Dutch Disease and Monetary Policy: The Case of Price and Wage Rigidity. PRELIMINARY.

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Abstract

We study a model of a small open economy that specializes in the production of commodities and that exhibits exogenous frictions in the setting of both prices and wages. We study the optimal response of monetary and exchange rate policy following a positive (negative) shock to the price of the exportable that generates an appreciation (depreciation) of the local currency. According to the model, the optimality of full inflation targeting is remarkably robust.

1. INTRODUCTION

In this paper we study optimal monetary and exchange rate policy in a small open economy with price and wage rigidity, following a shock to the price of an exportable commodity. From the point of view of theory, and as we will make precise in the paper, the presence of both types of rigidity implies that, to the extent that fiscal policy is unresponsive to shocks, full price stability is not optimal. The main exploration of this paper is a quantitative one: On one hand, we explore numerically how apart from full inflation targeting the optimal policy is; on the other, we compute the welfare difference between the optimal policy and full inflation targeting. We find that full inflation targeting is optimal in many cases and when not, it implies, in the worst case scenario, welfare losses that are less than 0.01% of lifetime consumption. Thus, according

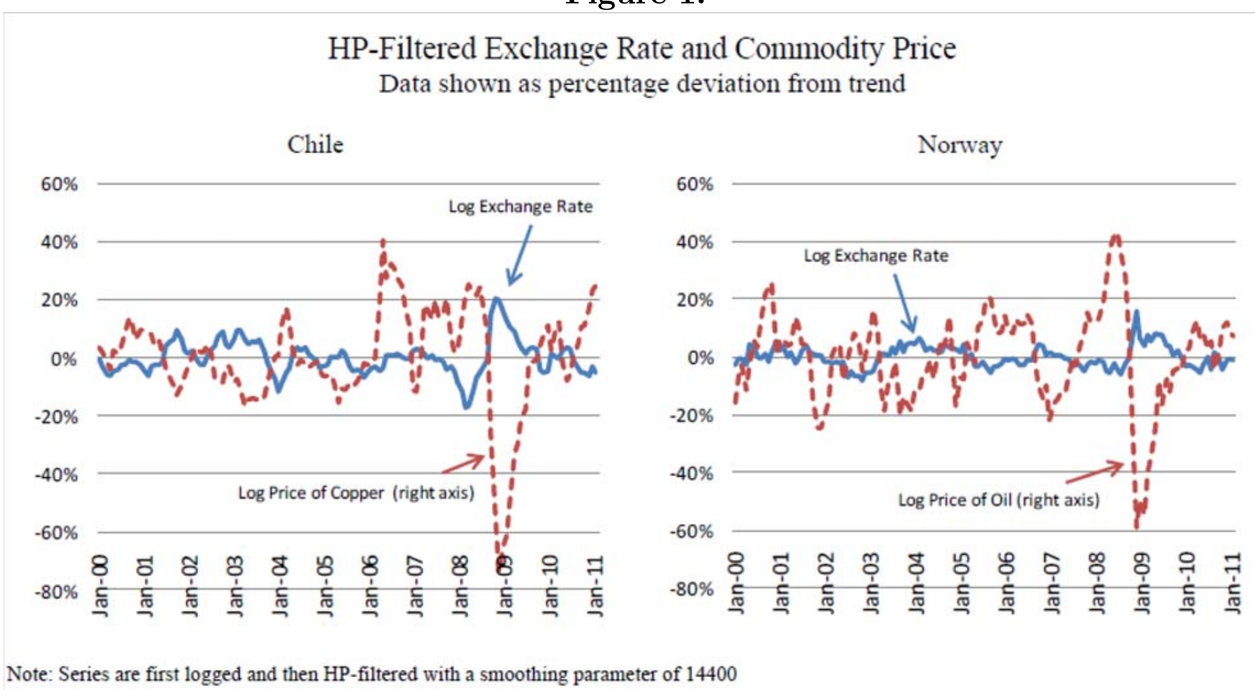
[1] The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or teh Federal Reserve System.

to this model, frictions in both prices and wages does not justify departing from full inflation targeting.

This paper is part of a research project that is motivated by the experiences of many small open economies that in the last two decades became - very effectively! - inflation targeters. Many of this economies are commodity producers and the size of the commodity sector to GDP is non-negligible. For example, in the decade that goes from the year 2000 to 2010, exports of copper and marine products for Chile were, on average, around 17% of GDP, while total exports of oil and marine products in Norway accounted for 20% of GDP. During the same decade, the real price of copper and oil experienced changes of around 300%. The size of these shocks is orders of magnitude above any business cycle shock we had ever seen.

These shocks have direct effects on the monetary side of these economies: At the business cycle frequency, the correlation between the price of the exportable and the nominal exchange rate ranges from -50% to -70%, for both countries, depending on whether one includes in the sample the last three periods of the decade, that included very large changes in commodity prices, commoving with the peso in Chile and the krone in Norway. In Figure 1, we plot the HP-filtered data for the nominal exchange rate and the relevant commodity price for both countries, where the correlation can almost be computed by the eye.

Figure 1.



Clearly, this correlation cannot be independent of the policy regime. In a currency board or a fixed exchange rate regime that correlation is naturally zero. Thus, one should expect the correlation between the price of copper and the exchange rate in Chile to be much closer to zero during the early nineties, in which inflation was drove down from close to 30% to below 10% using a managed exchange rate. But in a very successful inflation targeting regime, as the ones followed by both central banks during the period, the correlation will be determined by market forces. As our model below makes clear, the negative correlation is a direct implication of the inflation targeting regime.

Our interest is to study conditions under which the strict inflation targeting regime is optimal. In our view, this is one of the main policy questions in countries like Chile. Indeed, during the successful inflation targeting period, the Central Bank deviated from the strict rule twice, once in April 2008 and again in January 2011. In both occasions the justification for the intervention was essentially the same: the terms of trade are too high and the nominal exchange rate too low.

In a previous paper (Hevia and Nicolini 2013) we studied an economy with only price frictions and showed that even in a second best environment with distorting taxes, price stability is optimal as long as preferences are of the isoelastic type, typically used in the literature, even if fiscal policy cannot respond to shocks. In our conclusions we pointed out that our results fall aport in the presence of both price and wage frictions. To quantitatively explore this question is the purpose of this paper.

The model we use is the one explored in Hevia and Nicolini 2013 (HN), but allowing for heterogenous labor with market power, and frictions in the setting of wages. A virtue of the model is that it is fully consistent with the evidence presented in Figure 1. We present the model in Section 2. In section 3 we describe the numerical solutions and discuss optimal policy. A final section concludes.

2. THE MODEL

We study a discrete time model of a small open economy inhabited by households, the government, competitive firms that produce one of the tradable commodities, competitive firms that produce the final good, and a continuum of firms that produce differentiated intermediate goods. There are two differentiated traded final goods, one produced at home and the other produced in the rest of the world. The small ope economy faces a downward-sloping demand for the final good it produces but takes as given the international price of the foreign final good. There are also two commodities, one produces at home, the other imported, used in the production of intermediate goods. These intermediate goods are used to produce the final domestic good.

Households

A representative household has preferences over contingent sequences of two final consumption goods, C_t^h and C_t^f, and leisure L_t. The utility function is weakly separable between the final consumption goods and leisure and is represented by

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, L_t\right), \tag{1}$$

where $0 < \beta < 1$ is a discount factor, $C_t = H(C_t^h, C_t^f)$ is a function homogeneous of degree one and increasing in each argument, and $U\left(C, L\right)$ is increasing in both arguments and concave.

Sticky Wages. In order to allow for sticky wages, we assume the single household has a continuum of members indexed by $h \in [0,1]$, each supplying a differentiated labor input n_{ht}. Preferences of the household are described by (1), where leisure is

$$L_t = 1 - \int_0^1 n_{ht} dh. \tag{2}$$

The differentiated labor varieties aggregate up to total labor input N_t, used in production, according to the Dixit-Stiglitz aggregator

$$N_t = \left[\int_0^1 n_{ht}^{\frac{\theta^w - 1}{\theta^w}} dh \right]^{\frac{\theta^w}{\theta^w - 1}}, \ \theta^w > 1. \tag{3}$$

Each member of the household, which supplies a differentiated labor variety, behaves under monopolistic competition. They set wages as in Calvo (1983), with the probability of being able to revise the wage $1 - \alpha^w$. This lottery is *i.i.d.* across workers and over time. The workers that are not able to set wages in period 0 all share the same wage w_{-1}. Other prices are taken as given. There is a complete set of state-contingent assets. We consider an additional tax, a payroll tax on the wage bill paid by firms, τ_t^p.

Market Structure Financial markets are complete. We let $B_{t,t+1}$ and $B_{t,t+1}^*$ denote one-period discount bonds denominated in domestic and foreign currency, respectively. These are bonds issued at period t that pay one unit of the corresponding currency at period $t+1$ on a particular state of the world and zero otherwise.

The household's budget constraint is given by

$$\begin{aligned} & P_t^h C_t^h + P_t^f C_t^f + E_t \left[Q_{t,t+1} B_{t,t+1} + S_t Q_{t,t+1}^* \tilde{B}_{t,t+1}^* \right] \leq \\ & W_t \left(1 - \tau_t^n\right) N_t + B_{t-1,t} + S_t \frac{\tilde{B}_{t-1,t}^*}{1 + \tau_t^*}, \end{aligned} \tag{4}$$

where S_t is the nominal exchange rate between domestic and foreign currency, W_t is the nominal wage rate, τ_t^n is a labor income tax, τ_t^* is a tax on the return of foreign denominated bonds (a tax on capital flows), and $Q_{t,t+1}$ is the domestic currency price of the one-period contingent domestic bond normalized by the conditional probability of the state of the economy in period $t+1$ conditional on the state in period t. Likewise, $Q_{t,t+1}^*$ is the normalized foreign currency price of the foreign bond.[2] In this constraint, we assume that dividends are fully taxed and that consumption taxes are zero (we explain these choices below).

Using the budget constraint at periods t and $t+1$ and rearranging gives the no-arbitrage

[2] We use the notation $\tilde{B}_{t,t+1}^*$ instead of simply $B_{t,t+1}^*$ to distinguish foreign bonds held by the household sector from foreign bonds held by the aggregate economy.

condition between domestic and foreign bonds:

$$Q_{t,t+1} = Q^*_{t,t+1}\left(1+\tau^*_{t+1}\right)\frac{S_t}{S_{t+1}}. \tag{5}$$

Working with the present value budget constraint is convenient. To that end, for any $k > 0$, we let $Q_{t,t+k} = Q_{t,t+1}Q_{t+1,t+2}...Q_{t+k-1,t+k}$ be the price of one unit of domestic currency at a particular history of shocks in period $t+k$ in terms of domestic currency in period t; an analogous definition holds for $Q^*_{t,t+k}$. Iterating forward on (4) and imposing the no-Ponzi condition $\lim_{t\to\infty} E_0[Q_{0,t}B_t + S_t Q^*_{0,t}\tilde{B}^*_t] \geq 0$ gives

$$E_0 \sum_{t=0}^{\infty} Q_{0,t}\left(P^h_t C^h_t + P^f_t C^f_t - W_t\left(1-\tau^n_t\right)N_t\right) \leq 0, \tag{6}$$

where we have assumed that initial financial wealth is zero, or $B_{-1,0} = \tilde{B}^*_{-1,0} = 0$.

The household maximizes (1) subject to (6). The optimality conditions are given by

$$\frac{H_{C^h}(C^h_t, C^f_t)}{H_{C^f}(C^h_t, C^f_t)} = \frac{P^h_t}{P^f_t} \tag{7}$$

$$\frac{U_C\left(C_t, N_t\right) H_{C^h}(C^h_t, C^f_t)}{-U_N\left(C_t, N_t\right)} = \frac{P^h_t}{W_t\left(1-\tau^n_t\right)} \tag{8}$$

$$\frac{U_C\left(C_t, N_t\right) H_{C^h}(C^h_t, C^f_t)}{P^h_t} = \beta\frac{1}{Q_{t,t+1}}\frac{U_C\left(C_{t+1}, N_{t+1}\right) H_{C^h}(C^h_t, C^f_t)}{P^h_{t+1}}. \tag{9}$$

Government

The government sets monetary and fiscal policy and raises taxes to pay for exogenous consumption of the home final good, G^h_t.[3] Monetary policy consists of rules for either the nominal interest rate R_t or the nominal exchange rate S_t. Fiscal policy consists of labor taxes τ^n_t; payroll taxes τ^n_t, export and import taxes on foreign goods, τ^h_t and τ^f_t, respectively; taxes on returns of foreign assets τ^*_t; and dividend taxes τ^d_t.

The two sources of pure rents in the model are the dividends of intermediate good firms and the profits of commodity producers—equivalently, one can think of the latter as a tax on the rents associated with a fixed factor of production. Throughout the paper, we assume that all rents are fully taxed so that $\tau^d_t = 1$ for all t. The reason for this assumption is that if pure rents are not fully taxed, the Ramsey government will use other instruments to partially tax those rents. We deliberately abstract from those effects in the optimal policy problem.

Our description of fiscal policy is for completeness. As is well known[4], when fiscal policy

[3]It is straightforward to also let the government consume foreign goods.

[4]See Adao, Correia and Teles (2009), Correia, Nicolini and Teles (2008), Correia, Farhi, Nicolini and Teles

can respond to shocks and there is a complete set of instruments, price stability is optimal. The taxes described in this section do represent a complete set of instruments. The optimal monetary policy becomes non-trivial once fiscal instruments are exogenously restricted to be unresponsive to shocks.

Final good firms

Perfectly competitive firms produce the domestic final good Y_t^h by combining a continuum of non-tradable intermediate goods indexed by $i \in (0,1)$ using the technology

$$Y_t^h = \left[\int_0^1 y_{it}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}},$$

where $\theta > 1$ is the elasticity of substitution between each pair of intermediate goods. Taking as given the final good price, P_t^h, and the prices of each individual variety of intermediate goods, P_{it}^h for $i \in (0,1)$, the firm's problem implies the cost minimization condition

$$y_{it} = Y_t^h \left(\frac{P_{it}^h}{P_t^h} \right)^{-\theta} \tag{10}$$

for all $i \in (0,1)$. Integrating this condition over all varieties and using the production function gives a price index relating the final good price and the prices of the individual varieties,

$$P_t^h = \left(\int_0^1 P_{it}^{h1-\theta} di \right)^{\frac{1}{1-\theta}}. \tag{11}$$

Minimization of labor costs.

Before describing the technologies of the sectors that demand labor, it is useful to describe the labor cost minimization problem. Firms minimize $\int_0^1 w_{ht} n_{ht} dh$, where w_{ht} is the wage of the h-labor, for a given aggregate N_t, subject to (3). The demand for n_{ht} is

$$n_{ht} = \left(\frac{w_{ht}}{W_t} \right)^{-\theta^w} N_t, \tag{12}$$

where W_t is the aggregate wage level, given by

$$W_t = \left[\int_0^1 {w_{ht}}^{1-\theta^w} dh \right]^{\frac{1}{1-\theta^w}}. \tag{13}$$

It follows that $\int_0^1 w_{ht} n_{ht} dh = W_t N_t$.

(2012), Farhi, Gopinath and Itskhoki and Hevia and Nicolini (2013).

The optimal wage-setting conditions by the monopolistic competitive workers are now

$$w_t = \frac{\theta^w}{\theta^w - 1} E_t \sum_{j=0}^{\infty} \eta_{t,j}^w \frac{u_L(t+j)}{u_C(t+j)} \frac{\left(1+\tau_{t+j}^c\right) P_{t+j}}{\left(1-\tau_{t+j}^n\right)}, \tag{14}$$

with

$$\eta_{t,j}^w = \frac{\left(1-\tau_{t+j}^n\right)(\alpha^w\beta)^j \frac{u_C(t+j)}{\left(1+\tau_{t+j}^c\right)P_{t+j}} \left(W_{t+j}\right)^{\theta^w} N_{t+j}}{E_t \sum_{j=0}^{\infty} \left(1-\tau_{t+j}^n\right)(\alpha^w\beta)^j \frac{u_C(t+j)}{\left(1+\tau_{t+j}^c\right)P_{t+j}} \left(W_{t+j}\right)^{\theta^w} N_{t+j}}. \tag{15}$$

The wage level (13) can be written as

$$W_t = \left[(1-\alpha^w) w_t^{1-\theta^w} + \alpha^w W_{t-1}^{1-\theta^w}\right]^{\frac{1}{1-\theta^w}}. \tag{16}$$

Using (12), we can write (2) as

$$N_t = \left[\int_0^1 \left(\frac{w_{ht}}{W_t}\right)^{-\theta^w} dh\right]^{-1} (1-L_t). \tag{17}$$

From (13), it must be that $\int_0^1 \left(\frac{w_{ht}}{W_t}\right)^{-\theta^w} dh \geq 1$. This means that for a given total time dedicated to work, $1-L_t$, the resources available for production are maximized when there is no wage dispersion.

In equilibrium

$$1 - L_t = N_t \sum_{j=0}^{t+1} \varpi_j^w \left(\frac{w_{t-j}}{W_t}\right)^{-\theta^w},$$

where ϖ_j^w is the share of household members that have set wages j periods before, $\varpi_j^w = (\alpha^w)^j(1-\alpha^w)$, $j = 0, 2, ..., t$, and $\varpi_{t+1}^w = (\alpha^w)^{t+1}$, which is the share of workers that have never set wages and charge the exogenous wage w_{-1}.

Commodities sector

Two tradable commodities, denoted by x and z, are used as inputs in the production of intermediate goods. The home economy, however, is able to produce only the commodity x; the commodity z must be imported. We denote by P_t^x and P_t^z the local currency prices of the commodities.

Total output of commodity x, denoted as X_t, is produced according to the technology

$$X_t = A_t \left(n_t^x\right)^{\rho}, \tag{18}$$

where n_t^x is labor, A_t is the level of productivity, and $0 < \rho \leq 1$. Implicit in this technology is the assumption of a fixed factor of production (when $\rho < 1$), which we broadly interpret as land.

Profit maximization implies

$$\rho P_t^x A_t (n_t^x)^{\rho-1} = W_t(1+\tau_t^p) \tag{19}$$

Because the two commodities can be freely traded, the law of one price holds:

$$\begin{aligned} P_t^x &= S_t P_t^{x*} \\ P_t^z &= S_t P_t^{z*}, \end{aligned} \tag{20}$$

where P_t^{x*} and P_t^{z*} denote the foreign currency prices of the x and z commodities.[5]

We can use (20) into (19) and obtain

$$\rho S_t P_t^{x*} A_t (n_t^x)^{\rho-1} = W_t(1+\tau_t^p)$$

which, given values for the exogenous shocks and given an allocation, restricts the feasible values for $\{S_t, W_t, \tau_t^p\}$.

Intermediate good firms

Each intermediate good $i \in (0,1)$ is produced by a monopolistic competitive firm which uses labor and the two tradable commodities with the technology

$$y_{it} = \bar{\eta} Z_t x_{it}^{\eta_1} z_{it}^{\eta_2} (n_{it}^y)^{\eta_3},$$

where x_{it} and z_{it} are the demand for commodities, n_{it}^y is labor, Z_t denotes the level of productivity, $\eta_j \geq 0$ for $j = 1,2,3$, $\sum_{j=1}^3 \eta_j = 1$, and $\bar{\eta} = \eta_1^{-\eta_1} \eta_2^{-\eta_2} \eta_3^{-\eta_3}$.

The associated nominal marginal cost function is common across intermediate good firms and given by

$$MC_t = \frac{(P_t^x)^{\eta_1} (P_t^z)^{\eta_2} W_t^{\eta_3} (1+\tau_t^p) \eta^{\eta_3}}{Z_t}.$$

Using (19) and (20), the nominal marginal cost can be written as $MC_t = S_t MC_t^*$, where MC_t^*, the marginal cost measured in foreign currency, is given by

$$MC_t^* = \frac{(P_t^{x*})^{1-\eta_2} (P_t^{z*})^{\eta_2} (\rho A_t (n_t^x)^{\rho-1} (1+\tau_t^p))^{\eta_3}}{Z_t}. \tag{21}$$

That is, the marginal cost in foreign currency depends on the international commodity prices, on technological factors, and on the equilibrium allocation of labor in the commodities sector.

In addition, cost minimization implies that final intermediate good firms choose the same ratio

[5] We could also allow for tariffs on the intermediate inputs. However, these tariffs are redundant instruments in this environment.

of inputs,

$$
\begin{aligned}
\frac{x_{it}}{n_{it}^{y}} &= \frac{\eta_1}{\eta_3}\rho A_t \left(n_t^x\right)^{\rho-1}\left(1+\tau_t^p\right) \\
\frac{z_{it}}{n_{it}^{y}} &= \frac{\eta_2}{\eta_3}\frac{P_t^{x*}}{P_t^{z*}}\rho A_t \left(n_t^x\right)^{\rho-1}\left(1+\tau_t^p\right) \quad \text{for all } i \in (0,1)\,,
\end{aligned}
\tag{22}
$$

where we have used (19) in the second equation.

Introducing (22) into the production function gives

$$
y_{it} = n_{it}^{y}\frac{Z_t}{\eta_3}\left(\rho A_t \left(n_t^x\right)^{\rho-1}\left(1+\tau_t^p\right)\right)^{1-\eta_3}\left(P_t^{x*}\right)^{\eta_2}\left(P_t^{z*}\right)^{-\eta_2}. \tag{23}
$$

Each monopolist $i \in (0,1)$ faces the downward-sloping demand curve (10). We follow the standard tradition in the New Keynesian literature and impose Calvo price rigidity. Namely, in each period, intermediate good firms are able to reoptimize nominal prices with a constant probability $0 < \alpha^p < 1$. Those that get the chance to set a new price will set it according to

$$
p_t^h = \frac{\theta}{\theta-1}E_t\sum_{j=0}^{\infty}\chi_{t,j}\frac{(P_{t+j}^x)^{\eta_1}(P_{t+j}^z)^{\eta_2}\left[W_{t+j}(1+\tau_{t+j}^p)\right]^{\eta_3}}{Z_{t+j}}, \tag{24}
$$

where

$$
\chi_{t,j} = \frac{\alpha^{pj}Q_{t,t+j}(P_{t+j}^h)^{\theta}Y_{t+j}^h}{E_t\sum_{j=0}^{\infty}\alpha^j Q_{t,t+j}(P_{t+j}^h)^{\theta}Y_{t+j}^h}. \tag{25}
$$

The price level in (11) can be written as

$$
P_t^h = \left[(1-\alpha^p)\left(p_t^h\right)^{1-\theta} + \alpha^p\left(P_{t-1}^h\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{26}
$$

Foreign sector and feasibility

We assume an isoelastic foreign demand for the home final good of the form

$$
C_t^{h*} = \left(K_t^*\right)^{\gamma}\left(P_t^{h*}\right)^{-\gamma}, \tag{27}
$$

where $\gamma > 1$, P_t^{h*} is the foreign currency price of the home final good, and K_t^* is a stochastic process that transforms units of foreign currency into domestic consumption goods.[6]

The government imposes a tax $(1+\tau_t^h)$ on final goods exported to the rest of the world and a tariff $(1+\tau_t^f)$ to final good imports. The law of one price on domestic and foreign final goods

[6] We allow for the final goods to be traded, so a particular case of our model (the one with $A = 0$ and $\eta_1 = \eta_2 = 0$) without commodities is the one typically analyzed in the small open economy New Keynesian literature.

then requires

$$\begin{aligned} P_t^h(1+\tau_t^h) &= S_t P_t^{h*} \\ P_t^f &= S_t P_t^{f*}(1+\tau_t^f), \end{aligned} \tag{28}$$

where P_t^{f*} is the foreign currency price of the foreign final good.

Net exports measured in foreign currency are given by

$$m_t^* = P_t^{h*}C_t^{h*} - P_t^{f*}C_t^f + P_t^{x*}\left[X_t - \int_0^1 x_{it}di\right] - P_t^{z*}\int_0^1 z_{it}di. \tag{29}$$

Thus, the net foreign assets of the country, denoted by $B_{t,t+1}^*$, evolve according to

$$B_{t-1,t}^* + m_t^* = E_t B_{t,t+1}^* Q_{t,t+1}^*. \tag{30}$$

Solving this equation from period 0 forward, and assuming zero initial foreign assets, gives the economy foreign sector feasibility constraint measured in foreign currency at time 0:

$$E_0 \sum_{t=0}^{\infty} Q_{0,t}^* m_t^* = 0. \tag{31}$$

In addition, market clearing in domestic final goods requires

$$Y_t^h = C_t^h + C_t^{h*} + G_t^h, \tag{32}$$

and labor market feasibility is given by

$$N_t = \int_0^1 n_{it}^y di + n_t^x. \tag{33}$$

Fiscal and monetary policies

We now show how a flexible exchange rate system, coupled with a flexible payroll tax can jointly stabilize domestic prices and wages. First, using the law of one price for the commodities,

$$\begin{aligned} P_t^x &= S_t P_t^{x*} \\ P_t^z &= S_t P_t^{z*}, \end{aligned}$$

we can write the cost minimization condition in the commodity sector (19) and the marginal cost for the intermediate good firm as

$$\rho S_t P_t^{x*} A_t \left(n_t^x\right)^{\rho-1} = W_t(1+\tau_t^p)$$

$$MC_t = S_t \frac{\left(P_t^{x*}\right)^{1-\eta_2} \left(P_t^{z*}\right)^{\eta_2} \left(\rho A_t \left(n_t^x\right)^{\rho-1}\right)^{\eta_3}}{Z_t}.$$

As domestic prices are proportional to marginal cost, they will be constant once marginal costs are constant, which implies

$$MC = S_t \frac{\left(P_t^{x*}\right)^{1-\eta_2} \left(P_t^{z*}\right)^{\eta_2} \left(\rho A_t \left(n_t^x\right)^{\rho-1}\right)^{\eta_3}}{Z_t},$$

so the nominal exchange rate moves to absorb productivity and commodity price shocks. Note that the negative correlation between the nominal exchange rate and the prices of the exportable commodity, presented in Figure 1, follows as a direct result of price stability. We can then use this implied equilibrium relationship to solve for the nominal exchange rate and use it on the cost minimization condition of the commodity sector to obtain

$$\rho^{1-\eta_3} MC \left(\frac{P_t^{x*}}{P_t^{z*}}\right)^{\eta_2} Z_t A_t \left(n_t^x\right)^{(\rho-1)(1-\eta_3)} = W_t(1+\tau_t^p)$$

So, to stabilize wages, the payroll tax must move according to

$$(1+\tau_t^p) = \frac{1}{W} \rho^{1-\eta_3} MC \left(\frac{P_t^{x*}}{P_t^{z*}}\right)^{\eta_2} Z_t A_t \left(n_t^x\right)^{(\rho-1)(1-\eta_3)}$$

Clearly, to the extent that fiscal policy cannot be jointly used with monetary policy, there is a trade off between eliminating the distortion in prices and the distortion in wages. The numerical analysis of that question is addressed in the next section.

3. NUMERICAL ANALYSIS OF MONETARY POLICY.

Before we start, it is important to clarify one issue. Insofar, we had been silent with respect to the implementation of particular equilibria through policy. Since the work of Sargent and Wallace (1975) , a vast literature developed that analyzed the problem of unique implementation using particular policy targets. A summary of that literature is that in general, when the Central Banks use money or the interest rate as the policy instrument, there is typically multiple equilibria consistent with a single policy rule. On the contrary, if the exchange rate is pegged, uniqueness typically arises. Multiple solutions had been offered, the most popular is, in the context of a interest rate rules, to only consider at bounded equilibria and assume rules that satisfy the Taylor principle. We fully abstain from the issue of implementation, and simple assume that policy can successfully target a nominal variable (or a combination of two of them) like prices of domestic goods, P^h, the nominal wage, W_t, or the nominal exchange rate, S_t.

In order to capture our interpretation of the recent Chilean experience, we consider a regime in which price stability is the main stated objective, but with some interventions to reduce the volatility of the nominal exchange rate (as the interventions in 2008 and 2011).

Note that from the solution for the marginal cost, we can write

$$MC_t = S_t MC_t^*,$$

where

$$MC_t^* = \frac{\left(P_t^{x*}\right)^{1-\eta_2} \left(P_t^{z*}\right)^{\eta_2} \left(\rho A_t \left(n_t^x\right)^{\rho-1}\right)^{\eta_3}}{Z_t}$$

Clearly, MC_t^* - the marginal cost in foreign currency - is a function of the underlying shocks. As we mentioned above, full price stability implies constant marginal costs in local currency so

$$S_t = \frac{MC}{MC_t^*}.$$

We then allow for a general rule, in which the deviations of the log of the nominal exchange rate adjust a fraction of the deviations in the log of the marginal costs in foreign currency, or

$$d \ln S_t = -\upsilon d \ln MC_t^*.$$

Thus, when $\upsilon = 1$, we have pure inflation targeting, when $\upsilon = 0$ we have a currency peg and by letting $\upsilon \in (0, 1)$ we can have all intermediate cases: the lower the value for υ, the lower the volatility of the nominal exchange rate and the large the volatility of domestic inflation.

With the policy rule so specified, the model can be solved numerically. We use the quadratic approximation methods developed by Schmitt-Grohe and Uribe (2004). We simulate the model shutting down all shocks but the commodity price P_t^{x*}. To chose the parameters of the stochastic process for this price, we use quarterly data to fit an autoregressive process. The resulting values are depicted in the following table, together with the rest of the parameters. We set the Calvo parameter for prices to be $\alpha^p = 0.5$, while for wages we use the value in Christiano, Eichenbaum and Rebelo (2011), $\alpha^p = 0.85$. Most of the other parameter values are relatively standard, and are the same ones used in Hevia and Nicolini (2013). Table 1 summarizes the parameter values used.

Results

In Figure 2 we plot impulse responses for total output, the real wage, the real exchange rate and total labor and its distributions across sectors following a one standard deviation positive shock to the price of the commodity. The volatility of commodity prices is very high, as Figure 1 makes clear. One standard deviation is estimated to be 13.5%, so this is a large shock. The impulse responses are plotted for different values of υ. Note that as we go from a currency peg $\upsilon = 0$ to a full inflation targeting regime $\upsilon = 1$, the reaction of the real wage is amplified, so the effects on total labor and output are less pronounced. It would appear, therefore, that a currency peg accentuates the rigidity of the wages.

Then, in Figure 3, we plot the welfare change, in units of consumption, of alternative policy rules, relative to $\upsilon = 0$, a currency peg. As the figure makes clear, welfare monotonically increases the closer the policy rule is to pure inflation targeting. And the gain from a pure inflation targeting regime, relative to a peg is 0.4% of lifetime consumption. These results imply that the joint presence of price and wage frictions do not justify departures from full inflation targeting.

Table X. Baseline parameters

Parameter	Description	Value
β	Discount factor (utility)	0.987
σ	Risk aversion (utility)	2
ς	Parameter leisure (utility)	1
ψ	Exponent leisure (utility)	2
ϕ	Ela. of subst. h and f (utility)	2
ϖ	Share foreign good (utility)	0.2
ρ	Share of labor in commodities	0.1
η_1	Share home commodity intermediates	0.1
η_2	Share foreign commodity intermediates	0.4
η_3	Share of labor intermediates	0.6
α^p	Calvo parameter intermediates	0.5
α^w	Calvo parameter wages	0.85
θ^p	Ela. subst. intermediate varieties	6
θ^w	Ela. subst. labor types	6
γ	Elasticity foreign demand home goods	1.5
K^*	Parameter foreign demand home goods	0.1
ν	Policy parameter	Varies across experiments
ρ^x	Coefficient on lagged value home commodity price	0.95
η^x	Standard deviation shock to commodity price	0.135

An alternative policy rule.

The policy trade off implied by the previous rule may reflect the one implied by dirty floating regimes, in which some intervention in foreign exchange markets is allowed. According to the theory, dampening the movements in the nominal exchange rate implies increasing the volatility of marginal costs and therefore of the price level. However, what seems a more natural trade off, given the nature of the two distortions, is stabilizing prices versus stabilizing nominal wages. In the theory section we showed how a payroll tax can be used together with the nominal exchange rate to stabilize both prices and wages. Once the payroll tax cannot be used, the nominal exchange rate can be used to stabilize either of them, but not both. Thus, let

$$w_t^h \equiv \frac{W_t}{P_t^h}$$

Then, we can define a policy where

$$d \ln W_t = \upsilon d \ln w_t^h.$$

Thus, if $\upsilon = 0$, nominal wages are fully stabilized, while $\upsilon = 1$ implies full price stability.

Figure 4 plots the impulse response functions to a one standard deviation (15%) positive shock to the price of the exportable. When nominal wages are stabilized - the wage rigidity is eliminated - the real wage responds more to the shock, so labor responds less and so does output. As we move towards more price stability (larger values of υ), the response of the real wage is lower, so the larger is the effect on total labor and output. Note, on the other hand, that the magnitude of the changes in the impulse responses as we vary policy is way smaller than in the case before (Figure 2).

Finally, the welfare effects are depicted in Figure 5, which shows that the best policy is full wage stability. Note however, that the effects are very small, less than 0.01% of total consumption between the best and the worst policy. What seems striking from the Figure, is the nonconvexity of the effects. Notice that the two corners are local optima (considering only the set $\upsilon \in [0, 1]$). For these parameter values, fully stabilizing wages dominates fully stabilizing prices.

The price and wage frictions impose two different distortions. First, the price frictions imply that the price index of final domestic goods does not move according to shocks, so the relative price between domestic final goods and foreign final goods will be distorted. Notice that wage frictions do not affect this margin, so stabilizing prices minimizes this distortion. Second, both frictions affect the real wage faced by households, so they distort the labor-consumption choice. There is a sense in which the two frictions (price and wages) affect the same margin, so the optimal policy would lean towards stabilizing the more rigid sector, in this case, the wages (recall that the Calvo parameter for wages $\alpha^w = 0.85$ is higher than for prices $\alpha^p = 0.5$). Of course, second best arguments imply that one cannot analyze each distortion separately, so the previous discussion is just to illustrate that the trade off is rather complex, so the solution is not obvious. To further emphasize this, in Figure 6 we reproduce the welfare computations for the same parameter values than in Figure 5, except that we increase the rigidity of prices to make it the same as the rigidity in wages, so $\alpha^w = \alpha^p = 0.85$. The results change: now, the worst policy is to stabilize wages and the best policy is very close to full price stability. Overall, however, the welfare effects of different policies is very small, on the same order of magnitudes that before: Less than 0.01% of total consumption.

CONCLUSIONS

From the point of view of theory, the presence of price and wage rigidity implies that full inflation targeting is not the optimal policy. In commodity-export countries, subject to very large changes in commodity prices that generate very large swings in the real exchange rate, this could be a serious concern and the question of real exchange rate stabilization becomes central in policy debates. In this paper, we showed that in a small open economy model that is able to reproduce the large swings on nominal and real exchange rates and that exhibits price and wage frictions, full inflation targeting comes out very robustly to be an approximate optimal policy. Our conclusion is drawn from two policy experiments: First, we analyze a policy rule that trades of price versus nominal exchange rate stability. The results strongly support the optimality of full price stability and free floating. In addition, the welfare effects are relatively important. The difference between a currency peg and full price stability is close to 0.45% of lifetime consumption. Second we study a policy that trades off price versus nominal wage stability. In this case, the optimal policy critically depends on parameter values. However, the welfare differences between alternative policies is tinny: Less than 0.01% of consumption.

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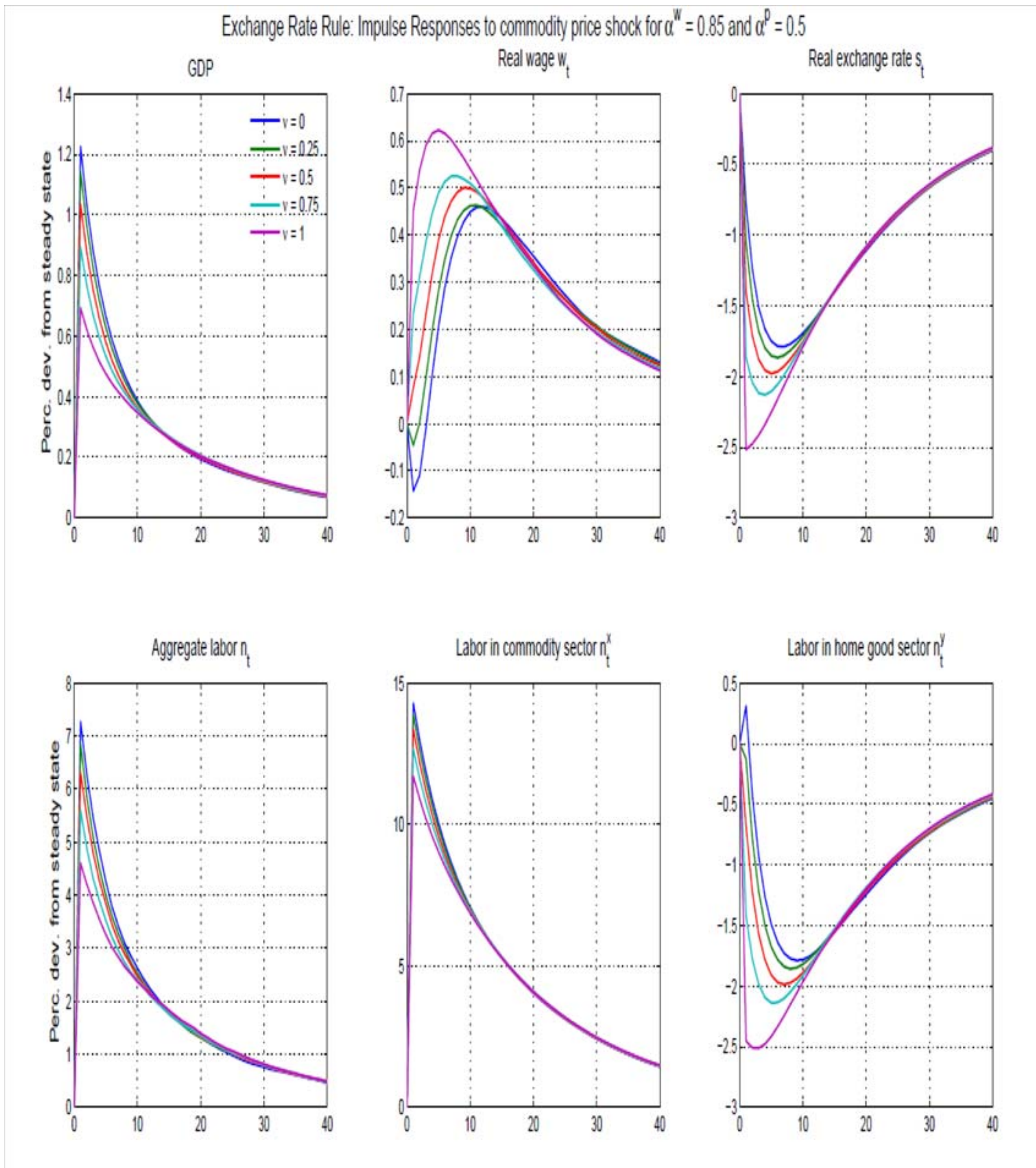
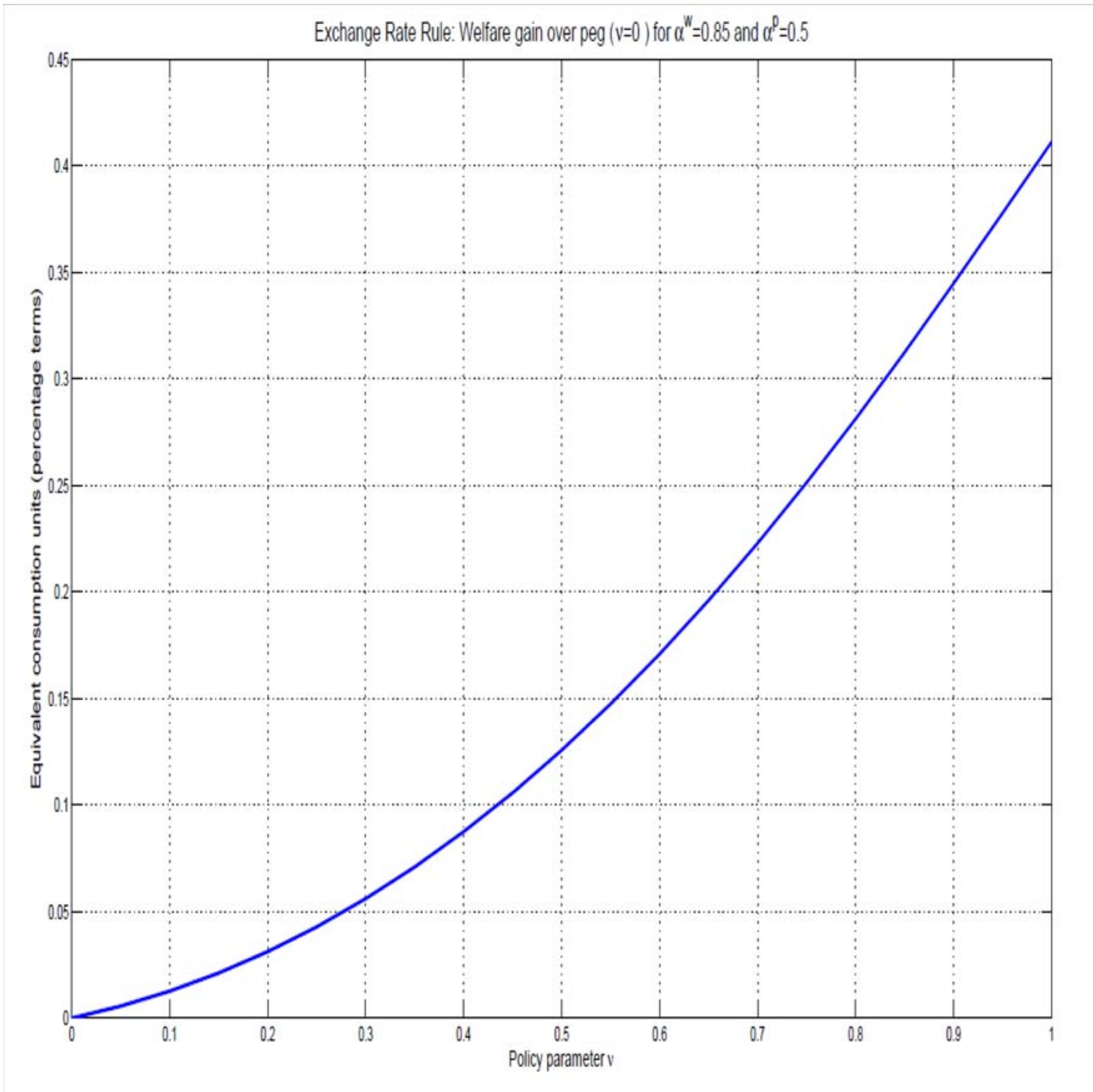
Figure 2



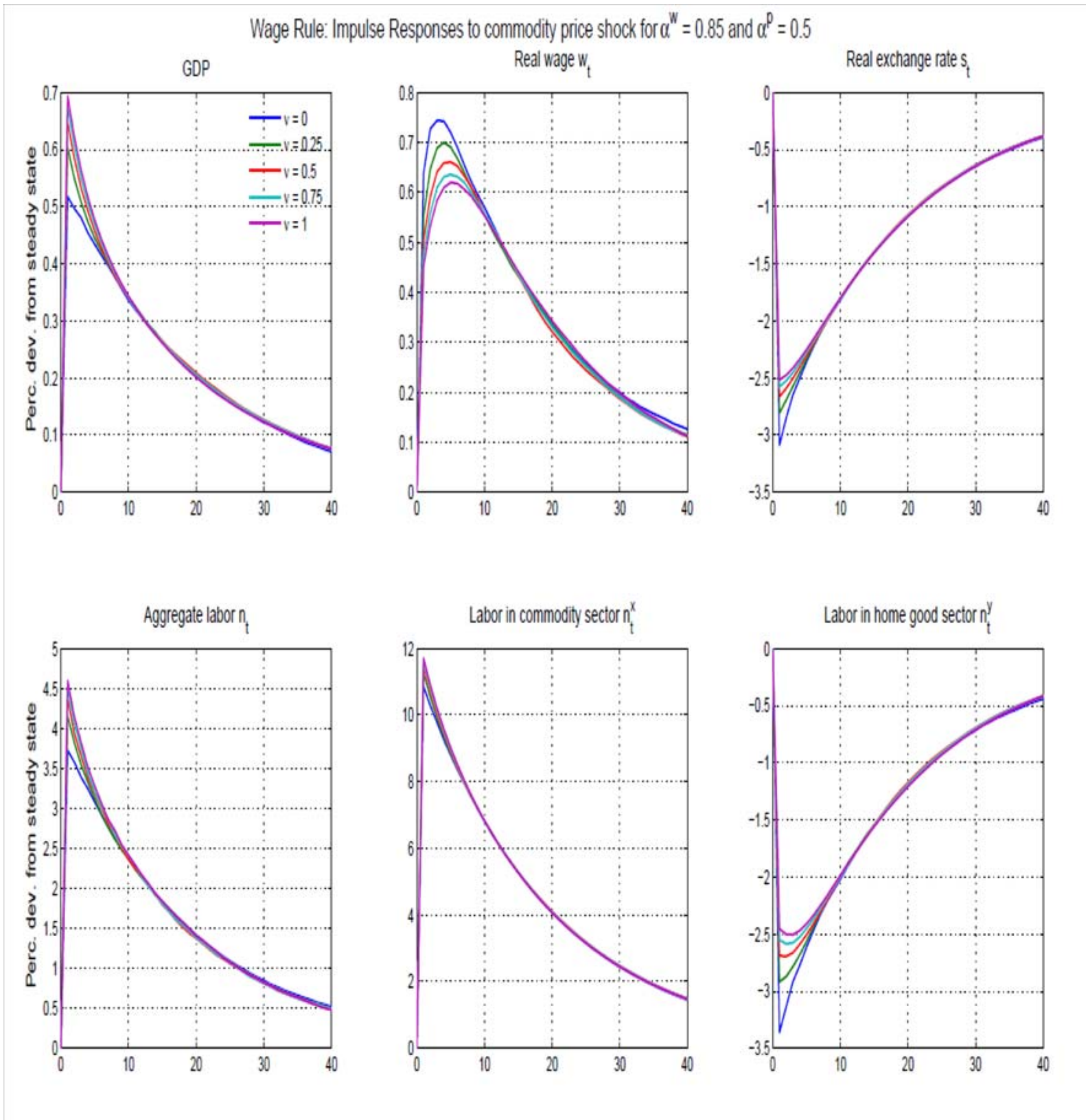
Exchange Rate Rule: Impulse Responses to commodity price shock for α^W = 0.85 and α^P = 0.5
GDP
Real wage w_t
Real exchange rate s_t
Aggregate labor n_t
Labor in commodity sector n_t^x
Labor in home good sector n_t^y
Perc. dev. from steady state
ν = 0
ν = 0.25
ν = 0.5
ν = 0.75
ν = 1

Figure 3



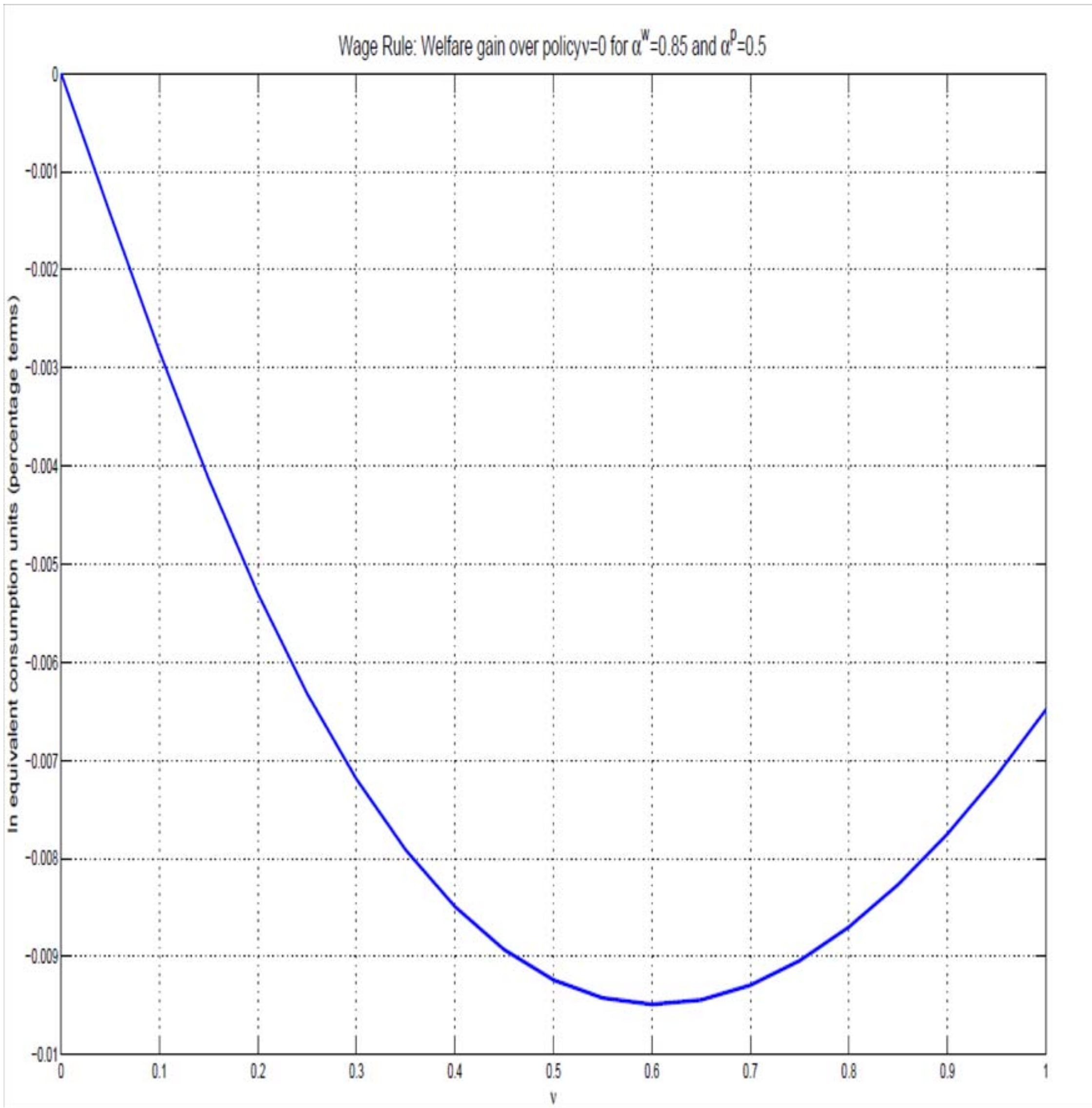
Exchange Rate Rule: Welfare gain over peg (v=0) for α^W=0.85 and α^P=0.5
Equivalent consumption units (percentage terms)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Policy parameter v

Figure 4



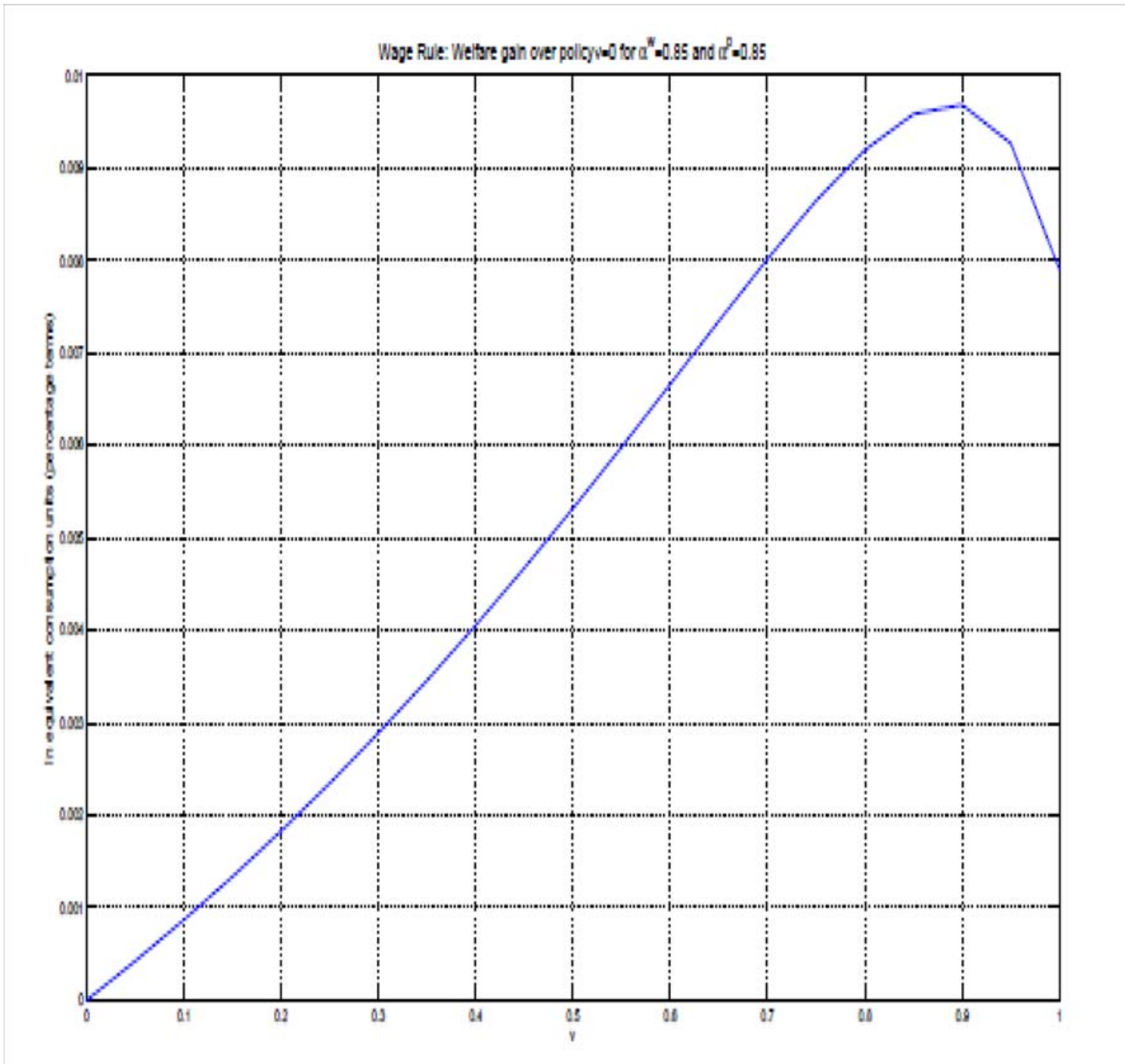
Wage Rule: Impulse Responses to commodity price shock for $\alpha^W = 0.85$ and $\alpha^P = 0.5$
GDP
Real wage w_t
Real exchange rate s_t
Aggregate labor n_t
Labor in commodity sector n_t^x
Labor in home good sector n_t^y
Perc. dev. from steady state
v = 0
v = 0.25
v = 0.5
v = 0.75
v = 1

Figure 5



Wage Rule: Welfare gain over policyv=0 for α^W=0.85 and α^P=0.5
In equivalent consumption units (percentage terms)
v
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.01
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 6



Wage Rule: Welfare gain over policy v=0 for α^W=0.85 and α^P=0.85
In equivalent consumption units (percentage terms)
v
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1