on the vertical axis as percent deviations from the steady-state. The number of quarters after the shock are shown on the horizontal axis.

Figure (4) shows the response of the endogenous variables to a transitory productivity shock. The dynamic of the transitory productivity shock considers a process with an autocorrelation coefficient of 0.9 (following the productivity shock parametrization in Ghironi and Melitz, 2005)[10]. The temporary increase in productivity generates a temporary increase in both the average profits of serving the domestic economy, $\tilde{d}_t$, and the average profits of serving the foreign market, $\tilde{d}_{x,t}$. Thus, the profits of the representative firm, $\tilde{D}_t$, increase temporarily as well. This implies that the domestic economy becomes more attractive and the number of entrants is higher, which translates into a higher number of producing firms. The increment in producing firms operating in the market put pressure on the wage level. So, the productivity shock brings along a higher wage. The rise in wage increases the input bundle cost, because the change in wage offsets the effect of the shock. A higher bundle cost leads to a higher average productivity for exporting firms.

The shock in productivity has a positive effect on the price of non-traded final goods domestically produced. This is because the increase in the wage level dominates the effect of the increase in the productivity (except at the onset of the shock in which the effect of the shock dominates the increase in wage).

The effect of the productivity shock is negatively related to the price of traded goods that are domestically produced. The response of $\tilde{p}_x$, which is different from the response of $\tilde{p}_t$, is due to the combined effect of the shock and the increase in $\tilde{z}_x$. This combined effect dominates the wage increase.

From the price index equation, the average productivity of exporting firms in the foreign economy, $\tilde{z}_x^*$, is positively related to the increase of the term $M_t \cdot \tilde{p}_t^{1-\sigma}$. The knowledge of $\tilde{z}_x^*$ pins

[10]Although, we do not estimate the autocorrelation parameter, the value chosen for this coefficient is quite common in the macroeconomic literature.

down the path for $M^*_{x,t}$ and $\tilde{p}^*_{x,t}$ which are both decreasing due to the small economy assumption and the increase in $\tilde{z}^*_x$.

The free entry condition shows the path of the value of a representative average firm, which increases as a response to the productivity shock, this is because the change in wage rate dominates the effect of the productivity shock.

The temporary increase of domestic producing firms increases the demand of the homogeneous good, which translates into a higher $Q_{o,t}$. The assumption of small open economy ($M^*_t$ is unaffected) and the decline of $M^*_{x,t}$ produce a decreasing path of $Q^*_{o,t}$. Overall, the total demand of the homogeneous good increases.

The increase in the total quantity of homogeneous good demanded leads to an increase in profits from the commodity trade which translates into an increase in the transfers to the households.

The combined effect of the increase in wage ($w_t$), the increase of domestic monopolistic competitive firms ($M_t$), the increase of profits of the representative firm ($\tilde{D}_t$), and the increase of the transfers $T_t$ outweights the increase in entrant firms ($M_{E,t}$), and the increase in the value of the domestic representative firm ($\tilde{v}_t$) in such a way that, from aggregate accounting, consumption temporary increases as a result of the shock.

In summary, a temporary productivity shock increases the average productivity of exporting firms, profits of the representative firm, consumption, and welfare in the short run. In the long run these effects disappear as the shock vanishes. However, as in Ghironi and Melitz (2005), the responses of the endogenous variables clearly highlight the substantial persistence of the shock on the endogenous variables.

Figure 4: Response to a transitory productivity shock

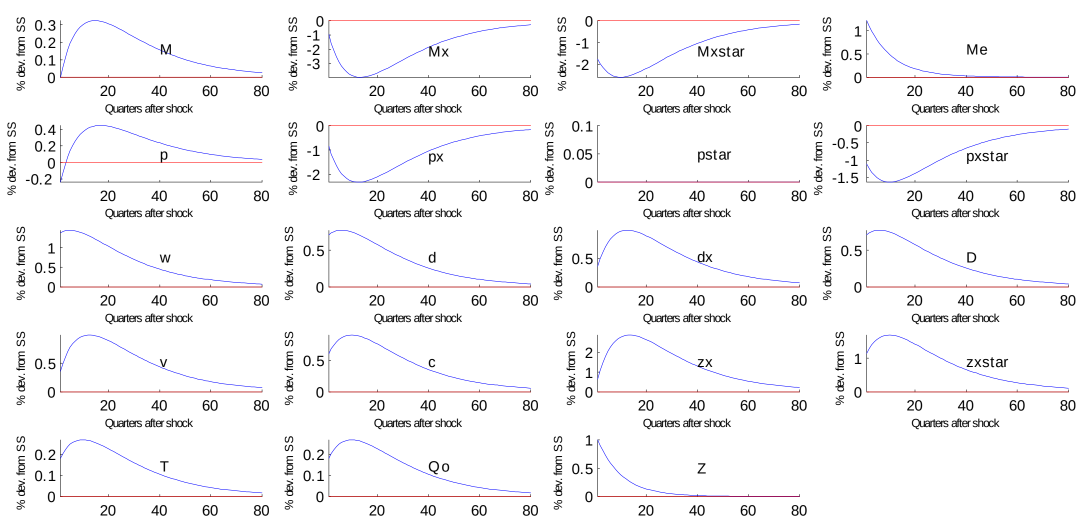



Figure (5) shows the response of key variables to a transitory one percent increase in the price of the homogeneous good. The commodity price process considers an autocorrelation coefficient of 0.8 which matches the real copper price autocorrelation for the last 50 years. The temporary increase in $p_{o,t}$ generates an increase in the cost of the homogeneous good, as input, for domestic firms in such a way that both the average profits from non-traded domestically produced goods, $\tilde{d}_t$, and the average profits from traded domestically produced goods, $\tilde{d}_{x,t}$, drop reaching a level lower than the original steady state level. Thus, the average profits for a representative firm $\tilde{D}_t$, falls and it lowers the value of the representative average firm $\tilde{v}_t$. From the free entry condition, the decline in $\tilde{v}_t$ translates into a temporary decline in the wage level $w_t$. It is also the case that the fall in $\tilde{D}_t$ makes the market less attractive in such a way that the number of new firms falls and the total number of firms operating falls as well.

The response in $\tilde{w}_t$ dominates the effect of the shock to $p_{o,t}$ such that the input bundle cost drops and, thus, the average productivity for domestic exporting firms, $\tilde{z}_{x,t}$, falls.

The domestic and foreign demand for the homogeneous good decrease in response to the commodity price shock. The effect of the quantity change offsets the effect of the commodity price change in such a way that transfers fall in response to the shock.

The decrease in labor income and the decrease in profits of the representative firm along with the fall in transfers translate into, from the aggregate accounting equation, a fall in consumption.

In summary, a transitory positive shock to $p_{o,t}$ temporary decreases: the average productivity of exporting firms, wages, profits of the representative firm, consumption, as well as welfare.

Our findings illustrate the effect of the so called Dutch disease. That is, the impact of a shock on the commodity price generates a significant drop in welfare. The dutch disease effect in this case is transitory, as is the shock. As the shock vanishes, so does the Dutch disease.

There are two variables adjusting over time which define the welfare evolution. These are the shock $p_{o,t}$, and the productivity threshold $\tilde{z}_{x,t}$. From equation (8), the immediate effect of a $\Delta p_{o,t}$ is to decrease welfare since it negatively affects $w_t$ by a factor $\frac{(1-\alpha)(\sigma-1)}{\alpha(\sigma-1)+1}\Delta p_{o,t}$. Furthermore, the path followed by the average productivity of domestic exporting firms $\tilde{z}_{x,t}$ in response to the shock, deepens the negative adjustment in the evolution of welfare. Thus, what ultimately determines the magnitude of the Dutch disease in a Melitz type dynamic model is the general equilibrium effect of the commodity price shock on the average productivity $\tilde{z}_{x,t}$. Therefore, the Dutch disease phenomenon can be characterized as the combination of the effect coming from the exogenous variation $p_{o,t}$, and the endogenous effect coming from the response of $\tilde{z}_{x,t}$.

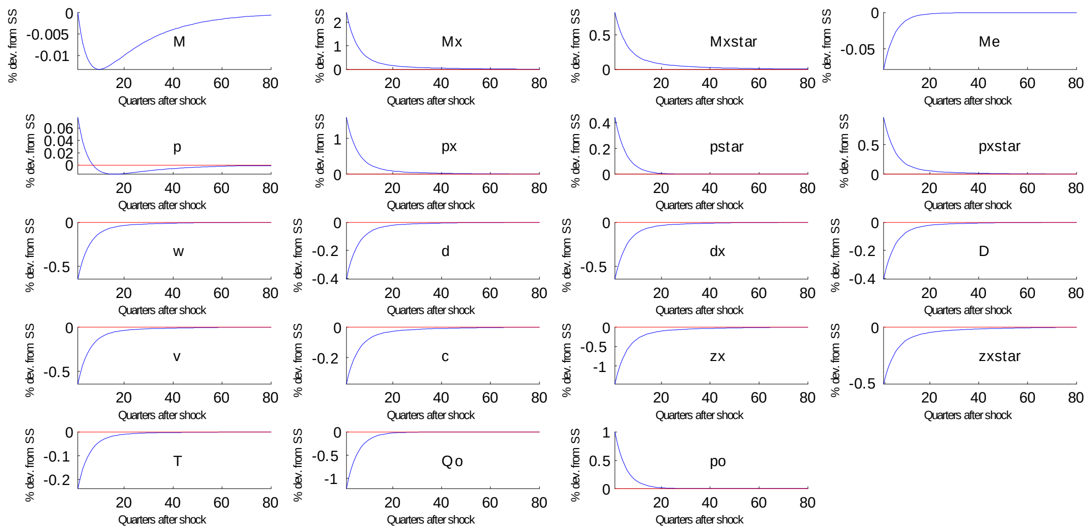
Another interesting exercise is to look at the potential correlation between the foreign demand and the price of the commodity. This is particularly interesting since it may be argued that recently China's investing patterns may be driving the price of commodities up. It that case, it is possible that we may be underestimating or overestimating the effect of a exogenous change in commodity price if we study this shock isolated (i.e. if do not consider correlation with the foreign demand as well).

The fast grow of the Chinese economy has translated in higher investment and the demand of copper has risen. The recent boom in copper price is partially explained by the increase in the demand of copper from China. More generally, the increase in the demand of cooper from the rest of world can be correlated to the price boom.

To study this scenario, we now consider a transitory shock in our model that takes into account this correlation. That is, we consider now a shock to $A_t$ which drives the commodity price along. The response of the endogenous variables to this scenario is shown in Figure (6).

The response of the endogenous variables to the correlated shock is qualitatively similar to the responses shown in Figure (5). However, there are two main points to highlight. First, the effect of the change in commodity price on the endogenous variables could be overestimated if it is analyzed isolated from an increase in foreign demand. How overestimated the effects are

Figure 5: Response to a transitory commodity price shock




depends on the degree of correlation between foreign demand and the commodity price. Second, the Dutch disease effect is still present even though the increase in the foreign demand, due to the shock to $A_t$, soften the drop in welfare.

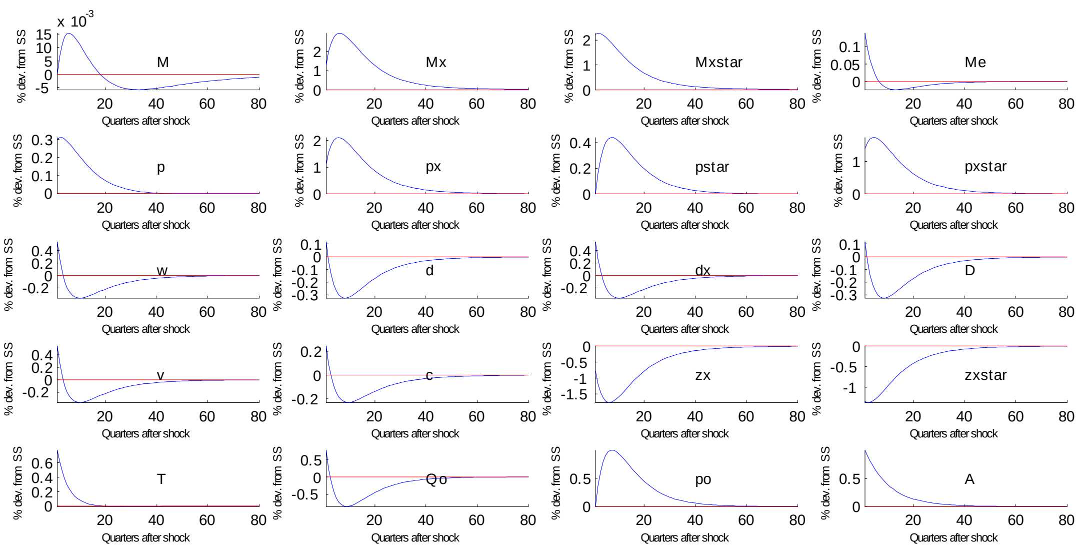
We now turn to analyze the effect of commonly used government policies on the Dutch disease. We would like to explore how these policies could help to mitigate the Dutch disease or aggravate it. In order to do so, we will look at fiscal policies that are commonly used in small open economies that trade commodities.

# 7 Government Policies and Financial Frictions

Economies that trade commodities have a large exposure to commodity price shocks. The dependence on commodity exports could bring along a considerable aggregate volatility in the economy. That is why governments have developed ways of insuring themselves against commodity price shocks. On the one hand, governments may accumulate stock of assets in commodity stabilization funds. This asset accumulation is intended as precautionary savings against uncertainty in future commodity prices. However, there are potential issues with this strategy. For instance, those funds may be misused because of weak governance losing the initial insurance purpose, or because the government tries to offset a permanent shock. Moreover, the accumulation of precautionary reserves comes at a cost of reducing consumption and welfare (Borensztein and Jeanne, 2012).

On the other hand, insurance against commodity price shocks could also be achieved by hedging. Although markets for hedging instruments have developed significantly in recent years,

Figure 6: Response to a transitory shock to the $A_t$ which correlates with $p_{o,t}$




it is still limited (Caballero and Cowan, 2007). Moreover, Borensztein and Jeanne (2012) show that most of the hedging instruments are limited to maturities of less than three months.

Lack of creditworthiness restricts the access of economies to international capital markets. Similarly, access to commodity linked hedging instruments is compromised as well. A limited access to international borrowings and the incompleteness of the commodity linked hedging market imply that economies to some extent will have to rely on methods of self-insurance. The mere existence of self-insurace mechanisms states the presence of international financial frictions.

A widely used self-insurance mechanism is the accumulation of foreign assets by the country to act as a commodity stabilization fund. For instance, a fund like this was established in Chile in 1985. During periods of high commodity prices and high exports earnings, the country would accumulate foreign assets which it would draw down in periods of low commodity prices. In general, the rate or the rule employed by the government to deplete this fund is completely arbitrary. The dynamic problem associated with the commodity stabilization fund is isomorphic to liquidity constrained individuals who have a demand for precautionary savings (Arrau and Claessens, 1992).

Now, we would like to study the potential interactions between the Dutch disease and common government policies adopted by small open economies that produce commodities.

It is generally the case that small open economies with commodities have the concern associated with the level and evolution of debt. This is because the cyclical nature of revenue income from the commodity market and the government decides over those revenues.

Countries around the world that produce commodities follow policies toward debt control or debt targets. Usually, governments set public deficit targets to keep under control both the level and the evolution of debt. In South America, Chile, Peru, and Brazil have policies that target debt. As shown in Table (8), these targets could be enforced by law or not. For instance, Chile and Peru follow government policies that target deficit limits which, in the case of Peru, is

Table 8: Countries with fiscal policy rules

| Country | Since | Enforced by Law? |
|---|---|---|
| Belgium | 1992 | No |
| Estonia | 1993 | No |
| New Zealand | 1994 | Yes |
| Sweden | 1997 | Yes |
| Poland | 1999 | Yes |
| Peru | 2000 | Yes |
| Brazil | 2000 | Yes |
| Chile | 2001 | No |
| Switzerland | 2003 | Yes |
| India | 2004 | Yes |
| Germany | 2012 | Yes |

Table 9: Fiscal Policy Rule: Chile and Peru

| | 2001 | 2003 | 2005 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| Peru (%GDP) | -1.5 | -2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| Chile (%GDP) | 1 | 0.8 | 1.1 | 1.1 | -1 | -3.1 | -2.1 | -1 | -0.4 | -0.5 |

enforced by law and, in the case of Chile, is not. Moreover, Chile and Peru follow deficit targets that are set as percentage of the GDP. Table (9) shows the evolution of such targets since 2001.

Similarly, in Europe, Belgium Germany, and Sweden among others have fiscal policy rules. Table (8) shows selected economies in which government policies based on fiscal rules are followed.

In the case of Chile, this country follows an structural deficit policy rule since 2001 to account for the cyclicality of the copper price. The parameters that characterize such rule are not dictated by law. Instead, a government committee decides it. Originally, the goal of the Chilean policy was to have a surplus equivalent to one percent of the GDP. Over time, this goal was reduced. Moreover, during the economic crises in 2009 and a massive earthquake that hit Chile in 2010, the policy rule ended up in a significant deficit level.

Since 2004, revenues from copper has become more important in the government budget. This is because of the recent shock in the price of the commodity. The cyclicality associated with commodity income pushes the government to implement debt control policies in order to keep or reduce the path of public debt over time according to some particular government macroeconomic objective (Table 9).

In this section, we would like to study if government policies have any interaction with Dutch disease. In particular, we would like to study the dynamic implications of common government policies. That is, whether government policies worsen or improve the Dutch disease phenomenon. In doing so, we will consider two type of frictions induced by commonly used government policies. On the one hand, we will consider the liquidity shortage induced by debt targets and we introduce this feature in our model as a borrowing constraint. On the other hand, we will consider a wasteful government that incurs in unproductive spendings.

Let us consider first the case of debt target policies. When debt target policies are implemented, this generates a liquidity constraint phenomenon in the economy. As shown in Woodford (1990), government debt (public debt) provides private liquidity. Thus, government policies designed to limit deficit or debt constraint the liquidity of the economy and diminishes the ability of households to smooth out consumption. Therefore, government policies associated with deficit control generates a financial friction in the form of a liquidity constraint.

The way we will study such financial friction in our model is by using a reduced form in which we take advantage of the small open economy assumption. For example, a frictionless benchmark case can be implemented by considering that households are able to borrow from the rest of the world at an exogenous interest rate. In this case, households are able to smooth out consumption. The case in which the economy is liquidity constrained due to the financial friction induced by government debt target policies can be implemented as a borrowing constraint in our model.

Another source of friction related to government policies is associated with unproductive government expenditure. This type of government expenditure can be thought as spending on war, corruption, subsidies, etc. The way we will incorporate this second friction in our model would be by considering that the government receives the revenue income from the commodity market, but this time instead of completely transferring it to households, the government incurs in an unproductive spending equivalent to a fraction $(1 - \Delta)$ of the commodity revenue. Thus, households receive a fraction $\Delta$ of the commodity revenue from the government, where $0 < \Delta < 1$.

In summary, we will explore the interaction of the Dutch disease with both frictions explained above, which are induced by common government policies employed by countries that produce commodities. Those policies are: debt targets and unproductive expenditure.

We are going to consider as a benchmark the case in which households can freely borrow from the rest of the world. Therefore, the effect of a commodity price shock on consumption can be smoothed out through bond trading. In this case, we also consider that operational profits from the commodity market are transferred to households. This frictionless case is isomorphic to the case in which transfers to households are constant and equal to the steady state level, and the government smooth out the cyclicality of the commodity revenue in the international market. The equilibrium conditions that characterize the dynamics in this benchmark case are equivalent to the ones shown in Table (3.1).

In order to analyze the interaction between the Dutch disease and financial frictions we are going to begin by considering an economy which is borrowing constrained[11]. This borrowing constraint is the rationalization of the liquidity shortage. We employ a borrowing constraint argument as a reduced form that characterize the liquidity issue associated with financial frictions. Thus, we consider first that households are able to borrow from the rest of the world. However, the households face an exogenous borrowing constraint of the form shown in (27).

$$B_t \leq m_t \bar{Y} \tag{27}$$

where $m_t$ is a policy parameter that characterizes the borrowing constraint.

Therefore, in general, our model would become:

$$\underset{C_t, B_{t+1}, x_{t+1}}{Max} \; E_t \left[ \sum_{s=t}^{\infty} \beta^{s-t} \frac{(C_s)^{1-\gamma}}{1-\gamma} \right]$$

subject to

[11] The mere existance of CSF as self-insurance mechanism unveil the existance of financial frictions that can be captured by a borrowing constraint.

$$(1 + r_t) B_t + \widetilde{v}_t M_{H,t} x_{t+1} + C_t = B_{t+1} + \left(\widetilde{D}_t + \widetilde{v}_t\right) M_t x_t + w_t L + T_t$$
$$B_{t+1} \leq m_t \bar{Y}$$

The system of equations that describes the solution path for the endogenous variables in our model is described in Table (1), except that we replace the Euler equation for bonds by equation (28).

$$(C_t)^{-\gamma} = \beta (1 + r_{t+1}) E_t \left[(C_{t+1})^{-\gamma}\right] + \Gamma_t \tag{28}$$

Denoting with $\Gamma_t$ the Lagrange multiplier on the borrowing constraint.

Additionally to the system of equations we have the following condition:

$$\lambda_t \left(B_t - m_t \bar{Y}\right) = 0 \tag{29}$$

Equation (29) plays an essential role describing the dynamic on the equilibrium path. Whenever $\Gamma_t > 0$, this means that the borrowing constraint is binding and the equilibrium system of equations is the one in Table (3.1) in addition to $B_t = m_t \bar{Y}$. On the other hand, when the constraint is slack, the complementary slackness condition implies $B_t \leq m_t \bar{Y}$ and $\Gamma_t = 0$. This means that the equilibrium system of equations is the one obtained when we consider the dynamic maximization problem without the borrowing constraint.

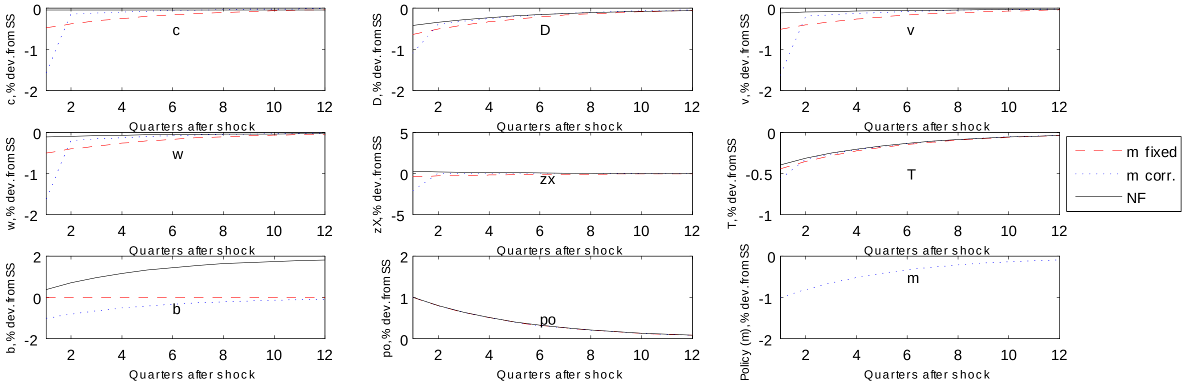
To capture the effect of the borrowing constraint in our model we will consider a positive shock to the commodity price. As in the previous section we consider a process for the commodity price which evolves according to an $AR(1)$ with autocorrelation coefficient of 0.8.

Within the borrowing constraint case, we now explore three scenarios. First, we consider the frictionless case in which agents can freely borrow from the rest of the world. Second, we introduce the case in which the economy is borrowing constrained in the form shown in (27). Third, we consider the case in which the policy parameter $m$ that characterizes the borrowing constraint correlates with the commodity price shock. This is a reduce form to consider actions adopted by the government in response to a commodity price shock. For example, changes in the deficit target. Thus, in our reduce form, as a response to the Dutch disease phenomenon, government actions could relax the borrowing constraint or tighten it.

Figure (7) illustrates the three scenarios explained above. The solid line shows the responses of the endogenous variables in our model when the households face the non frictional case ($NF$). The dashed line shows the responses of the endogenous variables in our model when the households face a borrowing constraint of the form shown in (27) in which the policy parameter is fixed ($m = 0.9$). The dotted line shows the responses of the endogenous variables of our model when the households face a borrowing constraint in which the parameter $m$ negatively correlates with the commodity price shock. That is, households are temporary more constrained under this case than when the commodity price shock does not correlate with the policy parameter $m$.

Households that achieve the first best are able to borrow from the rest of the world as an optimal response to the Dutch disease phenomenon generated by the positive commodity price shock. Thus, in the frictionless case, borrowing increases. Moreover, as a result of the transitory increase in $p_o$, the bundle cost to produce final goods increases affecting the total dividends of firms, $D$, as well as the value of the firms, $v$. These paths translates in a higher productivity threshold for domestic exporting firms.

Figure 7: Positive commodity price shock under borrowing constraint



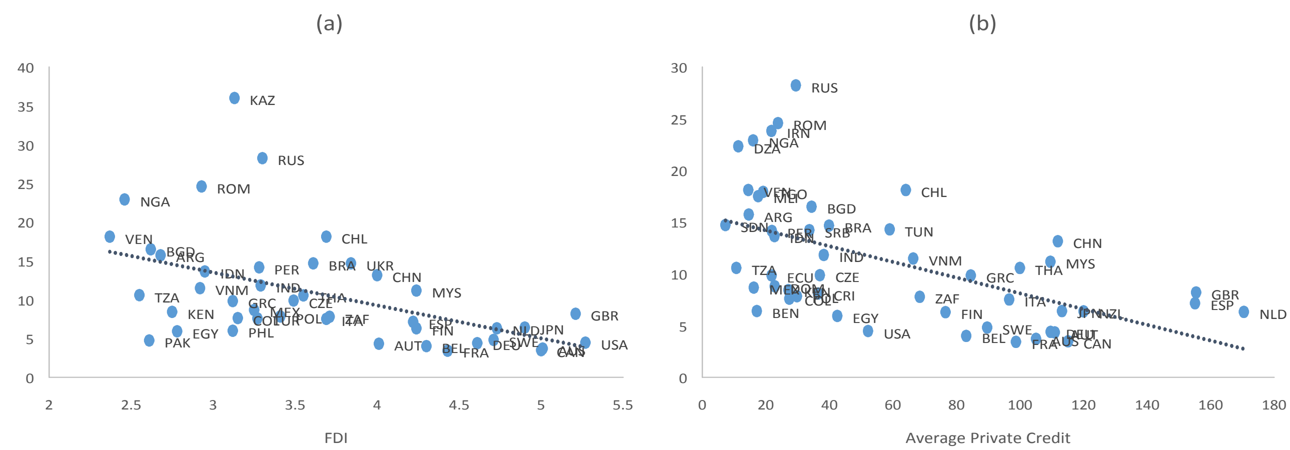

In the case of a borrowing constraint with fix policy parameter $m$, the commodity price shock makes the borrowing constraint more likely to bind, and thus $\Gamma_t > 0$. The drop in consumption in this case is greater because the household is not able to smooth out consumption by increasing borrowing from the rest of the world. The negative effect of the shock on the total dividends of firms, $D$, as well as on the value of the firms, $v$, is greater compared to the frictionless case. Thus, the decrease in wages is more severe in this case generating a drop in the bundle cost for firms producing final goods which translates into a fall in the average productivity of exporting firms. Then, welfare worsens in comparison to the benchmark case. This result is quite intuitive since basic theory tells us that welfare would be negatively affected as a result of a financial friction.

For the case analyzed as well in Figure (7) in which the policy parameter $m$ correlates with the commodity price shock, we can see that the effect of the Dutch disease is amplified with respect to the case in which $m$ is fixed. This is simply because the negative correlation between the shock and the parameter $m$ makes the households even more constrained. The borrowing constraint strengthen the effect of the Dutch disease. In other words, a relatively less constrained economy would face a lower drop in welfare due to a positive shock in the commodity price. This case is intended to rationalize the scenario in which the government imposes an extra burden on the financial friction by limiting debt due to some arbitrary policy rule. The way this feature is incorporated is by increasing the constraint on households. Our results, reinforce the results shown in Woodford (1990), in which the public debt provides private liquidity, and thus government debt could help out to improve welfare.

The aggregate quarterly Chilean data shows that the volatility of consumption increases during the period of the commodity price boom with respect to the previous period. This result holds with or without controlling for the subprime crises period. This empirical fact is consistent with the prediction from the model when the economy faces a commodity price shock and it is borrowing constrained. In such case, households are not able to smooth out consumption therefore consumption volatility increases. A similar result is obtained from the data when we look at the quarterly series for the manufacture production index (sales). The volatility of the manufacture production is greater after the commodity price shock. This increase in volatility is also in line with our findings, since the aggregate revenue in our model is a monotone transformation of wages[12].

More broadly, the model predicts that the tighter the constraint the greater is the consumption volatility induced by the commodity shock. Figure (8) shows consumption volatility for countries that trade commodities versus a measure of financial frictions. We will employ two measures for financial friction which are intended to capture how constrained an economy could be. We use the Financial Development Index (FDI)[13], and the average private credit for each economy[14]. Figure (8$a$) shows consumption volatility versus the FDI for 43 countries, and Figure (8$b$) shows consumption volatility versus the average private credit for 50 countries. It can be seen in both figures a negative correlation between consumption volatility and the financial friction measure.

Figure 8: Consumption Volatility versus measure of financial friction




Another prediction from the model is related to the volatility of the aggregate productivity[15]. The more constrained agents are, the higher is the volatility of productivity. Figure (9) shows aggregate productivity volatility for countries that trade commodities versus a measure of financial frictions. Figure (9$a$) shows aggregate productivity volatility versus the FDI for 19 countries, and Figure (9$b$) shows aggregate productivity volatility versus the average private credit for 20 countries. It can be seen in both figures a negative correlation between aggregate productivity volatility and the financial friction measure.

The aggregated monthly Chilean data for wages in the manufacturing sector shows that the volatility of wages increases during the period of the commodity price boom with respect

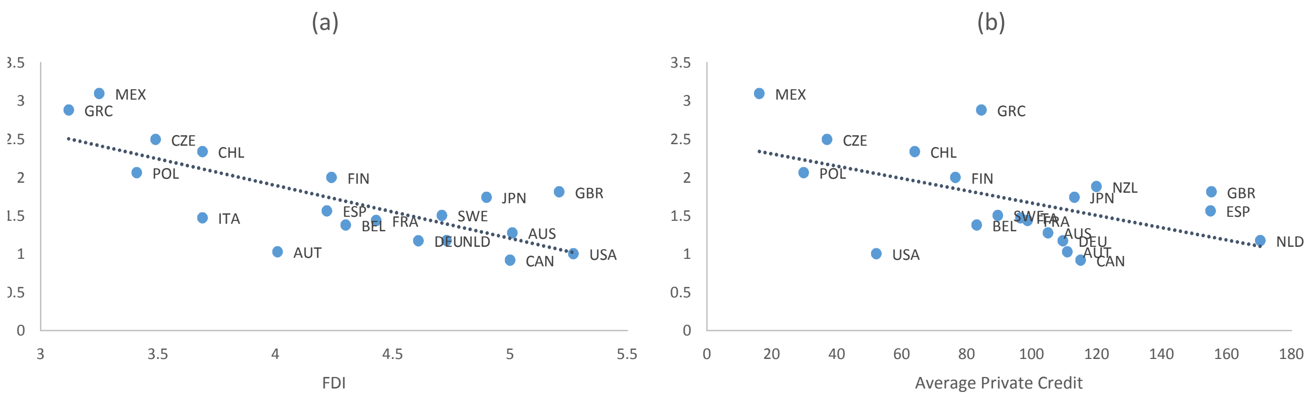
[12] See Appendix B for details.

[13] The FDI is an annual measure provided by the World Economic Forum.

[14] The average private credit is an annual measure provided by the World Bank and it is measure that captures both the size and the access to the financial market for each country.

[15] Aggregate Productivity is a measure provided by the OECD.

Figure 9: Productivity Volatility versus a measure of financial friction




to the previous period. This empirical fact is consistent with an economy which is borrowing constrained.

The model predicts that a tighter constraint would be associated with higher wage volatility. Figure (10) shows wage volatility for countries that trade commodities versus a measure of financial frictions[16]. Figure (10$a$) shows wage volatility versus the FDI for 24 countries, and Figure (10$b$) shows wage volatility versus the average private credit for 25 countries. It can be seen in both figures a negative correlation between wage volatility and the financial friction measure.

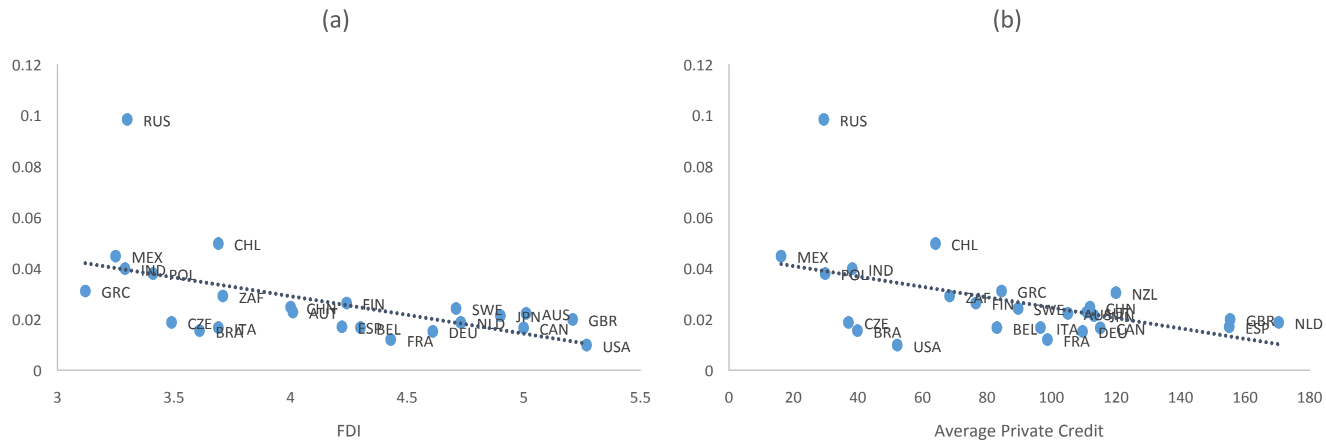
Figure (11) illustrates the effect of the Dutch disease considering quarterly data of the manufacturing sector in Chile. On the primary axis, the percentage change in the manufacture production index for the period 2003-2015 (quarterly) is shown. On the secondary axis we have the evolution of the copper price. There is, in average, a decreasing path in the production changes. This path coincides with the commodity shock. Essentially, this negative relationship is what is known as the Dutch disease.

Our results from the model suggest that a relaxation of the borrowing constraint (increase in $m$), which correspond to an increase in liquidity, improves welfare. As shown in Table (9), during the years 2009 and 2010 the fiscal policy rule is relaxed in Chile. In 2009 this relaxation is related to the global economic crises, and in 2010 this relaxation is related, mainly, to an earthquake and tsunami that affected Chile. The model developed in this paper predicts that such relaxation will bring along welfare improvement and would soften the effect of the Dutch disease due to the increase in liquidity. In Figure (11) we see a break in the downward sloping tendency of the manufacture sector during 2009 and 2010.

A similar pattern can be seen in Figure (12) where percentage change in consumption (quarterly) is shown in the primary axis while the evolution of the copper price is shown in the secondary axis. In this case, the Dutch disease is also embodied in the average negative relation-

[16]Hourly wage data by country is provided by OECD.

Figure 10: Wage Volatility versus a measure of financial friction




ship between the curves shown in Figure (12). The positive effect on consumption predicted by the model from the relaxation of the fiscal policy rule during 2009 and 2010 is observed in the break of the downward sloping tendency in consumption changes shown in Figure (12) for the years 2009 and 2010.

In general, the model developed in this paper suggests that the effect of the Dutch disease can be soften employing policies that reduce the effect of the financial friction. Within our model such policies meet the liquidity need of the economy and close the gap between the feasible allocations and the first best, improving welfare.

We now look at the financial friction implied by government expenditure in non-productive activities, $G_t$.

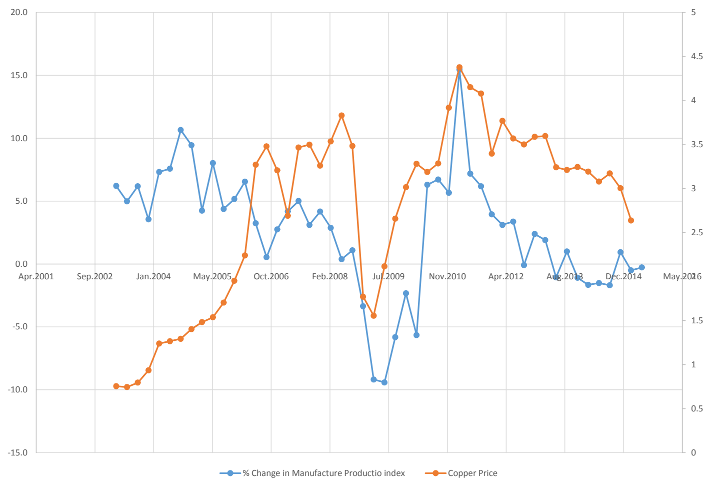
To model the effect of the non-productive expenditure, we consider a government that receives the profits from the commodity trade as income and it has spendings that consist in non-productive activities, $G_t$, and transfers to households, $T_t$. Thus, in this case, the government budget becomes:

$$T_t + G_t = IC_t$$

As mentioned before, we will consider that the government spends $G_t = (1 - \Delta) \cdot IC_t$ in non-productive activities. That is, the household receives transfers from the government given by $\Delta \cdot IC_t$. Thus, the households problem is as described in previous section except that the budget constraint now becomes as follows:

$$B_{t+1} + \widetilde{v}_t M_{H,t} x_{t+1} + C_t = (1 + r_t) B_t + \left( \widetilde{D}_t + \widetilde{v}_t \right) M_t x_t + w_t L + \Delta \cdot IC_t$$

Figure 11: Percentage change in Manufacture production and Copper price




To capture the effect of the friction induced by the non-productive expenditure incurred by the government in our model, we will consider a positive shock to the commodity price as before.

We explore two scenarios. The first scenario is the benchmark case explained before in which we have a frictionless economy and $\Delta = 1$, that is, the government does not incur in any non-productive spending. The second scenario considers a frictionless economy in which the government spends more as the commodity price shock hits the economy. Thus, in this case, we consider that the shock positively correlates with the fraction $1 - \Delta$ of commodity income that the government spends in unproductive activities.

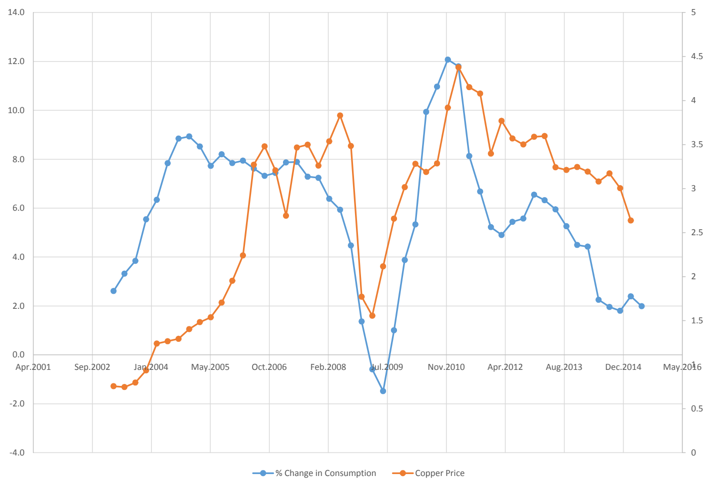
Figure (13) shows the two scenarios mentioned above. The solid line shows the responses of the endogenous variables in our model to the benchmark case ($\Delta = 1$). The dashed line shows the responses of the endogenous variables in our model to the case in which the fraction of the commodity revenue is positively correlated with the commodity price shock. This scenario intends to show the effect of a government policy in which the government becomes more wasteful as the price of the commodity rises.

As shown in Figure (13), an increase in unproductive government expenditure generates a drop in welfare respect to the benchmark case. In this exercise, consumption falls as a result of less resources available in the economy. As in the borrowing constrained case, the effect of the Dutch disease is amplified by the unproductive government spending. Therefore, our model predicts that the more wasteful or corrupted the government, the deeper the effect of the Dutch disease.

Thus, the model predicts that a higher unproductive government spending is associated with a higher volatility of the economy. In Figure (14) we show correlations between Consumption volatility ($a$), Productivity volatility ($b$), and Wage volatility ($c$) versus an average of the Corruption Perception Index (CPI)[17] across countries. It is shown that the volatility of consumption,

[17] The CPI is an annual measure provided by the Transparency International. We use the average between the years 1998 and 2011. The period 2012-2014 has been excluded because for that period the measure follows a different scale.

Figure 12: Percentage change in Consumption and Copper price




productivity, and wage across countries is negatively correlated with the CPI which means that the volatility of these variables is positively correlated with corruption perceptions.

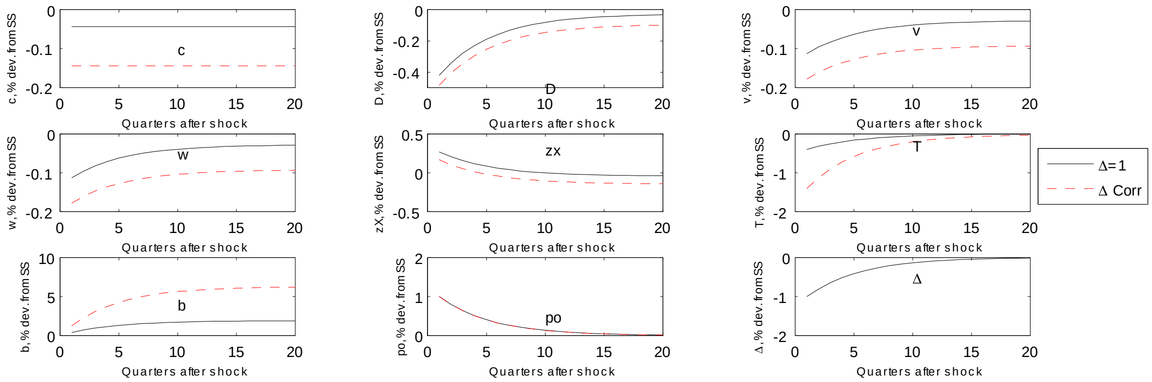
In our final exercise, we consider the two frictions associated to government policies, studied in this paper, acting together. That is, we consider an economy that faces a borrowing constraint as well as a government that increases unproductive expenditure as a response to a positive commodity price shock.

Figure (15) shows the responses path of the endogenous variables in our model to two scenarios. The first scenario, shown by the dashed line considers the case in which the households face a borrowing constraint. In the second scenario, shown by the dotted line, households face the borrowing constraint and the government incurs in unproductive expenditure according with the dynamic shown in Figure (15) for the variable $\Delta$.

As analyzed before, frictions associated to government policies aggravate the effect of the Dutch disease. When acting together, the effect of the Dutch disease is amplified even more respect to the case in which they act independently. Although, this complementary negative effect of frictions on the Dutch disease phenomenon is straightforward considering our previous results, it could help out explaining the outliers shown in Figure (8) and (14).

Our results indicate that common policies adopted by economies that produce commodities can be detrimental to welfare and act as amplifiers to propagate the effect of the Dutch disease. At the same time, our results indicate the direction in which those policies have the potential to mitigate the effect of the Dutch disease. Commodity booms accompanied by efficient use of resources and mitigation of financial friction are welfare improvement policies that soften the effect of the Dutch disease. Otherwise, commonly used policies may act as amplifier or accelerator for the Dutch disease phenomenon.

Figure 13: Positive commodity price shock under unproductive government expenditure




# 8 Conclusions

In this paper we have developed a dynamic model of a small open economy that produces and trades a commodity. This commodity is used as intermediate input to produce final goods in the home economy as well as in the rest of the world. We have studied the dynamic implications of productivity shocks and commodity price shocks. To do so, we have estimated the elasticity of substitution across final goods and the shape parameter of the Pareto distribution for the Chilean economy. We use Chilean data because it satisfies the small open economy assumption as well as the commodity production. Using these estimations we are able to compute the steady-state of the economy and study the dynamics implied by the model.

In this context, we have found that the commodity price shock generates the so called Dutch disease. That is, a positive shock in the commodity price generates a fall in welfare.

We study the effect of financial frictions induced by commonly used government policies on the Dutch disease. Policies of debt target are popular among countries that trade commodities. Such policies are employed to avoid undesirable levels of debt due to the cyclical revenue obtained from the commodity market. Our results indicate that common policies adopted by economies that produce commodities can be detrimental to welfare and act as amplifiers to propagate the effect of the Dutch disease. At the same time, our results indicate the direction in which those policies have the potential to mitigate the effect of the Dutch disease. Commodity booms accompanied by efficient use of resources and mitigation of financial friction are welfare improvement policies that soften the effect of the Dutch disease. Otherwise, commonly used policies may act as amplifier or accelerator for the Dutch disease phenomenon.

The main predictions from the model are in line with the empirical evidence available for Chile and across countries.

Figure 14: Volatility and Corruption Perception Index

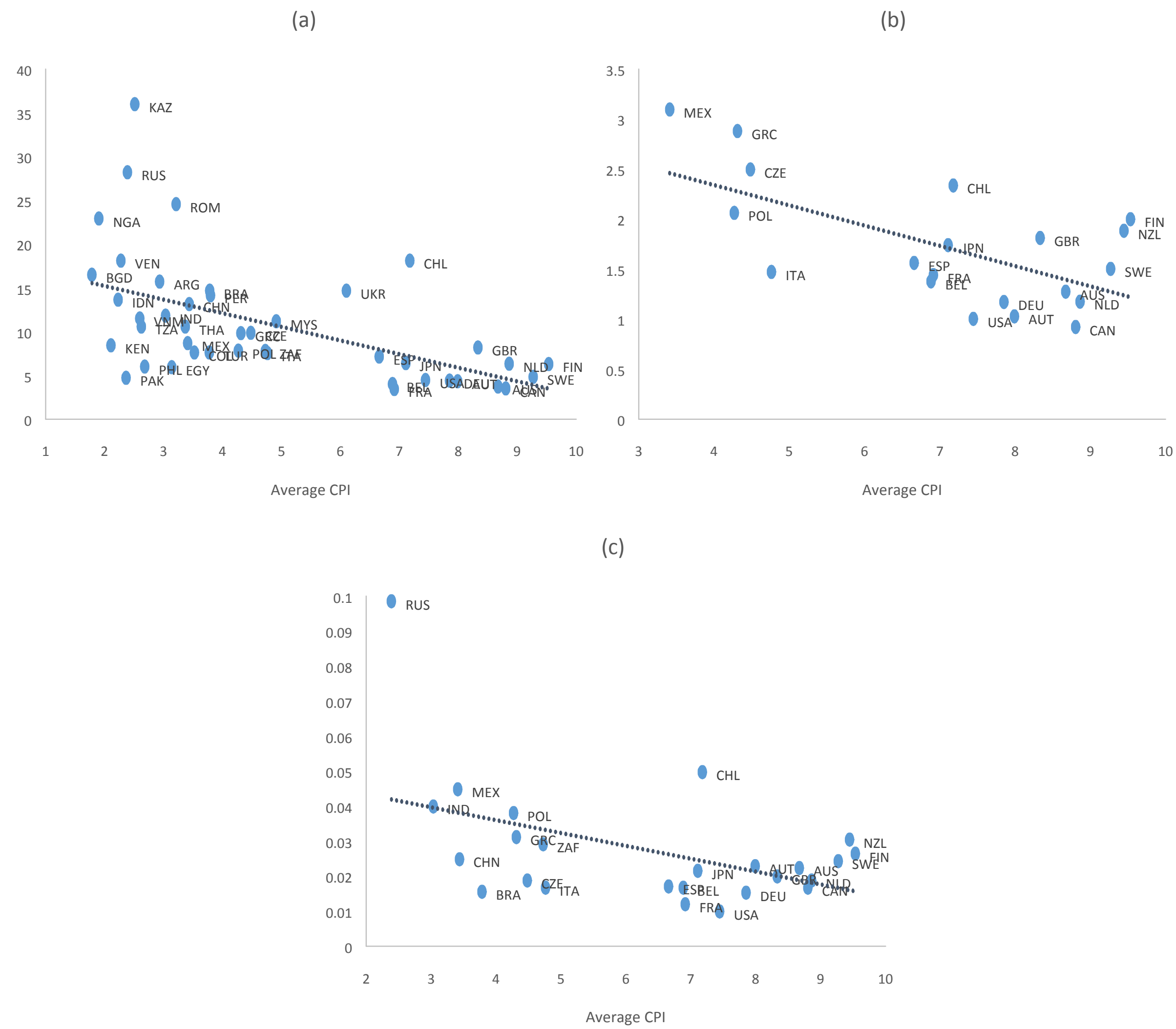
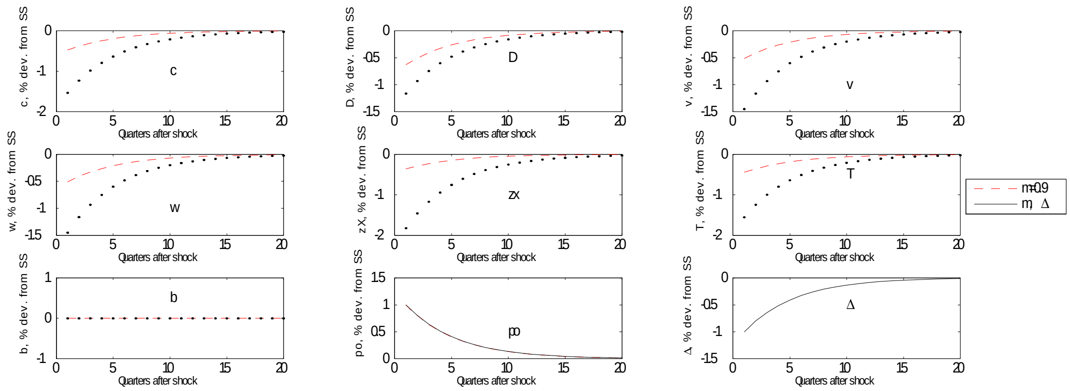


Figure 15: Positive commodity price shock under borrowing constraint and unproductive expenditure

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# 9 Appendix A

In general, let us write equation (21) as follows:

$$y_{it} = \alpha + l_{it}\beta + k_{it}\gamma + v_{it} + e_{it} \tag{30}$$

The theory underlying OP and LP is that there is an unknown function g such that:

$$v_{it} = g(k_{it}, m_{it})$$

where $m_{it}$ is a proxy variable which is investment in the case considered by OP, and intermediate inputs in LP.

Under the assumption $E(e_{it}|l_{it}, k_{it}, m_{it}) = 0$, we have the following regression:

$$E(y_{it}|l_{it}, k_{it}, m_{it}) = \alpha + l_{it}\beta + k_{it}\gamma + g(k_{it}, m_{it}) \tag{31}$$

$$E(y_{it}|l_{it}, k_{it}, m_{it}) = l_{it}\beta + h(k_{it}, m_{it})$$

where $h(k_{it}, m_{it}) = \alpha + k_{it}\gamma + g(k_{it}, m_{it})$.

Since $g(.)$ is allowed to be any function, when it is linear in $k_{it}$, then $\gamma$ is not identified from (31).

In both OP and LP, equation (31) is used to identify $\beta$ in a first stage. For the OP case, the use of investment as a proxy variable generates problems with the identification since there is evidence that investment at the firm level is lumpy. In the LP case, the identification of $\beta$ is not clear. As shown by ACF, if labor inputs are chosen at the same time as intermediate inputs, there is a fundamental identification problem in equation (31). That is, $l_{it}$ is some function of $(k_{it}, m_{it})$ which means $\beta$ is not identified.

Wooldrige (2009) proposes to estimate $\beta$ and $\gamma$ together. He assumes that:

$$E(e_{it}|l_{it}, k_{it}, m_{it}, l_{it-1}, k_{it-1}, m_{it-1}, ..., l_{i1}, k_{i1}, m_{i1}) = 0$$

and restricts the dynamics of productivity shocks as:

$$E(v_{it}|v_{it-1}, ..., v_{i1}) = E(v_{it}|v_{it-1}) = f(v_{it-1}) = f(g(k_{it-1}, m_{it-1}))$$

So, it is possible to express productivity innovations as:

$$a_{it} = v_{it} - f(v_{it-1})$$

where, $E(a_{it}|k_{it}, l_{it-1}, k_{it-1}, m_{it-1}, ..., l_{i1}, k_{i1}, m_{i1}) = 0$. This means that labor $l_{it}$ and the proxy variable $m_{it}$ can be correlated with productivity innovations $a_{it}$. However, $k_{it}$ and all past values of $l_{it}, k_{it}, m_{it}$ and the function of these are uncorrelated with $a_{it}$. Plugging into the production function yields:

$$y_{it} = \alpha + l_{it}\beta + k_{it}\gamma + f(g(k_{it-1}, m_{it-1})) + u_{it} \tag{32}$$

where $u_{it} = a_{it} + e_{it}$.

The problem is reduced now to estimate both equations, (30) and (32), using GMM or to estimate equation (32) using IV.

# 10 Appendix B

Revenue for a domestic exporting firm is given by:

$$R_{x,t}(z) = p_{x,t} \cdot q_{x,t} = \left( \frac{w_t^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\rho \cdot \theta \cdot Z_t \cdot z} \tau \right) \cdot \left( \frac{w_t^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\rho \cdot \theta \cdot Z_t \cdot z} \tau \right)^{-\sigma} A_t$$
$$= \left( \frac{w_t^{\alpha} \cdot p_{o,t}^{1-\alpha}}{\rho \cdot \theta \cdot Z_t} \tau \right)^{1-\sigma} \frac{A_t}{z^{1-\sigma}}$$

Then, employing the threshold equation (8) we can rewrite the revenue equation as:

$$R_{x,t}(z) = \sigma \cdot \frac{w_t \cdot f_x}{Z_t} \left( \frac{z}{z_{x,t}} \right)^{\sigma-1}$$