



# Natural-Resource Booms, Fiscal Rules and Welfare in a Small Open Economy

Jair N. Ojeda

Julián A. Parra-Polanía

Carmina O. Vargas

## ABSTRACT

This document analyzes the macroeconomic effects of a boom in a small-open economy's natural-resource sector. We study the effects of this shock on the most important macroeconomic variables, the resource reallocation across sectors and on welfare under alternative fiscal rules. We employ a DSGE featuring three productive sectors (non-tradable, manufacturing and commodity goods), government and two types of consumers (Ricardian and non-Ricardian).

Our results show that the natural-resource boom leads to an initial reduction of the manufacturing sector's employment and production. The opposite temporal effect is obtained in the remaining two productive sectors. However, the effect on welfare is positive for all consumers since the boom increases consumption in all households. Finally, we find that a countercyclical fiscal rule leads to a slight increase in welfare compared with a balanced-budget rule.

Keywords: Fiscal rule, Natural-Resource Boom, Consumer Welfare, Equilibrium Model

JEL Classification: E62; F47; H30; H63

The authors are Researchers at Banco de la República (Central Bank of Colombia). E-mails: [jojedajo@banrep.gov.co](mailto:jojedajo@banrep.gov.co); [jparrapo@banrep.gov.co](mailto:jparrapo@banrep.gov.co); [cvargari@banrep.gov.co](mailto:cvargari@banrep.gov.co).

January 2014. The authors wish to thank Ignacio Lozano, Luis F. Mejía, Hernán Rincón, Norberto Rodríguez, Hernando Vargas, Andrés Velasco and Juan P. Zárate for their useful comments and suggestions. All errors are the sole responsibility of the authors. The opinions expressed in this paper are those of the authors and not necessarily reflect the views of the Banco de la República nor its Board of Directors.

## 1. INTRODUCTION

Some time ago the Dutch disease literature brought attention to the fact that positive oil (price or productivity) shocks might cause a loss of competitiveness in the other tradable sectors. As a result, policy interventions may appear necessary and fiscal policy is seen as an important tool for stabilization of the economy and the management of higher income from exports.

In order to contribute to this analysis we explicitly model the energy sector and its interaction with the rest of the economy by setting up a dynamic stochastic general equilibrium (DSGE) model with three sectors (one non-tradable sector and two tradable ones, manufacturing and energy) plus government and two types of consumers according to their access to the financial market (Ricardians and Non-Ricardians) to analyze the effect of a positive oil productivity shock in a small open economy. The impact of this boom on the main macroeconomic variables (income, consumption, investment, real exchange rate, and others) and on the reallocation of resources between sectors is examined.

For the empirical part, the estimation of the model parameters is made by Bayesian methods using quarterly data of Colombian<sup>1</sup> main macroeconomic variables. Some parameters are not estimated, but instead fixed or calibrated in line with stylized facts of the Colombian economy and based on the relevant literature.

The paper also analyzes how macroeconomic variables react to the productivity shock when different fiscal policy rules are considered. In particular, we study four types of rules (with different degrees of pro- or counter-cyclicality) and the differences that these rules can generate on reallocation of resources and social welfare.

We find that the boom reduces the level of manufacturing production and leads to a transfer of resources from this sector to the other two sectors, common characteristics of what is known as the ‘Dutch disease’. However, the total effect on social welfare is positive due to the increase in the aggregate levels of households’ consumption and leisure.

Regarding the fiscal policy responses, it is concluded that there are no significant differences between rules with respect to the productivity shock’s final impact, neither on total welfare nor on the intensity of the Dutch disease. Furthermore, the Ricardian consumers experience higher welfare

---

<sup>1</sup> Colombia is a recent example of an energy-exporting country experiencing a boom in this sector. On the one hand, in 2011 more than 60% of Colombian exports corresponded to the mining-energy sector (mainly oil and coal). On the other hand, the average crude oil production in Colombia in March 2012 was approximately 951.000 barrels per day, that is, 7,2% above the production in the same month of 2011, which in turn was a 13% higher than the average production in 2010.

under a balanced-budget fiscal rule while the non-Ricardian consumers are better off under the most counter-cyclical one.

The document is divided into seven sections, this being the first. The following section presents a revision of the previous literature on Dutch disease and fiscal policy responses to mitigate the negative effects of that phenomenon. The third section describes the model and its equilibrium conditions. The fourth corresponds to the empirical estimation of the model parameters. The fifth section shows the analysis of the impulse-response functions of private consumption, production, external sector and fiscal variables. The welfare analysis is presented in the sixth section. The seventh section concludes.

## **2. LITERATURE REVIEW**

Income from natural resources have been both beneficial and problematic, a “curse” and a “blessing”. The empirical evidence suggests that either outcome is possible (van der Ploeg, 2011). Therefore, policymakers from countries with income from natural resources have faced serious concerns because of its potential effects on macroeconomic stability, the competitiveness of the export sector, and the external viability of the recipient countries. Institutional arrangements cannot be excluded from the analysis, as evidence shows that social norms, a social contract, transparency and rule of law may contribute to limiting rent seeking (Røed-Larsen, 2004). One of the pioneering works on studying the macroeconomic effects of a booming sector is Corden and Neary (1982) which is interested in the medium-run effects of asymmetric growth on resource allocation and income distribution.

Of particular interest to the present paper are models that look at the role that fiscal policy could play in managing that income. Most of those models seek to answer the question of what is the appropriate framework for fiscal policy in order to mitigate the potential costs of commodity price fluctuations, where the “appropriateness” is determined by its welfare effects. Pieschacón (2012) shows, by analyzing data for Mexico and Norway, that fiscal policy is a key transmission channel that affects the degree of exposure to oil shocks. She finds that fiscal policies that insulate the country from exogenous oil price shocks seem to be welfare improving over those that are pro-cyclical.

The Chilean economy has been an interesting case for this literature, since an important source of its income comes from copper production and exports, and the country have implemented a fiscal rule as part of the mechanisms to manage the income from copper. Various DSGE models have compared the effect of transitory copper-price shocks under different fiscal rules, like for example a

budget balance rule and a structural rule (see, among others, Medina and Soto (2007) and Garcia and Restrepo (2007)). In a model with New Keynesian features and with some Non-Ricardian (hand-to-mouth) households, Garcia et al. (2008) find that an acyclical fiscal rule benefits households that do not enjoy access to capital markets but reduces welfare for households that enjoy full access to capital markets. A fiscal policy in between a pro-cyclical balanced budget policy and an acyclical structural surplus may be preferred by all agents. See also Kumhof and Laxton (2010), De Gregorio and Labbe (2011), Engel et al. (2011).

Other works argue that the optimal fiscal policy of a country is conditioned by the country's access to world capital markets. Kuralbayeva (2011) shows that both public investment and public consumption are pro-cyclical in countries at all levels of development, but are more strongly so in developing countries. She shows that these empirical differences have a theoretical explanation in the framework of optimal fiscal policy given the country's conditions of access to world capital markets. Therefore, it is important to model financial frictions in deciding which fiscal rule would be welfare improving when managing income from natural resources.

The patterns of consumption and saving (both, public and private) out of income from natural resources seem to affect the degree of Dutch disease experienced by the country. In that sense, some papers have looked specifically at optimal consumption (and saving) patterns. In a model with learning by doing, Matsen and Torvik (2005) find that some Dutch disease is always optimal in the sense that a positive fraction of the resource wealth should be consumed in each period. Akram (2005) proposes a rule (efficient consumption rate) that would make the behavior of the real exchange rate mimic that of the real exchange rate in the absence of natural resources in order to reduce macroeconomic costs associated with the consumption of revenues from natural resources.

Developing economies, though, face the question not only of how much to save but also of what assets should be acquired. A strand of the literature argues that capital-scarce countries should prioritize domestic investment. In capital-scarce economies, investment within the country yields on average higher returns than foreign financial assets, allowing for faster growth of the domestic economy, (Collier et al., 2010). Similarly, van der Ploeg and Venables (2011) argue that in capital-scarce developing economies incremental consumption should be skewed towards present generations, and savings should be directed to accumulation of domestic private and public capital rather than foreign assets. They show that the optimal policy depends on the impact of distortionary taxation and the ability of consumers to borrow against future revenues.

Other literature have looked at the structure of production in the country experiencing a boom in natural resources to find out the conditions that would lead to, or help avoid, the Dutch disease.

Beverelli et al. (2011) show that when there are input-output linkages between the manufacturing sector and the natural resource sector the appreciation of the real exchange rate can be escaped if patterns of specialization shift towards the manufacturing industries that use oil more intensively. That is, a country experiencing discoveries of natural resources is not necessarily bound to experience the Dutch disease. The policy implication is that natural resource rich countries could escape from de-industrialization if part of the resources produced is consumed domestically as input in resource-intensive manufacturing industries.

Monetary policy has also been considered as a tool for managing income from natural resources. Benkhodja (2011) analyzes how monetary policy should be conducted to insulate the economy from the main impact of a boom in an oil-exporting country using a multisector DSGE model with nominal and real rigidities. In a related article, Lartey (2008) analyzes the impact of capital inflows to a small open economy with a discussion on the role and welfare effects of monetary policy.

In a small open economy model with nominal rigidities and a learning-by-doing externality in the tradable sector, Lama and Medina (2010) find that exchange rate intervention is a welfare-reducing policy to counteract the effects of the Dutch disease. In other model, Kuralbayeva and Vines (2008) analyze a small open economy with international capital mobility that experiences terms of trade and risk premium shocks. The improvement in the terms of trade leads to a decrease in the risk premium on lending and therefore an expansion of the capital-intensive traded sector, hence it leads to pro-industrialization even though there is appreciation of the real exchange rate.

In this paper, we propose a dynamic stochastic general equilibrium model based on Acosta, Lartey and Mandelman (2009) but including explicitly a productive energy sector that uses capital and labor in its production process. We follow Corden and Neary (1982) in assuming sector-specific capital accumulation. Also, as in their work, we focus the analysis on the effects of a productivity shock in the energy sector on the reallocation of inputs among sectors and on welfare. Furthermore, based on García et al. (2011), we include a fiscal sector with different reaction rules to the business cycle. We evaluate the efficacy of these rules for smoothing the effects of Dutch disease.

The model we propose in this paper has three major contributions to the literature: 1) it explicitly models the energy-good production, taking into account its input utilization, making the analysis of general equilibrium more realistic; 2) the parameters' calibration and Bayesian estimation render a more rigorous quantitative simulation and results; 3) this is the first paper that has a welfare analysis of a productivity shock in the energy sector under different fiscal rules and with the characteristics described in 1) and 2).

### 3. THE MODEL

The model consists of three types of agents: households, firms and government. The problem that each type faces is described in detail in this section. The model structure is based on Acosta et al. (2009), who propose a model with two sectors (non-tradable and tradable or manufacturing) to analyze the impact of remittances on a small open economy. This paper extends their model to include the energy sector, the government through the fiscal policy and to differentiate households according to their access to the financial market.

#### 3.1. Households

There is a continuum (of measure one) of identical households that, every period, decide their level of real consumption and work effort to offer in a perfectly competitive market. There are two types: Ricardians, who are a proportion  $z$  of households and Non-Ricardians, who are the rest,  $1-z$ . Ricardian agents ( $R$ ) have access to the financial market and therefore they also decide about the level of debt/savings (bonds) and their participation in firms (shares) for the next period. In contrast, Non-Ricardians ( $NR$ ) cannot save or borrow and their income is completely determined by their participation in the labor market. There is no other difference between Ricardians and Non-Ricardians in the model, apart from their access to financial markets.

The utility of each household, in period  $t$ , is represented by Cobb-Douglas preferences on the consumption index  $C_t$  and work effort  $L_t$ :

$$u(C_t^h, L_t^h) = \frac{[(C_t^h)^{(1-\omega)}(1 - L_t^h)^\omega]^{1-\gamma} - 1}{1 - \gamma}$$

where  $h = R, NR$ ,  $\omega \in [0,1]$  and  $\gamma > 0$ . The index of consumption  $C$  is a composite of non-tradable and tradable consumption,  $C_N^h$  and  $C_T^h$  respectively. In turn, tradable consumption is a composite of the consumption of domestic manufactured goods  $C_M^h$  and imported goods  $C_F^h$ .<sup>2</sup> It is assumed that the domestic production of energy goods is entirely exported and, therefore, domestic consumption of this type is zero.

---

<sup>2</sup> The total consumption index is  $C_t^h = \left[ (\gamma_c)^{\frac{1}{\rho_c}} (C_{N,t}^h)^{\frac{\rho_c-1}{\rho_c}} + (1 - \gamma_c)^{\frac{1}{\rho_c}} (C_{T,t}^h)^{\frac{\rho_c-1}{\rho_c}} \right]^{\frac{\rho_c}{\rho_c-1}}$  and the consumption of tradable goods index is  $C_{T,t}^h = \left[ (\gamma_m)^{\frac{1}{\rho_m}} (C_{M,t}^h)^{\frac{\rho_m-1}{\rho_m}} + (1 - \gamma_m)^{\frac{1}{\rho_m}} (C_{F,t}^h)^{\frac{\rho_m-1}{\rho_m}} \right]^{\frac{\rho_m}{\rho_m-1}}$ . The parameters  $\gamma_c$  and  $\gamma_m$  correspond to the share of non-tradable goods in total consumption and the participation of domestic goods in the consumption of tradable goods, respectively. The parameters  $\rho_c$  and  $\rho_m$  represent the corresponding elasticities of substitution.

Households maximize:

$$E_o \left\{ \sum_{t=0}^{\infty} \exp\left[\sum_{\tau=0}^{t-1} \beta_{\tau}\right] u(C_t^h, L_t^h) \right\} \quad (1)$$

where  $\beta_t = -\kappa \log(1 + C_t^{(1-\omega)}(1 - L_t)^{\omega})$  and, therefore, the intertemporal discount factor is modeled endogenously<sup>3</sup>. The endogenous discount factor has been used in previous works such as Mendoza (1991) and Acosta et al. (2009). Furthermore, it ensures that the model has a stable solution, as shown by Schmitt-Grohé and Uribe (2003).

The budget constraint for the Ricardian households is:

$$P_t C_t^R + v_{M,t} \chi_{M,t+1} + v_{E,t} \chi_{E,t+1} \leq (v_{M,t} + d_{M,t}) \chi_{M,t} + (v_{E,t} + d_{E,t}) \chi_{E,t} + w_t L_t^R - B_t + \frac{1}{1+r} B_{t+1} + Tr_t \quad (2)$$

where  $P_t$  is the consumer price index (which is a composite of the price of non-tradable goods  $P_{N,t}$  and the price of tradable goods  $P_{CT,t}$ <sup>4</sup>).  $\chi_{M,t+1}$  and  $\chi_{E,t+1}$  are the household's shares, purchased in  $t$ , in the firms' profits in manufacturing and energy sectors, respectively. The unit prices for such shares are  $v_{M,t}$  and  $v_{E,t}$  and their respective dividends are noted by  $d_{M,t}$  and  $d_{E,t}$ .  $w_t$  represents the wage, expressed in terms of the manufactured good. International financial transactions are made through one-period risk-free bonds ( $B_t$ ). The international interest rate is constant and equal to  $r$ .  $Tr_t$  corresponds to lump-sum transfers from the government to consumers (see section 3.3.).

The solution to the Ricardian consumer's problem yields the following first order conditions with respect to bonds  $B_{t+1}$ , shares  $\chi_{M,t+1}$  and  $\chi_{E,t+1}$ , labor supply  $L_t$  and consumption, respectively:

$$1 = \exp(\beta_t) E_t \left[ \frac{\lambda_{C,t+1}}{\lambda_{C,t}} (1+r) \frac{P_t}{P_{t+1}} \right] \quad (3)$$

$$v_{M,t} = \exp(\beta_t) E_t \left[ \frac{\lambda_{C,t+1}}{\lambda_{C,t}} (v_{M,t+1} + d_{M,t+1}) \frac{P_t}{P_{t+1}} \right] \quad (4)$$

$$v_{E,t} = \exp(\beta_t) E_t \left[ \frac{\lambda_{C,t+1}}{\lambda_{C,t}} (v_{E,t+1} + d_{E,t+1}) \frac{P_t}{P_{t+1}} \right] \quad (5)$$

<sup>3</sup> It is assumed that the discount rate depends on the average levels of consumption and work effort of the economy and, as a result, the household takes these values as given to maximize utility. These average levels are  $C_t = zC_t^R + (1-z)C_t^{NR}$  and  $L_t = zL_t^R + (1-z)L_t^{NR}$ . Other types of aggregate consumption are calculated in the same way (e.g.  $C_M$ ).

<sup>4</sup> The consumer price index is  $P_t = [(\gamma_c(P_{N,t})^{1-\rho_c} + (1-\gamma_c)(P_{CT,t})^{1-\rho_c})^{\frac{1}{1-\rho_c}}]$  and  $P_{CT,t} = [\gamma_m + (1-\gamma_m)(P_{F,t})^{1-\rho_m}]^{\frac{1}{1-\rho_m}}$ . The price of the manufactured good is used as the numeraire and  $P_{F,t}$  is the domestic price of imported goods.

$$\frac{\omega}{1-\omega} \frac{C_t^R}{(1-L_t^R)} = \frac{w_t}{P_t} \quad (6)$$

$$\frac{C_{N,t}^R}{C_{T,t}^R} = \frac{\gamma_c}{1-\gamma_c} \left( \frac{P_{N,t}}{P_{CT,t}} \right)^{-\rho_c}, \quad \frac{C_{M,t}^R}{C_{F,t}^R} = \frac{\gamma_m}{1-\gamma_m} \left( \frac{1}{P_{F,t}} \right)^{-\rho_m} \quad (7)$$

where the marginal utility of consumption is  $\lambda_{c,t} = (1-\omega)(C_t^R)^{(\gamma-1)(\omega-1)-1}(1-L_t^R)^{\omega(1-\gamma)}$ .  $P_{F,t}$  is the domestic price<sup>5</sup> of imported goods (consumption or investment) and the price of the domestic manufactured good is used as numeraire, and therefore is equal to one.

Since Non-Ricardian consumers do not have access to the financial market, their budget constraint is given by  $P_t C_t^{\text{NR}} = w_t L_t^{\text{NR}} + \text{Tr}_t$ . As a result, the first order conditions of their problem are similar to equations (6) and (7) but with the corresponding levels of Non-Ricardian consumption and labor.

### 3.2. Firms

The model has three sectors (non-tradable  $N$ , tradable manufacturing  $M$ , and tradable energy sector  $E$ ). Firms demand inputs (labor and capital) in perfectly competitive markets. We assume that firms in the non-tradable sector only need labor for production.

The accumulation of capital for sector  $j$ ,  $j = \{M, E\}$ , takes the form  $K_{j,t+1} - K_{j,t} = I_{j,t} - \delta_j K_{j,t}$  where  $K$  is capital,  $I$  the level of investment, and  $\delta$  the depreciation rate. It is also assumed that one unit of manufacturing good can be transformed into a unit of domestic investment good without incurring any cost. The capital of sector  $j$  is subject to installation costs  $\frac{\phi_j}{2} \left( \frac{I_{j,t}}{K_{j,t}} - \delta_j \right)^2 K_{j,t}$  which are proportional to the capital stock. Labor is perfectly mobile across sectors and, as a result, wages are the same for the entire economy. The total labor supply is the sum of the labor employed in each sector,  $L_t = L_{N,t} + L_{M,t} + L_{E,t}$ .

#### 3.2.1. Non-tradable Sector

Non-tradable firms use labor as the only input and their production function is  $Y_{N,t} = \exp(a_{N,t})L_{N,t}$ , where  $a_{N,t} = \bar{a}_N + \varrho_n a_{N,t-1} + \varepsilon_{n,t}$  is an exogenous stochastic process related to the sector productivity and  $\varepsilon_{n,t}$  is white noise. The sector has a tax rate  $\tau_n$  on the value of production. The profit maximization of this sector implies the following labor demand function:

---

<sup>5</sup> Since the analysis of the model is made in terms of real variables, for the sake of simplicity the value of the nominal exchange rate is normalized to one.

$$\frac{(1-\tau_n)Y_{N,t}}{L_{N,t}} = \frac{w_t}{P_{N,t}} \quad (8)$$

### 3.2.2. Tradable Manufacturing Sector

Manufacturing firms demand a composite  $I_M$  of a domestic investment good  $I_H$  and a foreign (imported) investment good  $I_{MF}$ <sup>6</sup>. Firms produce manufactured goods using a constant returns to scale technology:  $Y_{M,t} = \exp(a_{M,t})K_{M,t}^{\alpha_m}L_{M,t}^{1-\alpha_m}$ , where  $a_{M,t} = \bar{a}_M + \varrho_m a_{M,t-1} + \varepsilon_{m,t}$  is an exogenous stochastic process related to the sector productivity and  $\varepsilon_{m,t}$  is white noise. The sector has a tax rate  $\tau_m$  on the value of production. The firms of this sector maximize the value of dividends as defined in equation (9). In turn, the dividends each period are set as the difference between the value of production and costs, as it appears in equation (10).

$$E_t \sum_{s=t}^{\infty} \exp(\beta_s^{s-t}) \left( \frac{\lambda_{C,s} P_t}{\lambda_{C,t} P_s} \right) d_{M,s} \quad (9)$$

$$d_{M,s} = (1 - \tau_m)Y_{M,s} - P_{IM,s} \left( I_{M,s} + \frac{\phi_m}{2} \left( \frac{I_{M,s}}{K_{M,s}} - \delta_m \right)^2 K_{M,s} \right) - w_s L_{M,s} \quad (10)$$

$P_{IM}$  is the investment price index in the manufacturing sector<sup>7</sup>. The maximization of (9), taking (10) into account and subject to capital accumulation, yields the following first order conditions with respect to capital  $K_{M,t+1}$ , investment  $I_{M,t}$ , labor demand  $L_{M,t}$  and the investment composition:

$$E_t \exp(\beta_{t+1}) \left( \frac{\lambda_{C,t+1} P_t}{\lambda_{C,t} P_{t+1}} \right) \left[ P_{IM,t+1} \left( \phi_m \left( \frac{I_{M,t+1}}{K_{M,t+1}} - \delta_m \right) \frac{I_{M,t+1}}{K_{M,t+1}} - \frac{\phi_m}{2} \left( \frac{I_{M,t+1}}{K_{M,t+1}} - \delta_m \right)^2 \right) + \alpha_m \frac{(1-\tau_m)Y_{M,t+1}}{K_{M,t+1}} + \lambda_{IM,t+1}(1 - \delta_m) \right] = \lambda_{IM,t} \quad (11)$$

$$P_{IM,t} \left( 1 + \phi_m \left( \frac{I_{M,t}}{K_{M,t}} - \delta_m \right) \right) = \lambda_{IM,t} \quad (12)$$

$$(1 - \alpha_m)(1 - \tau_m) \frac{Y_{M,t}}{L_{M,t}} = w_t \quad (13)$$

---

<sup>6</sup> The composite investment good is  $I_{M,t} = \left[ (\gamma_i)^{\frac{1}{\rho_i}} (I_{H,t})^{\frac{\rho_i-1}{\rho_i}} + (1 - \gamma_i)^{\frac{1}{\rho_i}} (I_{MF,t})^{\frac{\rho_i-1}{\rho_i}} \right]^{\frac{\rho_i}{\rho_i-1}}$ . The parameter  $\gamma_i$  corresponds to the domestic investment goods share in the manufacturing sector investment. The parameter  $\rho_i$  represents the corresponding elasticity of substitution.

<sup>7</sup>  $P_{IM,t} = [\gamma_i + (1 - \gamma_i)(P_{F,t})^{1-\rho_i}]^{\frac{1}{1-\rho_i}}$ . As it was explained at the beginning of section 3.2, the manufacturing good can be transformed at no cost into a domestic investment good and, hence, the price of the latter is the same as the former (equal to one).

$$\frac{I_{H,t}}{I_{MF,t}} = \frac{\gamma_i}{1-\gamma_i} \left( \frac{1}{P_{F,t}} \right)^{-\rho_i} \quad (14)$$

The variable  $\lambda_{IE}$  represents the shadow price of a unit of capital in the manufacturing sector.

### 3.2.3. Tradable Energy Sector

It is assumed that in this sector all investment is imported ( $I_{E,t} = I_{EF,t}$ ). The energy good is produced using a constant returns to scale technology:  $Y_{E,t} = \exp(a_{E,t}) K_{E,t}^{\alpha_e} L_{E,t}^{1-\alpha_e}$ .  $a_{E,t} = \bar{a}_E + \varrho_e a_{E,t-1} + \varepsilon_{e,t}$  is an exogenous stochastic process, related to productivity, where  $\varepsilon_{e,t}$  is white noise. The entire domestic production of this sector is exported. The price of the energy good, measured in manufacturing goods, is noted as  $P_E$  and there is a tax rate  $\tau_e$  on the value of production. The firms in this sector also maximize the present value of dividends:

$$E_t \sum_{s=t}^{\infty} \exp(\beta_s^{s-t}) \left( \frac{\lambda_{C,t+1} P_t}{\lambda_{C,t} P_s} \right) d_{E,t} \quad (15)$$

$$d_{E,t} = (1 - \tau_e) P_{E,s} Y_{E,s} - P_{F,s} \left( I_{E,s} + \frac{\phi_e}{2} \left( \frac{I_{E,s}}{K_{E,s}} - \delta_e \right)^2 K_{E,s} \right) - w_s L_{E,s} \quad (16)$$

Similarly to the manufacturing sector, the maximization of (15) results in the following first order conditions with respect to capital  $K_{E,t+1}$ , investment  $I_{E,t}$ , labor demand  $L_{E,t}$  and the composition of investment:

$$E_t \exp(\beta_{t+1}) \left( \frac{\lambda_{C,t+1} P_t}{\lambda_{C,t} P_{t+1}} \right) \left[ P_{F,t+1} \left( \phi_e \left( \frac{I_{E,t+1}}{K_{E,t+1}} - \delta_e \right) \frac{I_{E,t+1}}{K_{E,t+1}} - \frac{\phi_e}{2} \left( \frac{I_{E,t+1}}{K_{E,t+1}} - \delta_e \right)^2 \right) \right. \\ \left. + \alpha_e P_{E,t+1} \frac{(1-\tau_e) Y_{E,t+1}}{K_{E,t+1}} + \lambda_{IE,t+1} (1 - \delta_e) \right] = \lambda_{IE,t} \quad (17)$$

$$P_{F,t} \left( 1 + \phi_e \left( \frac{I_{E,t}}{K_{E,t}} - \delta_e \right) \right) = \lambda_{IE,t} \quad (18)$$

$$(1 - \alpha_e)(1 - \tau_e) \frac{Y_{E,t}}{L_{E,t}} = \frac{w_t}{P_{E,t}} \quad (19)$$

The parameter  $\lambda_{IE}$  represents the shadow price of a unit of capital in the energy sector.

### 3.3. Fiscal Sector

The government obtains revenue ( $T$ ) from taxes ( $\tau_i$ ) on the value of production of the manufacturing, energy and non-tradable sectors:

$$T_t = \tau_m Y_{M,t} + \tau_n P_{N,t} Y_{N,t} + \tau_e P_{E,t} Y_{E,t}$$

The government uses this revenue to make lump-sum transfers ( $Tr$ ) to households without distinction between Ricardians and Non-Ricardians. The government's budget constraint for each period is given by:

$$B_{G,t} = B_{G,t-1}(1 + r) + Tr_t - T_t \quad (21)$$

where  $B_{G,t}$  is the government debt (if it is negative, then it corresponds to government credits) at the end of period  $t$ .

Following Garcia, et al. (2011), a general fiscal rule that may consider different degrees of counter-cyclicality can be written as:

$$Tr_t = \bar{T} - (1 + r + \mu)B_{G,t} + \varphi(T_t - \bar{T}) \quad (22)$$

Where  $\bar{T}$  denotes the government's steady-state revenue; that is, it does not contain any cyclical components.  $\mu$  is an adjustment factor for the debt's interest payments, which in general can be interpreted as the debt level target<sup>8</sup>. In turn,  $\varphi$  determines the level of counter- or pro-cyclicality of the government transfers.  $r$  is the international interest rate.

Then, with  $\varphi = 1$  and  $\mu = 0$ , this rule turns into a balanced budget constraint in which the government always transfers all of its revenue without incurring deficits or surpluses. In this case, the government acts pro-cyclically, reducing transfers (or raising taxes) during recessions and doing the opposite during expansions. With  $\varphi = 0$  and  $0 < \mu < (1 + r)^{-1}$ , the rule compares to an acyclical regime in which transfers are completely attached to the long-term level of revenue ( $\bar{T}$ ). In this rule, the government saves during expansions and benefits from borrowing opportunities during recessions. We can think of a continuum of intermediate rules in which  $-1 < \varphi < 1$  and  $0 < \mu < (1 + r)^{-1}$ , thus capturing different degrees of counter- or pro-cyclicality in transfers.

For this work, we consider four scenarios: balanced budget, an acyclical regime, a pro-cyclical scenario with  $\varphi = 0.5$  and a counter-cyclical scenario where  $\varphi = -0.5$ . In the last three cases, it is assumed that  $\mu = 0,01$ .

---

<sup>8</sup> This adjustment factor allows the government to accumulate assets (for precautionary purposes) that it could use at the time of recessions.

### 3.4 Aggregate Constraints and External Sector

The resource constraint in the manufacturing sector is given by  $Y_{M,t} = C_{M,t} + G_{M,t} + I_{M,t} + X_{M,t}$ . The exported component of the manufacturing sector is denoted by  $X_{M,t}$ . That is to say, domestic production of the manufacturing good is used for private consumption, government consumption, investment and exports. Following Acosta et al. (2009), we use the following notation for these exports:  $X_{M,t} = e_t^\xi Y_{F,t}$ . In this specification,  $\xi > 0$  is the elasticity of exports to the real exchange rate ( $e_t$ ), and  $Y_{F,t}$  is the aggregate output of the rest of the world. Furthermore, the exchange rate is given by the ratio of the price of the imported consumption basket to the consumer price index<sup>9</sup>  $e_t = \frac{P_{F,t}}{P_t}$ .

The non-tradable sector production is equivalent to the consumption of the same sector. In the energy sector, total production is exported. Aggregate output in units of manufacturing good is given by  $Y_t = Y_{M,t} + P_{N,t}Y_{N,t} + P_{E,t}Y_{E,t}$ . The current account is given by:

$$CA_t = -r(B_t + B_{G,t}) + X_{M,t} - P_{F,t}(C_{F,t} + I_{E,t} + I_{MF,t}) + P_{E,t}Y_{E,t} \quad (23)$$

## 4. BAYESIAN ESTIMATION AND CALIBRATION

Some parameters of the model are estimated by Bayesian methods. The popularity of these methods has been growing not only in macroeconomics but also in other disciplines. This technique uses a general-equilibrium approach that intends to solve the identification problems of reduced-form models and has the advantage of performing well in small-sample estimations<sup>10</sup>.

The estimations are made using quarterly data on total real GDP, real exchange rate, real non-tradable GDP and real mining GDP in Colombia from 1996Q1 to 2011Q3 (63 observations per series). The final series are expressed in logarithms and detrended using the Hodrick-Prescott filter.

The remaining parameters are fixed or calibrated.

### 4.1. Calibration

Some parameters are set following the estimations by Acosta et al. (2009) for El Salvador. Others are calibrated to match some stylized facts of the Colombian economy.

The international interest rate, in steady state, is fixed so that the quarterly rate satisfies  $(1 + \bar{r}) = 1/0.99$ . That is, in annual terms the real interest rate is approximately 4%. The value of  $\kappa$ , in the

<sup>9</sup> This is a real model. The consumer price index is then the value of the total consumption basket in terms of the numeraire, which is the domestic manufacturing good. See footnote 4.

<sup>10</sup> When compared to other techniques, for example, the Generalized Method of Moments and Maximum Likelihood methods.

intertemporal discount rate, is endogenously determined to be consistent with the value of  $\bar{r}$ . The weight of leisure in the utility function ( $\omega$ ) is set to 0.3.

The steady state value of employment in the manufacturing sector is normalized to  $L_{M,t} = 0.2$ . For the manufacturing sector we assume an annual rate of depreciation  $\delta_m = 3\%$ . For the energy sector the depreciation rate is endogenously determined to guarantee that the steady state real wage is equal across sectors. The elasticity of substitution between domestic goods and foreign investment is set to  $\rho_i = 0.2$ .

The parameter that measures the share of capital in the Cobb-Douglas production function is set to  $\alpha_m = 0.33$  for the manufacturing sector and to  $\alpha_e = 0.92$  for the energy sector. The latter is obtained from an official report about the Colombian fiscal rule (Banco de la Republica, Ministerio de Hacienda y Credito Publico and Departamento Nacional de Planeacion, 2010).

The installation cost of capital for the manufacturing sector ( $\phi_m$ ) is set to 2.2, following Acosta et al. (2009) and that of the energy sector ( $\phi_e$ ) is estimated (see the next subsection).

With reference to consumption, the participation of non-tradable goods in total consumption in steady state is fixed at  $\gamma_c = 0.5$ , the elasticity of substitution between tradable and non-tradable consumption at  $\rho_c = 0.4$  and the share of domestic goods in tradable consumption at  $\gamma_m = 0.4$ . The inverse of the intertemporal elasticity of substitution ( $\gamma$ ) is set to 2.0.

The proportion of Non-Ricardian agents in the economy ( $1 - z$ ) is set to 50%. The levels of public and private debt ( $B_G, B$ ) are assumed to be zero in steady state. The value of taxes ( $\tau_m, \tau_n, \tau_e$ ) on the production of the manufacturing, non-tradable and energy sectors is set to 20%, the effective tax rate in Colombia according to the estimation by Hamman et al. (2011).

#### 4.2. Estimation

The following twelve parameters are estimated by Bayesian methods:

- (Consumers) The elasticity of substitution between consumption of domestic and foreign tradable goods ( $\rho_m$ ).
- (Firms) The share of domestic investment in the total of manufacturing investment ( $\gamma_i$ ). Installation costs of capital for the energy sector ( $\phi_e$ ).
- (Exports) The elasticity of exports to the real exchange rate ( $\xi$ ).
- (Exogenous shocks) The persistence of the exogenous stochastic processes ( $\rho_e, \rho_m, \rho_n, \rho_f$ ) and the standard deviations of their respective error terms ( $\sigma_{\varepsilon_e}, \sigma_{\varepsilon_m}, \sigma_{\varepsilon_n}, \sigma_{\varepsilon_f}$ ).

The shapes of the prior distributions are chosen taking into account the parameters' domain. To set the means of these distributions, similar values are taken to those obtained by Acosta et al. (2009) and relatively large values of standard deviations are assumed so that the kurtosis of posterior distributions mainly depends on empirical data.

Table 1 presents the estimation results. The estimates obtained for the posterior means are used for model simulation and impulse-response analysis in the next section.

**TABLE 1**  
**Bayesian Estimation Results\***

Parameter	Distribution	Prior		Posterior – Confidence Interv.		
		Mean	St.Dev.	Mean	10%	90%
$\rho_m$	Gamma	0.50	0.30	0.73	0.49	0.94
$\gamma_i$	Beta	0.50	0.20	0.10	0.05	0.16
$\phi_e$	Gamma	2.20	0.80	2.45	2.10	2.80
$\xi$	Gamma	1.10	0.60	0.63	0.24	1.05
$\varrho_e$	Beta	0.80	0.10	0.97	0.97	0.98
$\varrho_m$	Beta	0.80	0.10	0.62	0.58	0.65
$\varrho_n$	Beta	0.80	0.10	0.96	0.94	0.99
$\varrho_f$	Beta	0.80	0.10	0.99	0.99	1.00
$\sigma_{\varepsilon_e}$	Inv. Gamma	0.05	$\infty$	0.07	0.05	0.09
$\sigma_{\varepsilon_m}$	Inv. Gamma	0.05	$\infty$	0.05	0.04	0.06
$\sigma_{\varepsilon_n}$	Inv. Gamma	0.05	$\infty$	0.03	0.03	0.04
$\sigma_{\varepsilon_f}$	Inv. Gamma	0.05	$\infty$	0.05	0.04	0.06

\*Results are based on 1.000.000 iterations of the Metropolis-Hastings algorithm.

Source: Authors' calculations

## 5. IMPULSE-RESPONSE RESULTS

Following Corden and Neary (1982), we simulate the effects of a productivity shock in the energy sector and interpret it as a boom in the same sector. Using the parameters estimated and calibrated above, we compute the implied impulse-response functions of all endogenous variables in the model. The figures in this section show responses of macroeconomic variables under a balanced-budget fiscal policy, unless stated otherwise. A common result in this exercise is that the qualitative response of these variables does not vary across fiscal-policy regimes.

We simulate a transitory shock on the stochastic component of the energy sector's productivity ( $a_{E,t}$ ). The size of this shock is of one estimated standard deviation (7.03%) and its estimated persistence is  $\varrho_e=0.97$ . Figure 1 shows the dynamic behavior of this shock.

[Fig. 1 goes here]

### **Effects on Employment**

The effect of the productivity shock on employment is positive in the non-tradable sector but it is negative in both energy and manufacturing. In the non-tradable sector, the initial impact is 2.7% and then gradually increases up to 7.5% about 40 quarters after the shock. The reason for this positive effect is the increased aggregate demand which is the result of the increased productivity in the energy sector.

The effect on both tradable sectors (energy and manufacturing) is negative. This effect consists of an initial negative impact which gets more pronounced until about 46 quarters later, when employment starts returning to its steady-state. The main difference between these tradable sectors is that the extent of employment deviation from the steady-state is more pronounced in the energy sector (-17.5%) than in the manufacturing sector (-16%). The reason for this effect is the substitution of labor by capital in both tradable sectors and the increased demand for non-tradable goods which leads to greater absorption of employment in this sector.

The effect on total employment is slightly negative (-0.8% deviation from steady-state) due to the negative effect of higher income on labor supply.

[Figure 2 goes here]

Figure 3 shows the effect of the shock on Ricardian consumers' total employment across alternative fiscal policy rules. After an initial hump-shaped effect, employment decreases and reaches a trough 51 quarters after the initial shock. This lowest point is more pronounced when the fiscal policy is counter-cyclical (-3.0%) than when it follows a balanced budget (-2.4%). In general, this negative effect on employment is the result of the higher unexpected income which increases the marginal utility of leisure at each point of time.

[Figure 3 goes here]

Figure 4 shows the effects of the shock on the employment of Non-Ricardian consumers. After a similar hump-shaped effect, employment increases gradually reaching a peak around 44 quarters after the shock. The effect on this maximum point is higher when the fiscal policy rule is counter-cyclical (1.3%) than under a balanced budget (0.7%). The reason for this result is that under more counter-cyclical rules, government's savings are higher and therefore Non-Ricardian workers need to work further hours in order to compensate for the associated decrease in transfers.

[Figure 4 goes here]

### **Effects on Capital Accumulation**

In Figure 5 it is clear that the capital stock in the energy sector increases gradually right after the productivity shock. This increase reaches a maximum of 22.3% with respect to the steady-state. This maximum takes place 17 quarters after the shock. After this peak, the capital stock starts returning gradually to its steady state.

Figure 5 also shows that the effect on the capital stock of the manufacturing sector is initially negative reaching a lower point (-10% of steady state) 7 quarters after the shock. This negative effect is the result of the presence of crowding-out from the accelerated accumulation of capital in the energy sector. 20 quarters after the shock the effect turns positive and starts increasing gradually until reaching, 39 quarters later, a high value of 19.8% of the steady state. This late positive effect is driven by the appreciation of the real exchange rate which allows increasing imports of capital goods.

[Fig. 5 goes here]

### **Effects on Output**

Figure 6 shows the effect of the productivity shock on total output and output by sectors. The energy boom has positive effects on non-tradable production due to the associated increase in aggregate income. This sector's output increase gradually during the first 40 quarters after the shock reaching a maximum of 7.5% of positive deviation from the steady state.

Output in the energy sector also increases but at a faster pace than the non-tradable sector due to its rapid capital accumulation. The maximum increase (24.3% with respect to the steady state) is reached 16 quarters after the shock. In contrast, manufacturing output decreases during the first 14 quarters after the shock reaching a maximum effect of -8.8% with respect to the steady state. The reason for this negative effect is the crowding-out of labor from this sector to the non-tradable sector (Figure 2) and the initial reduction of this sector's capital (Figure 5).

Summing up, the effect on total output is initially driven by the manufacturing sector since it is negative at first and reaches a trough (-2.9% ) just 9 quarters after the shock. 13 quarters later the effect turns positive and reaches a maximum point (5.4%) 60 quarters after the initial shock. This positive effect is mainly driven by the non-tradable sector and the late recovery of the manufacturing sector.

[Fig. 6 goes here]

### **Effects on Consumption**

Figure 7 shows that the dynamic effect on private consumption is positive in all sectors. The effect on consumption of manufactured goods is higher (17.5% on its peak) than on the consumption on non-tradables (7.5% on its peak). Therefore, the effect on total consumption is a weighted average of these two consumption sectors. The peak of these effects is located around 38 quarters after the initial shock. Notice that the implied increase in tradable consumption implies an important increase in manufactured imports since manufactured output decreases (Figure 6).

[Fig. 7 goes here]

Figure 8 shows the positive effect of the energy shock on consumption of Ricardian consumers. This effect is not very different across types of fiscal rules and reaches a peak 41 quarters after the shock. The maximum deviation from the steady state is 14.6 % under the counter-cyclical fiscal rule, slightly higher than in the case of a balanced-budget rule (14.1%).

[Fig. 8 goes here]

The analogous effect on Non-Ricardian consumers is shown in Figure 9. Although the effects are qualitatively similar across fiscal rules, it is evident that the more counter-cyclical the fiscal rule is, the smoother the effect is on consumption. Therefore, while under a balanced budget the effect reaches a peak increase of 9.4%, the same peak increment is 8.6% under the counter-cyclical rule. Notice that this effect is stronger for Ricardian consumers since they enjoy not only wage increases but also higher returns from firms' ownership.

[Figure 9 goes here]

### **Effects on real wages and the price level**

Figure 10 shows that the effect of the shock on real wages becomes positive 11 quarters after the shock. Then, 44 quarters later this effect reaches a peak of 11.5%. Notice that the impulse response on wages is qualitatively similar to the one for total output (Figure 6). Therefore, the initial negative effect on real wages is closely related to the initial decrease in total output in that figure.

The impulse-response on the price level shows an initial negative effect that reaches a lowest point of -10.3%, with respect to the steady-state, 11 quarters after the initial shock. This negative phase is closely related to the lower prices of tradable goods which result from the real exchange rate appreciation (Figure 11). The impulse-response of the price level becomes positive 41 quarters after

the initial shock and reaches a maximum point (3.9%) 36 quarters later. This positive phase is related to the positive effects of the shock on real wages as shown in Figure 10.

[Figure 10 goes here]

### **Effects on External-Sector Indicators**

In Figure 11, it is clear that the productivity shock has a negative effect on the real exchange rate, that is, the price of foreign goods decreases with respect to the price of domestic goods. The immediate effect on the real exchange rate is -8.0% under a fiscal policy with balanced budget. The real exchange rate gradually becomes more appreciated during 26 quarters when it reaches a lower point of -26.1%. Figure 11 also shows that this effect is very similar across fiscal policy rules. The reason of this negative effect on the real exchange rate is the significant increase of imports which are used for capital accumulation in the energy sector. The relative abundance of these goods in the economy leads to a decrease in their relative price.

[Figure 11 goes here]

Figure 12 shows the effect of the shock on the current-account balance. The initial effect is driven by the rapid appreciation of the real exchange rate (Figure 11), since it reduces the value of imports. These imports are composed of foreign goods for consumption and investment. The price of these imports, measured in domestic tradable goods, is reduced as the real exchange rate falls. However, real quantities are mainly driven by the optimal consumption and investment plans of consumers and firms, respectively. Therefore, the net effect on the value of imports is negative and thus the effect on the current account balance is positive.

[Figure 12 goes here]

The current account balance in Figure 12 starts with a surplus of around 8% of GDP. Then, this balance remains positive during 37 quarters, approximately. This deficit evolves slowly and becomes more prominent for more counter-cyclical fiscal rules. The reason for this result is the behavior of Non-Ricardian consumption which decreases more slowly for more counter-cyclical fiscal rules.

### **Effects on fiscal-sector variables**

Figure 13 shows that the effect of the shock on government income is very similar to the effect on total output (Figure 6). This effect is initially negative as consequence of the strong initial reduction

on manufacturing output and thus on the associated tax income. This effect becomes positive 22 quarters after the shock and increases gradually to reach a maximum effect (5.4%) 39 quarters later. Notice that this peak is only slightly lower (0.1%) under the more counter-cyclical fiscal rule.

[Fig. 13 goes here]

The effect of the shock on government debt is clearly different across fiscal rules (Figure 14). Under a balanced-budget rule, debt remains at zero during the whole duration of the shock. Under the remaining fiscal rules, there is a gradual accumulation of debt during the first 36 quarters after the shock. The government hires this debt in order to smooth the effect of the initial slowdown on economic activity (Figure 6) on consumption. After this debt is paid off, the government starts saving by accumulating international reserves. The purpose of these reserves is saving some of the increased income in order to have a higher level of consumption during later periods. Figure 14 also shows that both accumulations, debt and reserves, are more pronounced the more counter-cyclical the fiscal rule is.

[Fig. 14 goes here]

Figure 15 shows that the effect of the shock on government transfers is quite different across fiscal rules. Under a balanced-budget policy, transfers follow the behavior of government income (Figure 13). Under both the pro-cyclical and neutral rules, there is an initial period in which transfers decrease below their steady state and can be considered as a “saving” period. Soon, these transfers move up and remain above the steady state for a long “spending” period after the shock. Under the counter-cyclical fiscal rule, there is a short initial period (15 quarters) when transfers are above its steady-state value. Then a “saving” period starts and lasts 43 quarters. Only then, a quite long “spending” period starts 59 quarters after the shock.

[Figure 15 goes here]

## 6. WELFARE ANALYSIS

The energy boom in itself increases the welfare of both types of consumers when comparing to the steady state. This gain in welfare is calculated as the percentage of consumption that makes households indifferent between being in a steady-state economy or being in an economy that experiences a productivity shock in the energy sector. In steady state, the welfare of each household type is  $W_o^h$ , and it is determined by the values of steady-state consumption and labor. In an economy with boom, welfare is given by the optimal paths of consumption  $\{C_t^h\}_{t=0}^{\infty}$  and labor  $\{L_t^h\}_{t=0}^{\infty}$ . The size of compensated consumption is calculated then as the proportion  $\pi^h$  such that

$$W_o^h = E_0 \sum_{t=0}^{\infty} (\beta^t u(C_t^h(1 - \pi^h), L_t^h))$$

The proportion  $\pi^h$  is calculated from the solution to the equilibrium conditions of the model using a second-order approximation around the steady state, following the methodology by Schmitt-Grohé and Uribe (2004) and Kim, Kim, Schaumberg and Sims (2008). A constant discount rate is assumed to be equal to  $\beta=0.99$ .

TABLE 2

Fiscal Regime	$\pi$ (%)	
	Ricardians	Non-Ricardians
Budget balance (chi=1)	6.96	4.77
Pro-cyclical (chi=0.5)	6.92	4.81
Neutral or acyclical (chi=0)	6.89	4.86
Counter-cyclical (chi= -0.5)	6.85	4.90

Note: authors' calculations

Table 2 shows the results of the welfare calculations. The gain for both household types is significant, but there are no important changes in households' welfare from experiencing the productivity shock under one or other fiscal regime. In any case, the welfare gain from the shock is bigger for Ricardian households, since they have access to financial markets. Also, going from a balance-budget rule to a counter-cyclical rule decreases the welfare gain for Ricardians, but increases that of Non-Ricardians.

## 7. CONCLUSIONS

The present document analyzes the effects, on a small open economy, of a temporary raise in the energy sector productivity. For this purpose we use a DSGE model with three sectors (one service or non-tradable sector and two tradable sectors: a manufacturing sector and an energy sector) plus government and two types of consumers according to their access to the financial market (Ricardians and Non-Ricardians). The estimation of the model parameters is made by Bayesian methods using Colombian macroeconomic quarterly data for the period 1996-2011. Some parameters were not estimated, but instead were fixed or calibrated in line with stylized facts of the Colombian economy or based on the relevant literature.

The document also analyzes the implications of the productivity shock considering four different fiscal policy rules with different degrees of pro- or counter-cyclicality. The results suggest that a

temporary increase equivalent to one standard deviation (7%) in the energy sector productivity leads to a temporary fall in the manufacturing sector production (the initial impact is of about 5%) and a transfer of resources from this sector to the others, typical characteristics of the Dutch disease phenomenon. Nonetheless, given the increase of the aggregate consumption and leisure levels, the total effect on the social welfare is positive (in terms of compensated consumption, about 7% for Ricardians and 5% for Non-Ricardians).

With regard to the analysis of fiscal responses to the boom, no significant differences, neither in the intensity of the Dutch disease nor in social welfare, were found for the different policy rules. However, while Ricardian consumers experience higher welfare under a balanced-budget fiscal rule, Non-Ricardians experience higher welfare under the most counter-cyclical rule. This conclusion is consistent with the standard results found in the literature since Ricardian consumers can smooth the optimal consumption and labor paths themselves.

## **REFERENCES**

Acosta P.; Lartey E.; Mandelman F. “Remittances and the Dutch Disease”, *Journal of International Economics*, vol. 79, pp. 102-116, 2009.

Akram, Q. “Efficient Consumption of Revenues from Natural Resources. An Application to Norwegian Petroleum Revenues”, Working Paper, vol. 2005, No. 1, Norges Bank, 2005.

Banco de la República, Ministerio de Hacienda y Crédito Público, Departamento Nacional de Planeación. “Regla Fiscal para Colombia”, can be downloaded in the following link: <http://www.banrep.gov.co/es/node/24574>, 2010.

Benkhodja, M. “Monetary Policy and the Dutch Disease in a Small Open Oil Exporting Economy”, Working Paper, vol. 1134, Groupe d’Analyse et de Théorie Economique (GATE), Centre National de la Recherche Scientifique (CNRS), Université Lyon 2, École Normale Supérieure, 2011.

Beverelli C.; Dell’Erba, S.; Rocha, N. “Dutch Disease Revisited. Oil Discoveries and Movements of the Real Exchange Rate when Manufacturing is Resource-Intensive”, *International Economics and Economic Policy*, vol. 8, No. 2, pp. 139-153, 2011.

Collier, P.; van der Ploeg, R.; Spence, M.; Venables, A. “Managing Resource Revenues in Developing Economies”, *Staff Papers*, vol. 57, No. 1, IMF, 2010.

Corden W.; Neary, J. “Booming Sector and De-Industrialisation in a Small Open Economy”, *The Economic Journal*, vol. 92, pp. 825-848, 1982.

De Gregorio, J.; Labbe, F. “Copper, the Real Exchange Rate and Macroeconomic Fluctuations in Chile”, Working Paper, No. 640, Banco Central de Chile, 2011.

Engel, E.; Neilson, C.; Valdes, R. “Chile’s Fiscal Rule as Social Insurance”, Working Paper, No. 627, Banco Central de Chile, 2011.

García, C.; Restrepo, J. “The Case for a Countercyclical Rule-based Fiscal Regime”, Working Paper, No. 183, Ilades-Georgetown University, 2007.

García, C., Restrepo, J.; Tanner, E. “Designing Fiscal Rules for Commodity Exporters”, Working Paper, 199, Ilades-Georgetown University, 2008.

García, C.; Restrepo J.; Tanner; E. “Fiscal rules in a Volatile World: A Welfare-Based Approach”, *Journal of Policy Modeling*, vol. 33, No. 4, pp. 649-676, 2011.

Hamann, F.; Lozano, I.; Mejía, L. F. “Sobre el impacto macroeconómico de los beneficios tributarios al capital”, *Borradores de Economía*, No. 668, Banco de la República, 2011.

Kim, J.; Kim, S.; Schaumberg, E.; Sims, C. “Calculating and Using Second Order Accurate Solutions for Discrete Time Dynamic Equilibrium Models”, *Journal of Economic Dynamics and Control*, vol. 32, pp. 3397-3414, 2008.

Kumhof, M.; Laxton, D. “Chile’s Structural Fiscal Surplus Rule: A Model-Based Evaluation”, *Journal Economía Chilena*, vol. 13, No. 3, pp. 5-32, 2010.

Kuralbayeva, K. “Fiscal Policy Adjustment to Shocks in Commodity-Producing Countries”, *OxCarre Working Papers*, vol. 60, University of Oxford, Oxford Centre for the Analysis of Resource Rich Economies, 2011.

Kuralbayeva, K.; Vines, D. “Shocks to Terms of Trade and Risk-Premium in an Inter-temporal Model: The Dutch Disease and a Dutch Party”, *Open Economies Review*, vol. 19, No. 3, pp. 277-303, 2008.

Lama, R.; Medina, J. “Is Exchange Rate Stabilization an Appropriate Cure for the Dutch Disease?”, Working Paper, vol. 10, No. 182, IMF, 2010.

Lartey, E. "Capital Inflows, Dutch Disease Effects and Monetary Policy in a Small Open Economy", *Review of International Economics*, vol. 16, No. 5, pp. 971-989, 2008.

Matsen, E.; Torvik, R. "Optimal Dutch Disease", *Journal of Development Economics*, vol. 78, No. 2, pp. 494-515, 2005.

Medina J. P.; Soto, C. "Copper Price, Fiscal Policy and Business Cycle in Chile", Working Paper, No. 458, Banco Central de Chile, 2007.

Mendoza E. "Real Business Cycles in Small Open Economies", *American Economic Review*, vol. 81, pp. 797-818, 1991.

Pieschacón, A. "The Value of Fiscal Discipline for Oil-Exporting Countries", *Journal of Monetary Economics*, vol. 59, pp. 250-268, 2012.

Røed-Larsen, E. "Escaping the Resource Curse and the Dutch Disease? When and Why Norway Caught up with and Forged Ahead of Its Neighbors", *Discussion Papers*, vol. 377, Research Department of Statistics Norway, 2004.

Schmitt-Grohé, S.; Uribe, M. "Closing Small Open Economy Models", *Journal of International Economics*, vol. 61, pp. 163-185, 2003.

Schmitt-Grohé, S.; Uribe, M. "Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function", *Journal of Economic Dynamics and Control*, vol. 28, pp. 755-775, 2004.

Van der Ploeg, F. "Natural Resources: Curse or Blessing?", *Journal of Economic Literature*, vol. 49, No. 2, pp. 366-420, 2011.

Van der Ploeg F.; Venables, A. "Harnessing Windfall Revenues: Optimal Policies for Resource-Rich Developing Economies", *The Economic Journal*, vol. 121, pp. 1-30, 2011.

## FIGURES

Figure 1: Productivity shock in the energy sector: percent deviations from steady state

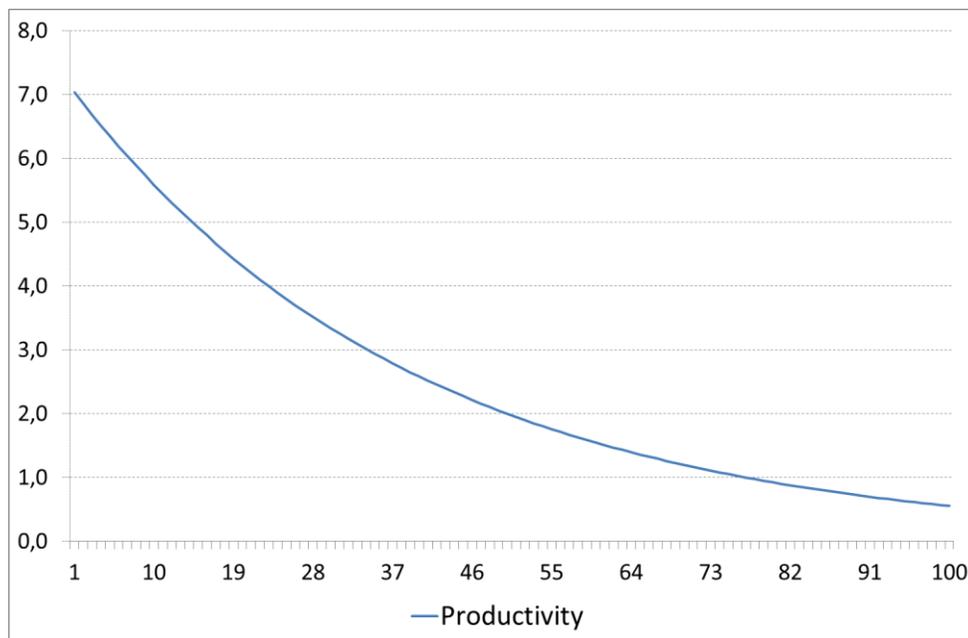


Figure 2: Effects on employment by sector: Percent deviations from steady state

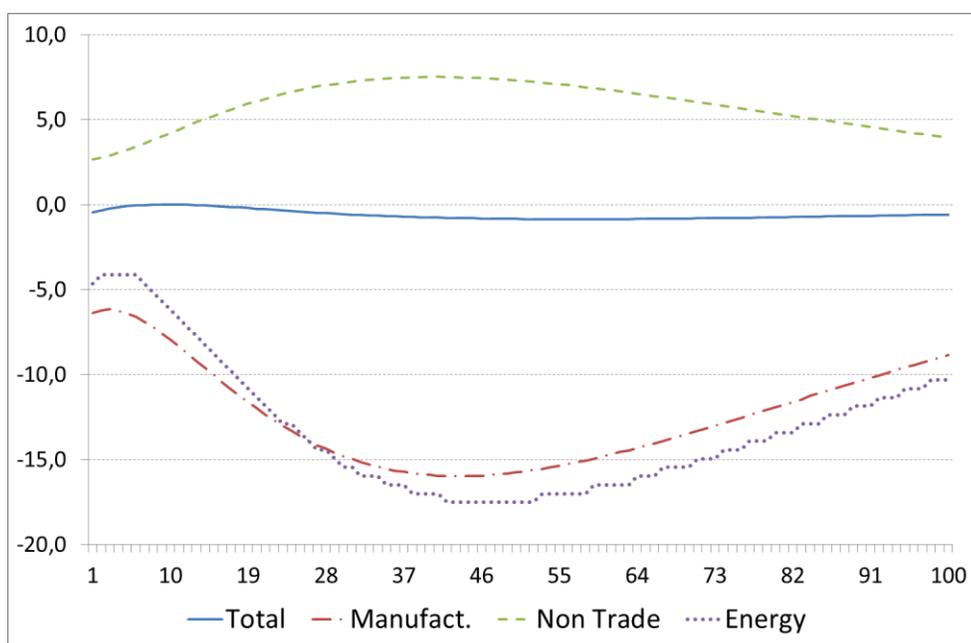


Figure 3: Effects on Ricardian consumers' employment: Percent deviations from steady state under each fiscal policy rule

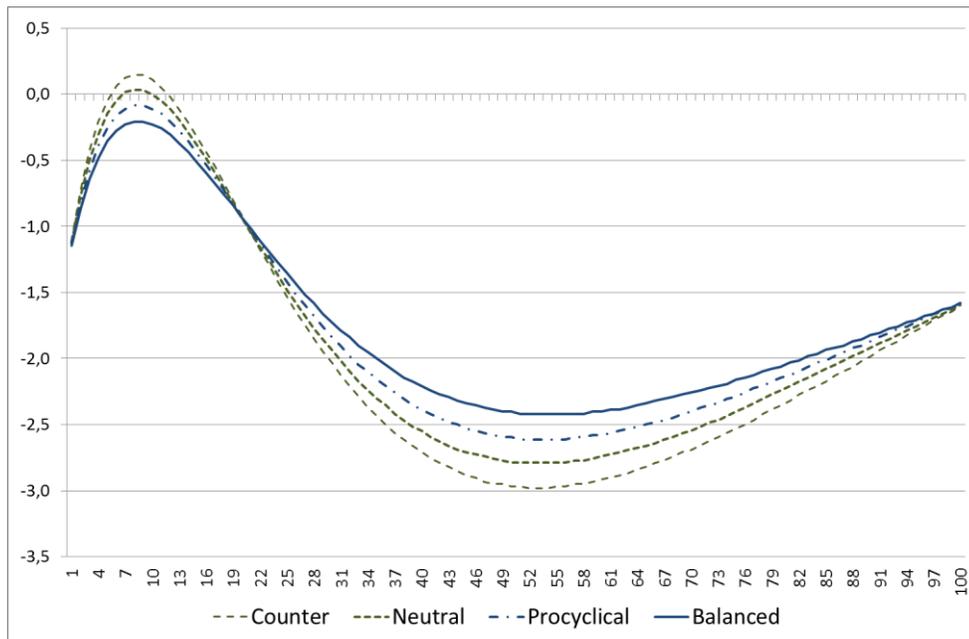


Figure 4: Effects on Non-Ricardian consumers' employment: Percent deviations from steady state under each fiscal policy rule

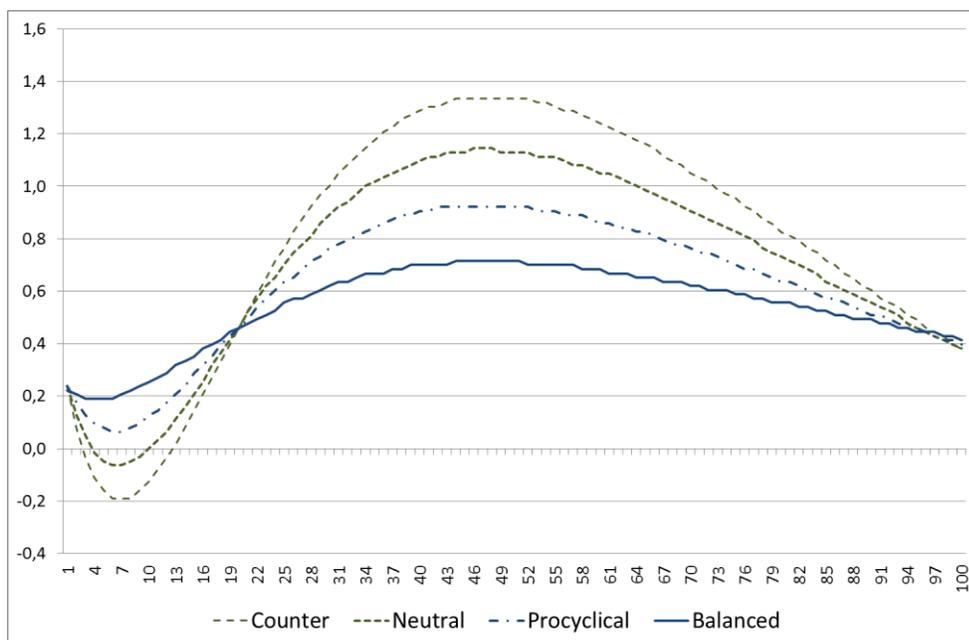


Figure 5: Effects on capital accumulation by sector: Percent deviations from steady state

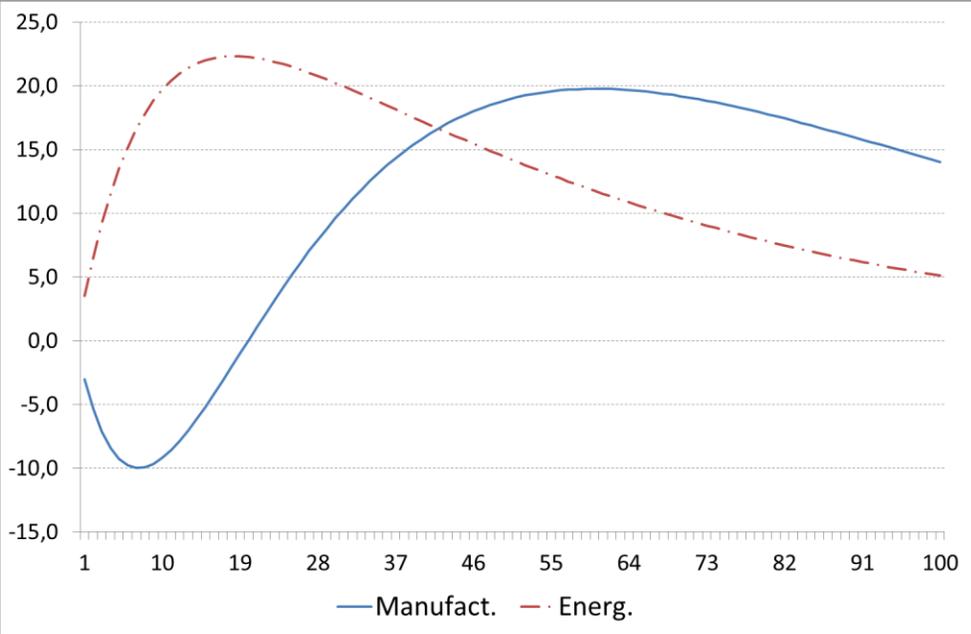


Figure 6: Effects on output by sector: Percent deviations from steady state

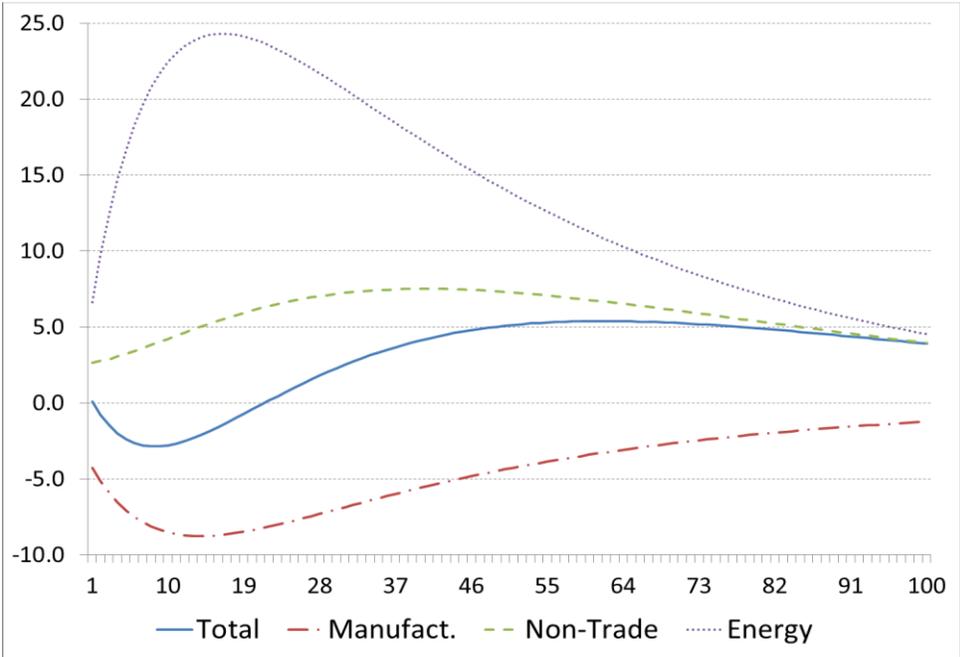


Figure 7: Effects on Private Consumption by sector: Percent deviations from steady state

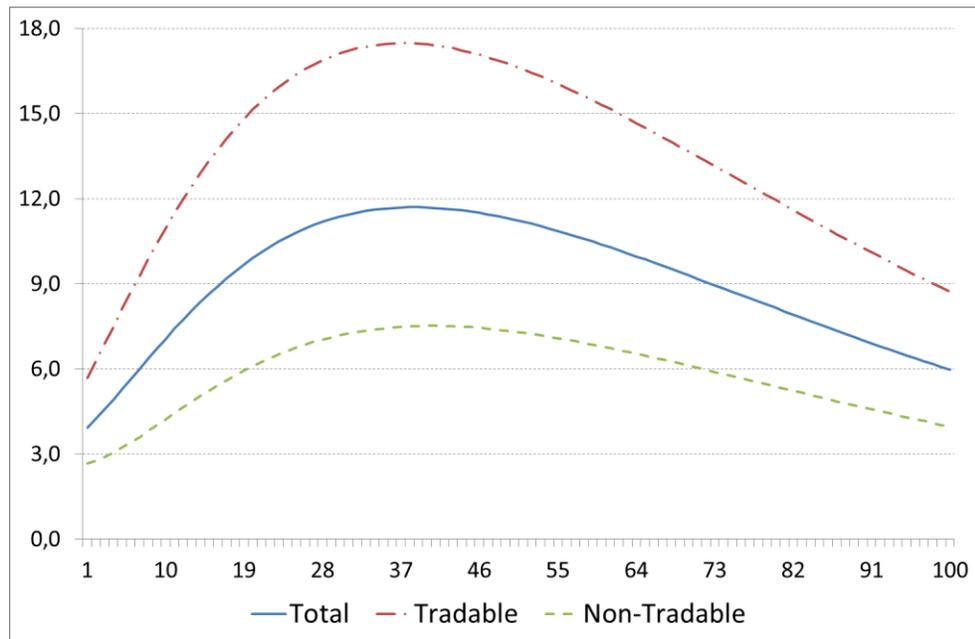


Figure 8: Effects on Ricardian consumption: Percent deviations from steady state under each fiscal policy rule

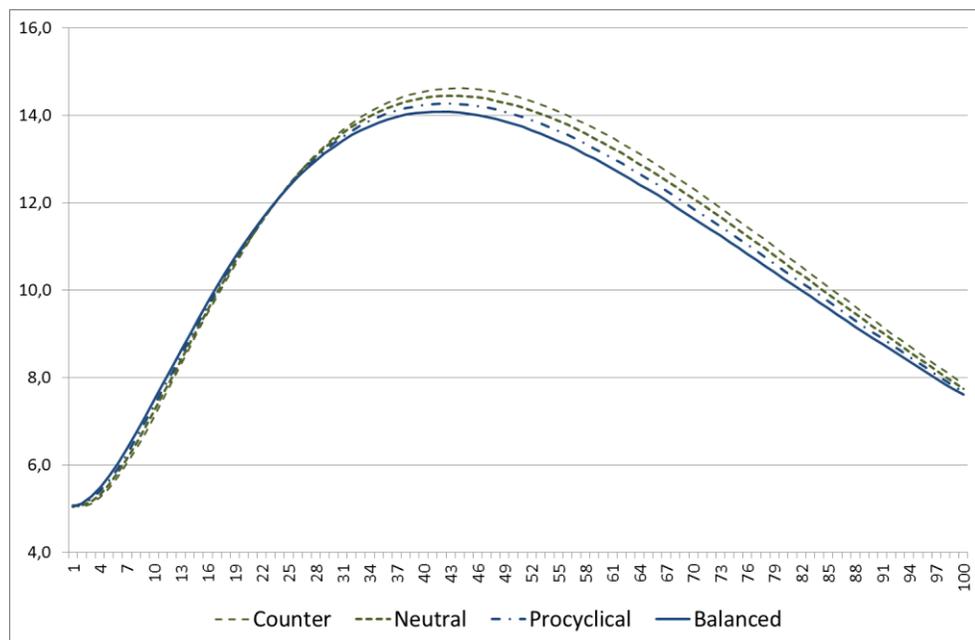


Figure 9: Effects on Non-Ricardian consumption: Percent deviations from steady state under each fiscal policy rule

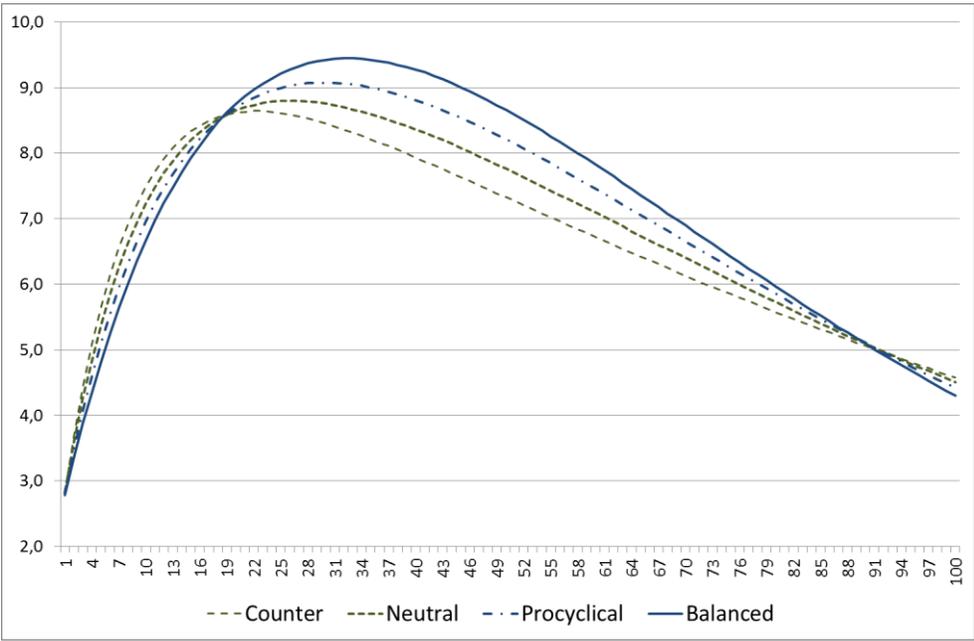


Figure 10: Effects on real wages and the consumer price level: Percent deviations from steady state



Figure 11: Effects on the real exchange rate: Percent deviations from steady state under each fiscal policy rule

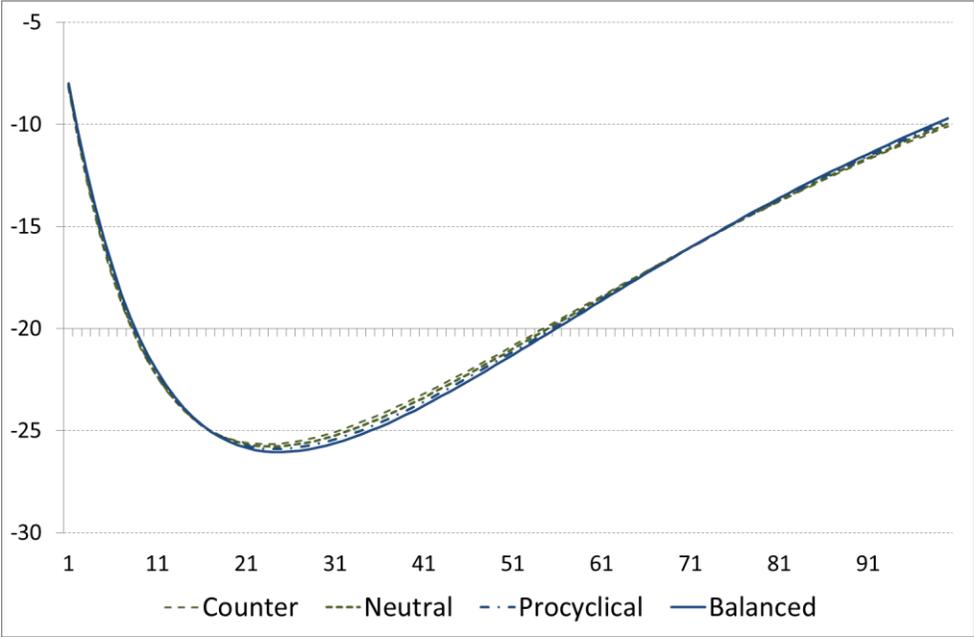


Figure 12: Effects on the current account balance: Percent deviations from the GDP, at its steady state, under each fiscal policy rule

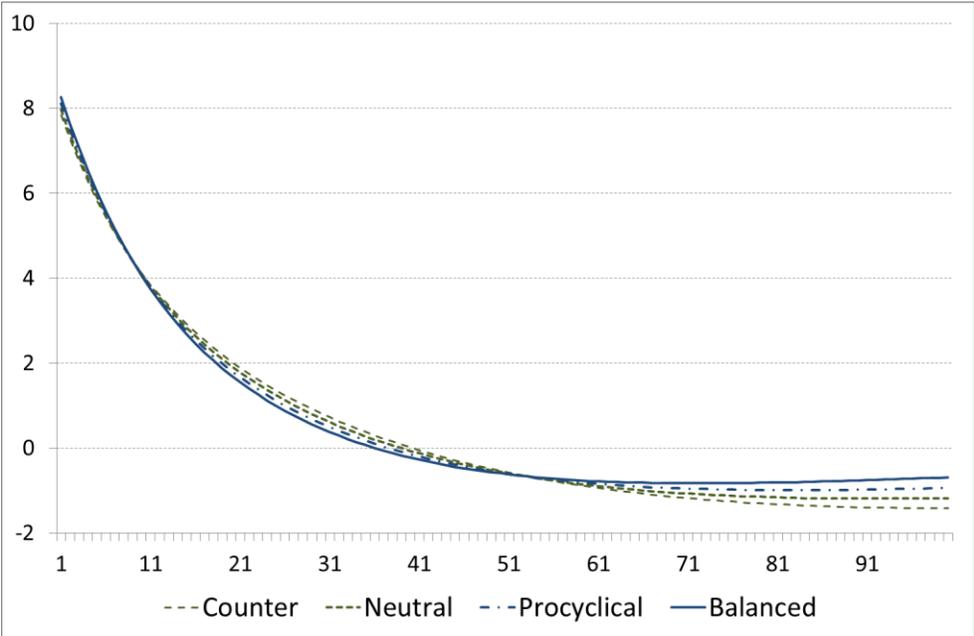


Figure 13: Effects on government income: Percent deviations from steady state under each fiscal policy rule

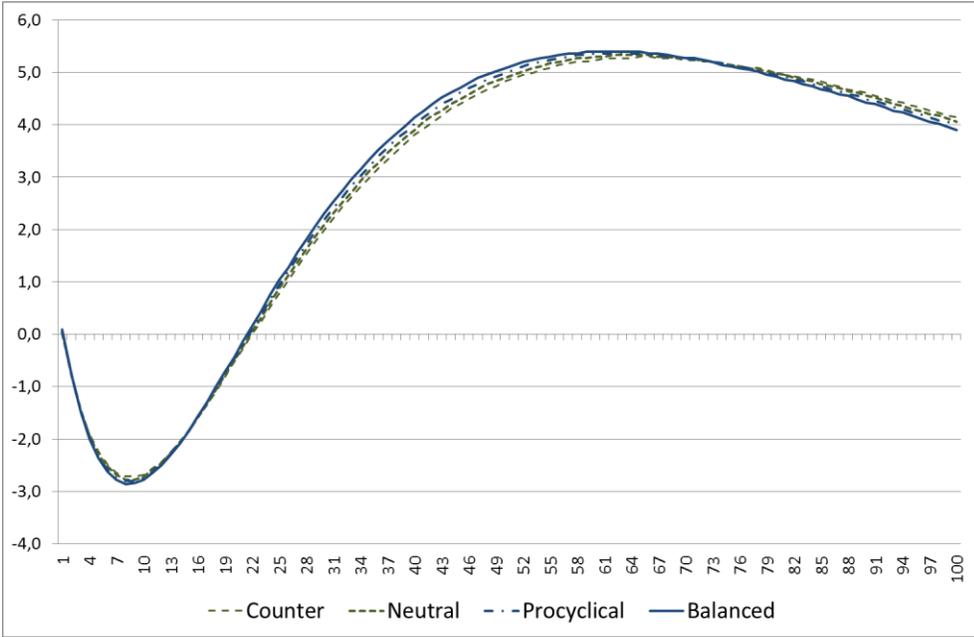


Figure 14: Effects on government debt: Percent deviations from the GDP, at its steady state, under each fiscal policy rule

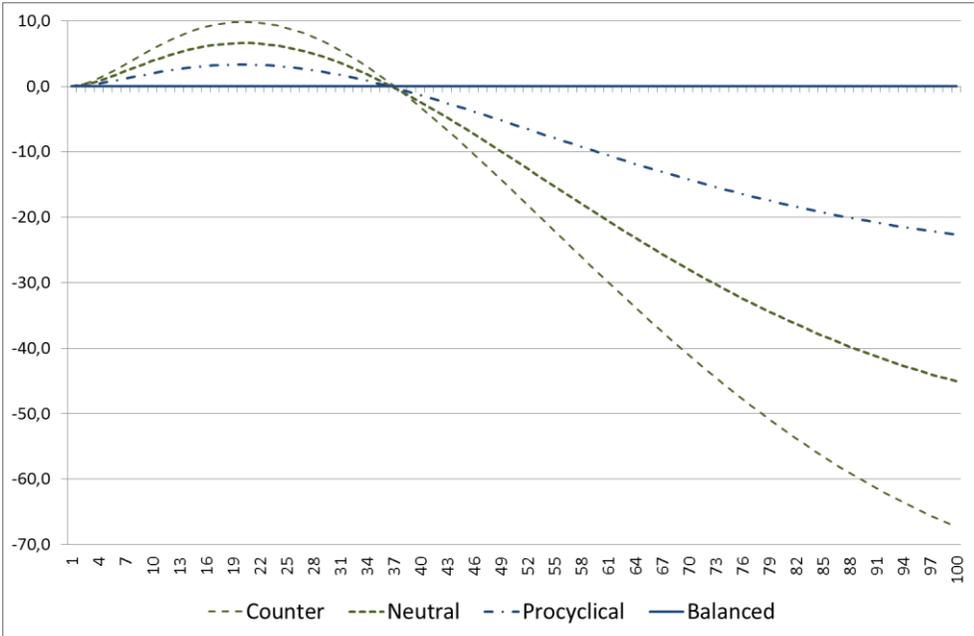


Figure 15: Effects on government transfers: Percent deviations from steady state under each fiscal policy rule

