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Fiscal Rules for Resource Windfall Allocation: The Case of Trinidad and Tobago

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Abstract

Managing resource revenues is a critical policy issue for small open resource-rich countries. This paper uses an open economy dynamic stochastic general equilibrium model to analyze the transmission of resource price shocks and a shock to resource production in the Trinidad and Tobago economy. It also applies alternative fiscal rules to determine the optimal allocation of resource windfalls between spending today and saving in a sovereign wealth fund. The results show that spending all the resource windfall on consumption and investment creates more volatility and amplifies Dutch disease effects, when compared to the case where all the excess revenues are saved. Also, neither a policy of full spending nor full saving of the surplus revenue inflows is optimal if the government is concerned about both household welfare and fiscal stability. In order to minimize deviations from both objectives, the optimal fiscal response suggests that a larger fraction of the resource windfalls should be saved.

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I. Introduction

A key issue facing policymakers in resource-rich developing countries is the prudent management of natural resource wealth. Resource revenue is difficult to manage due to highly volatile commodity prices and production discoveries. This volatility leads to increased revenue fluctuations and overall macroeconomic instability as it creates boom-bust cycles in natural resource-rich countries (Asik (2013)). Revenue volatility is the key reason why fiscal policy has been procyclical in some resource-abundant countries, such as Trinidad and Tobago (see Artana et al. (2007), International Monetary Fund (2012a) and Céspedes and Velasco (2014)).[1] Also, the exhaustibility of non-renewable resources poses uncertainty about future income and complicates fiscal planning. This raises concern about how living standards are maintained once resources are depleted. The exhaustibility and volatility of natural resource revenue therefore pose great challenge to policymakers and raise concern about how much of the resource wealth to consume or save.

There are different views on the management of natural resource revenues. The *Permanent Income Hypothesis* (PIH) approach recommends that a resource-rich country should sustain a constant flow of consumption that is equal to the implicit return on the present value of future resource revenue (International Monetary Fund (2012a)). Another approach, the *Bird-in-Hand* policy, suggests that resource revenue should be used to accumulate financial assets in a sovereign wealth fund, and only the interest accrued from these assets should be spent. Also, it has been argued that because citizens own the resources, the resource rents should be transferred to them in the form of direct transfer programmes or conditional cash transfer schemes (Gelb and Grasmann (2010)).[2] Furthermore, Takizawa et al. (2004) examined the *Hand-to-Mouth* rule, which posits that countries can be better off spending all their resource wealth upfront if the initial capital stock is low. Other studies have noted that resource revenue should be saved in the form of government financial assets, which can then be used to make domestic and international loans (Collier et al. (2010)).

Given the infrastructure gaps and capital scarcity in resource-rich developing countries, saving all the resource windfalls impose severe constraints for these economies. By contrast, spending all the resource windfalls can make these countries more susceptible to boom-bust cycles and create macroeconomic instability. These bring the issue of optimal fiscal management of resource windfalls to the fore. Several researchers provide formal discussions on the management of natural resource revenue. Contributions along these lines include Collier et al. (2010), Venables (2010), van der Ploeg (2011), van der Ploeg and Venables (2011, 2013), and van der Ploeg (2012). Some of these studies also address the issue of optimal allocation

[1] Frankel et al. (2013) noted that procyclical spending arises because the government increases spending proportionately, or more than proportionately, when revenue rises in booms.

[2] Gelb and Grasmann (2010) also noted that resource rents can be transferred to citizens in the form of lower nonoil taxes, lower prices, increased employment opportunities and subsidies.

of resource windfalls, using arbitrary allocation rules to determine how much of the windfall should be saved. One limitation though is because of the nonstochastic nature of the models used in these studies, they are unable to determine the optimal allocation based on measures of volatility. At the same time, existing stochastic models that examine the transmission of resource price shocks focus on combining fiscal and monetary policy to mitigate Dutch disease effects, and the implications of using natural resource revenue for public investment. Therefore, these studies did not examine the critical issue of optimal resource windfall allocation (see Dagher et al. (2012), Berg et al. (2013), Richmond et al. (2013) and Samake et al. (2013)).

Agénor (2016) is the first paper to provide a methodological contribution to the literature on the issue of optimal allocation of resource windfalls in a Dynamic Stochastic General Equilibrium (DSGE) model using a social loss function defined in terms of consumption volatility and fiscal or macroeconomic stability. The Agénor framework incorporates a range of externalities associated with public infrastructure, which include a direct complementary effect with private investment and lower distribution costs, to capture the constraints faced by low-income countries. Additionally, public capital is subject to congestion and absorption constraints. The key insight of Agénor's analysis is that the optimal allocation rule of resource windfalls involves internalizing a *dynamic volatility trade-off*: spending less today tends to reduce volatility today in the economy, but the greater the proportion of the windfall that is saved, the greater the proceeds from these assets that governments can spend later on, and the greater the volatility that is injected back in the economy over time. The slope of this trade-off depends in general on the structure of the model and the parameters that characterize the economy, including the accumulation rule for foreign assets. The optimal policy (that is, the optimal share of a resource windfall that must be accumulated today in a sovereign fund) minimizes a social loss function defined earlier.[3] Because Agénor's analysis is fundamentally a methodological contribution, developed with a new oil producer in mind, it is important to apply some of the features of this model to a mature resource producing country.

Although the Trinidad and Tobago economy has been producing oil for over 100 years, it only established an interim sovereign wealth fund in 2000, which was later formalized in 2007. Despite the fact that the sovereign wealth fund specifies rules regarding deposits into the fund, these guidelines were not based on any rigorous framework but rather on adhoc rules which may not have taken specific issues such as household welfare and fiscal stability into account. Thus, a key issue facing policymakers in Trinidad and Tobago is how to determine the optimal allocation of resource windfalls between spending today and saving in the sovereign wealth fund, so welfare can be improved and at the same time there can be a lasting impact on development (Velculescu and Rizavi (2005); Williams (2013)). The aim of this study is to examine the transmission of energy price and production shocks, and to determine the optimal allocation of resource windfalls between spending and saving. To do so this paper applies a modified

[3] Agénor also shows that following a temporary increase in resource prices the optimal fiscal policy always dominates a policy of direct cash transfer to households.

version of the model developed in Agénor (2016) to the Trinidad and Tobago economy. The contribution of this research is that it is the first country application of the Agénor framework. This paper is also the first attempt to provide a rigorous assessment of how much of the resource windfall should be used for consumption and savings in a general equilibrium framework which takes some of the features of the Trinidad and Tobago economy into account.

This study departs from Agénor (2016) in the following ways: distribution costs are excluded because of the low cost of transport fuel in Trinidad and Tobago; there is no complementary effect with private investment; the model accounts for domestic consumption of natural resource products; the framework includes imperfect capital mobility; and the overall primary balance to output ratio (rather than the nonresource primary balance to output ratio) is the key fiscal indicator. Further, owing to the fact that Trinidad and Tobago is a country with absorptive capacity concern, public capital is subject to absorption constraints which affects investment efficiency. The results show that spending all the resource windfall on consumption and investment creates a lot of volatility, whereas saving all the windfall reduces volatility and mitigates Dutch disease effects initially, but increases volatility later, as interest income is spent. As noted earlier, this dynamic volatility trade-off is the key insight of the analysis in Agénor (2016). Moreover, if the government is equally concerned about household welfare and fiscal stability, the optimal rule suggests that the government should save about 80 percent of the excess resource revenues. In general, the greater the concern for fiscal stability, the larger the proportion of the surplus resource revenue that should be saved. These findings provide evidence that fiscal policy can help to reduce the effects of resource price and production shocks.

The rest of this paper is organized as follows. Section II provides some background information on the natural resource sector in Trinidad and Tobago. Section III presents the model and Section IV outlines the key steady-state and log-linearized equations of the model. Section V provides a discussion of the calibration for the Trinidad and Tobago economy. The dynamic transmission of resource price shocks under alternative fiscal rules is examined in Section VI, while Section VII presents the determination of the optimal allocation of resource windfalls between spending and saving. In Section VIII, sensitivity analysis is provided to test the robustness of the results obtained from the optimal allocation rule. Penultimately, Section IX examines the transmission and optimal allocation of windfalls emanating from a shock to resource production. The final section summarizes the key results and discusses their implications for fiscal policy in Trinidad and Tobago.

II. Background

Trinidad and Tobago is a high-income economy[4], endowed with vast energy resources (oil and natural gas). The economy is classified as being "resource-rich", given the significant share of export earnings and government revenue obtained from oil and natural gas.[5] The heavy dependence on the fortunes of the energy sector makes the economy highly vulnerable to energy price shocks. Table 1 shows the economic contribution of the energy sector to the Trinidad and Tobago economy. Since 2000, the economy has become more fiscally dependent on the energy sector—which accounts for over 80 percent of merchandise export earnings. However, although the energy sector is a major source of wealth, it accounts for less than 4 percent of the labour force, because the capital intensive nature of oil and gas industries cannot provide substantial employment opportunities.

Over the last decade, Trinidad and Tobago has benefited from surpluses on its fiscal accounts, supported largely by buoyant energy prices. High energy prices have been accompanied by increased government expenditure, which are likely to be unsustainable if oil and gas prices decrease dramatically. Between 2000 and 2013 for example, government expenditure to GDP increased by over 10 percent. In addition, the higher level of government spending, coupled with lower non-energy revenue, has caused a deterioration in the non-energy fiscal deficit as a ratio of GDP, which deteriorated from 2.4 percent in 2000 to 10.2 percent in 2013. Although there have been some fluctuations in the overall primary balance as a percent of GDP, it recorded surpluses for most of the period, with the exception of 2009 and 2012.

The abundance of oil and gas in the Trinidad and Tobago economy has caused a decline in the non-energy traded goods sector. Figure 1 shows that since 1996, the non-energy tradable sector has been constantly shrinking as a share of GDP. At the same time, the energy sector has expanded, making the economy more resource-dependent and increasing the risks associated with commodity price shocks. Despite the decline in the relative size of the nontradable sector over the period, it still accounts for the largest share of total output. Overall, the characteristics of the production structure provide supporting evidence to Dutch disease effects, which appear to be a permanent feature of the economy given the historical preponderance of oil and natural gas in government revenue and export receipts. The inflow of capital from the oil boom has caused the real exchange rate to appreciate (see Figure 2), which in turn resulted in a loss of international competitiveness in nonresource tradable goods.

In natural resource-rich developing countries and developing countries in general, public resources are often wasted. Trinidad and Tobago, like many resource-rich developing countries, has a low efficiency of public investment. Dabla-Norris et al. (2012) estimated the efficiency

[4] GNI per capita of US$14,710 in 2012 (see The World Bank (2014)).

[5] Lundgren et al. (2013) define a resource-rich economy as one in which resource revenue exceeds 20 percent of total government revenue, and at least 25 percent of total exports are from natural resources.

of public investment to be 0.275, which indicates that more than 70 percent of investment spending is unproductive. Moreover, despite the abundant resource wealth, infrastructure in the economy is inadequate and poor when compared to other high-income countries (Artana et al. (2007)). The poor infrastructure facilities in the economy are primarily due to underinvestment. Having realized this, the government has recently been increasing investment in infrastructure through the Public Sector Investment Programme (PSIP) in an attempt to improve the level of infrastructure. However, governance reforms are also critical, in light of the poor efficiency of investment spending alluded to earlier.

The government of Trinidad and Tobago formally established a sovereign wealth fund—The Heritage and Stabilisation Fund (HSF)—in March 2007.[6] The purposes of the Fund include to sustain public expenditure capacity during periods of revenue downturn, caused by a fall in crude oil or natural gas prices and to provide savings for future generations. According to the deposit rules for the HSF, quarterly deposits are made to the fund when actual petroleum revenues in each quarter of the financial year exceed the estimated petroleum revenues for that quarter by more than 10 percent and when actual revenues exceed estimated revenues by less than 10 percent.[7] Furthermore, a minimum of 60 percent of the excess total revenues shall be deposited to the Fund in any financial year. Withdrawals are permitted from the Fund in cases where the petroleum revenues collected in any financial year fall below the estimated petroleum revenues for that financial year by at least 10 percent.[8] In 2013 total assets in the HSF were approximately 19 percent of GDP.

A key issue on the agenda of policymakers in Trinidad and Tobago is to determine an appropriate deposit rule for the HSF that is backed by a rigorous framework. This is particularly important given the decline in oil production and prices, as well as the fall in Trinidad and Tobago's exports of LNG to the U.S.—arising from an increase in U.S. shale gas production. These developments have caused a decline in energy sector revenues. It is therefore important to determine the share of the excess revenue that should be deposited into the Fund, to provide a balance between immediate consumption and savings.[9]

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[6] During the 1970s and early 1980s the economy benefited tremendously from higher oil prices and an increase in oil production. But because there was no saving fund in place, government spending went unchecked and the windfalls were not properly managed (Williams (2011)). In the mid-1980s when oil prices declined sharply the economy faced financial difficulties and had to enter into structural adjustment programmes with the International Monetary Fund and the World Bank. These experiences caused the government to formally establish a sovereign wealth fund (The Sovereign Wealth Fund Initiative (2012)).

[7] In the case where the surplus is by less than 10 percent, the Minister of Finance *may* deposit all or part of the excess into the Fund.

[8] See The Heritage and Stabilisation Fund Act, No. 6 of 2007 for further details on the deposit and withdrawal rules.

[9] See similar discussions in International Monetary Fund (2012b).

III. The Model

The framework considered is an open economy general equilibrium model with three production sectors: a nonrenewable resource sector (which represents the oil and natural gas sector and is identified with superscript O), a nonresource tradable sector (identified with superscript T), and a nontradable sector (identified with superscript N). Resource output is a flow endowment that is owned by all citizens, where the government acts as the trustee or custodian for the resources. Some of the resource products are consumed domestically (by households), and the rest are exported. Tradable output and nontradable output are produced competitively. The tradable good can either be consumed or invested, whereas the nontradable good is a pure consumption good.

Households purchase and consume both tradables and nontradables, whereas the government buys the nonresource tradable and nontradable goods and consumes only nontradables. Private investment consists of tradables only, whereas public investment consists of both tradables and nontradables. As is common in developing countries, public capital is subject to absorption constraints, which affect the efficiency of public investment (See Agénor (2010, 2012)). The model also accounts for imperfect intersectoral capital mobility, and both households and the government have imperfect access to world capital markets.

In the model, prices are flexible and the resource price is exogenously determined outside the home country. The world price of a unit of the nonresource tradable good is unity and purchasing power parity (PPP) holds at the wholesale level and retail level for tradable goods.

A. Total Output

Total domestic output, Y_t, measured in foreign currency, is given by,

$$Y_t = Y_t^T + z_t^{-1} Y_t^N + P_t^O Y_t^O, \tag{1}$$

where Y_t^T, Y_t^N, Y_t^O denote nonresource tradable output, nontradable output and natural resource output, respectively. P_t^O is the world resource price and z_t^{-1} is the real exchange rate.

B. Tradable Production

Labour, L_t^T, capital, K_t^T, and public capital, K_t^G are used to produce tradable goods. The production function of tradables is given by,

$$Y_t^T = (L_t^T)^{\beta} (K_t^T)^{1-\beta} (K_t^G)^{\omega_T}, \tag{2}$$

where $\beta \in (0,1)$ and $\omega_T > 0$. The first-order conditions for the economy-wide wage rate, w_t, and rental rate of capital in the tradable sector, $r_t^{K,T}$, take the standard form,

$$w_t = \beta(\frac{Y_t^T}{L_t^T}), \tag{3}$$

$$r_t^{K,T} = (1-\beta)(\frac{Y_t^T}{K_t^T}). \tag{4}$$

C. Nontradable Production

Nontradable goods are produced using labour, L_t^N, private capital, K_t^N, and public capital. The production function is given by,

$$Y_t^N = (L_t^N)^{\eta}(K_t^N)^{1-\eta}(K_t^G)^{\omega_N}, \tag{5}$$

where $\eta \in (0,1)$, $\omega_N > 0$. The elasticity of output of nontradables with respect to public capital is assumed to be same in both production sectors, so that $\omega_N = \omega_T$. The first-order conditions are,

$$z_t w_t = \eta(\frac{Y_t^N}{L_t^N}), \tag{6}$$

$$z_t r_t^{K,N} = (1-\eta)(\frac{Y_t^N}{K_t^N}), \tag{7}$$

where $r_t^{K,N}$ is the rental rate of capital in the nontradable sector.

D. Resource Production and Prices

In the model, natural resource output follows an exogenous stochastic process:

$$Y_t^O = (Y_{t-1}^O)^{\rho^{YO}} \exp(\epsilon_t^{YO}), \tag{8}$$

where $\rho^{YO} \in (0,1)$ is the autoregressive coefficient, and ϵ_t^{YO} a normally distributed random shock with zero mean and a constant variance.

The international resource price, P_t^O, follows an exogenous process given by

$$P_t^O = (P_{t-1}^O)^{\rho^{PO}} \exp(\epsilon_t^{PO}), \tag{9}$$

where $\rho^{PO} \in (0,1)$ is the autoregressive coefficient, and ϵ_t^{PO} a normally distributed random shock with zero mean and a constant variance.

E. Households

In the first stage, households determine the optimal level of total consumption, and in the second stage, the optimal level of consumption chosen is allocated between spending on tradable goods and nontradable goods. The objective of the representative household is to maximize the following utility function,

$$E_t \sum_{s=0}^{\infty} \Lambda^s \left\{ \frac{(C_{t+s})^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} - \frac{\eta_L}{1+\psi}(L_{t+s})^{1+\psi} \right\}, \tag{10}$$

where E_t is the expectations operator conditional on the information available in period t, and $\Lambda \in (0,1)$ denotes the discount factor. The term ς represents the intertemporal elasticity of substitution for consumption, whereas ψ is the inverse of Frisch elasticity of labour supply, and $\eta_L > 0$ is a preference parameter.

There is imperfect capital mobility across production sectors. The accumulation equation for the stock of private capital is given by,

$$K_t^P = (1-\delta^P)K_{t-1}^P + I_{t-1}^P - \Gamma(K_t^P, K_{t-1}^P), \tag{11}$$

where I_t^P is private investment, $\delta^P \in (0,1)$ gives a constant rate of depreciation, and $\Gamma()$ is a capital adjustment cost function specified as,

$$\Gamma(K_t^P, K_{t-1}^P) = 0.5\kappa(\frac{K_t^P}{K_{t-1}^P} - 1)^2 K_{t-1}^P, \tag{12}$$

where $\kappa > 0$ measures the magnitude of adjustment costs.

Households own both types of firms but do not earn any profit from them because of perfect competition. Their net income consists of after-tax nonresource income and after-tax resource income. The households' end-of-period budget constraint is given by,

$$\begin{aligned} D_{t+1}^P = (1+r_t^W)D_t^P - (1-\tau^{NO})(Y_t^T + z_t^{-1}Y_t^N) \\ -\psi^O(1-\tau^O)P_t^O Y_t^O + C_t + I_t^P + T_t^L, \end{aligned} \tag{13}$$

where D_t^P represents foreign-currency debt, r_t^W is the world interest rate, $\tau^{NO} \in (0,1)$ denotes the nonresource tax rate, $\tau^O \in (0,1)$ is the resource tax rate, and $\psi^O \in (0,1)$ is the share of the non-taxed resource windfall that domestic households (as opposed to nonresidents) receive.

Each household maximizes lifetime utility with respect to C_t, L_t, K_t^P, and D_t^P. Thus, maximizing (10) subject to (11) to (13) yields the following first-order conditions,

$$C_t^{-\varsigma^{-1}} = \Lambda \left(1 + r_t^W\right) E_t(C_{t+1}^{-\varsigma^{-1}}), \tag{14}$$

$$L_t = \left[\frac{(1-\tau^{NO})w_t}{\eta_L C_t^{\varsigma^{-1}}} \right]^{\frac{1}{\psi}}, \tag{15}$$

$$E_t \left\{ \left[\kappa(\frac{K_{t+1}^P}{K_t^P} - 1) + 1 \right]^{-1} \left[(1-\tau^{NO}) r_{t+1}^K + 1 - \delta^P + \frac{\kappa}{2} (\frac{\Delta (K_{t+2}^P)^2}{(K_{t+1}^P)^2}) \right] \right\} = 1 + r_t^W, \tag{16}$$

where $\Delta(K_{t+2}^P)^2 = (K_{t+2}^P)^2 - (K_{t+1}^P)^2$. Equation (14) is the standard Euler equation, (15) defines labour supply, and (16) shows the expected return on capital is related to the world interest rate.

Private consumption is a bundle of tradable consumption, C_t^T, and nontradable consumption, C_t^N,

$$C_t = (C_t^N)^{\theta} (C_t^T)^{1-\theta}, \tag{17}$$

where $\theta \in (0,1)$. The representative household maximizes (17) subject to the static budget constraint,

$$C_t = C_t^T + z_t^{-1} C_t^N. \tag{18}$$

The first-order conditions are given by,

$$C_t^N = \theta z_t C_t, \tag{19}$$

$$C_t^T = (1-\theta)\, C_t. \tag{20}$$

Tradable consumption consists of a bundle of natural resource products, C_t^{TO}, and nonresource related goods C_t^{TNO},

$$C_t^T = (C_t^{TO})^{\theta^T} (C_t^{TNO})^{1-\theta^T}, \tag{21}$$

where $\theta^T \in (0,1)$, and the budget constraint for tradable goods is,

$$C_t^T = C_t^{TNO} + P_t^O C_t^{TO}. \tag{22}$$

Maximizing (21) subject to (22) the solution is given by,

$$C_t^{TO} = \theta^T \left(P_t^O \right)^{-1} C_t^T, \tag{23}$$

$$C_t^{TNO} = \left(1 - \theta^T \right) C_t^T. \tag{24}$$

F. Government

The government collects resource revenue, T_t^O, nonresource revenue, T_t^{NO}, and lump-sum taxes, T_t^L. It also receives interest income on the stock of foreign-currency assets, F_t, held in a sovereign wealth fund. The interest rate accrued on the assets in the sovereign wealth fund is r_t^F. Thus, total government revenue, T_t, is given by,

$$T_t = T_t^O + T_t^{NO} + T_t^L + r_t^F F_t. \tag{25}$$

As noted earlier, resource output is taxed at the rate τ^O, and the tax rate on nonresource output is τ^{NO}. Thus, resource revenue and nonresource revenue collected each period are,

$$T_t^O = \tau^O P_t^O Y_t^O, \tag{26}$$

$$T_t^{NO} = \tau^{NO}(Y_t^T + z_t^{-1} Y_t^N). \tag{27}$$

Therefore, (25) can be written as,

$$T_t = \tau^O P_t^O Y_t^O + \tau^{NO}(Y_t^T + z_t^{-1} Y_t^N) + T_t^L + r_t^F F_t. \tag{28}$$

Government spending, G_t, is allocated in fixed fractions to investment, I_t^G, and consumption, C_t^G,

$$I_t^G = \upsilon^G G_t, \tag{29}$$

$$C_t^G = (1 - \upsilon^G) z_t G_t, \tag{30}$$

where $\upsilon^G \in (0, 1)$. Government spending in foreign-currency terms is,

$$G_t = I_t^G + z_t^{-1} C_t^G. \tag{31}$$

In the log-linearized system, where variables are defined as deviations from the steady state, the definition of government spending will depend on the fiscal rule at hand, whereas in the steady state, government spending is calculated as a constant fraction, $\psi^G \in (0, 1)$, of output.

Investment spending is allocated in fixed shares between spending on nontraded goods, $I_t^{G,N}$, and nonresource traded goods, $I_t^{G,T}$:

$$I_t^{G,N} = \upsilon^{G,N} z_t I_t^G, \tag{32}$$

$$I_t^{G,T} = (1 - \upsilon^{G,N}) I_t^G, \tag{33}$$

where $\upsilon^{G,N} \in (0, 1)$. Thus total public investment, I_t^G, is given by,

$$I_t^G = I_t^{G,T} + z_t^{-1} I_t^{G,N}. \tag{34}$$

The public capital stock is given by,

$$K_t^G = (1 - \delta^G) K_{t-1}^G + \varphi_{t-1} I_{t-1}^G, \tag{35}$$

where $\delta^G \in (0,1)$ is the depreciation rate and φ_t is an indicator of efficiency of spending on infrastructure, as first proposed in Agénor (2010). The efficiency parameter—which captures absorption constraints—is negatively related to the ratio of public investment to public capital,

$$\varphi_t = \varphi_0 \left(\frac{I_t^G}{K_t^G} \right)^{-\varphi_1}, \tag{36}$$

where $\varphi_1 > 0$.

The government's flow budget constraint is,

$$D_{t+1}^G = (1 + r_t^W) D_t^G + G_t - T_t, \tag{37}$$

where D_t^G is the government's foreign-currency denominated debt.[10]

The overall primary balance, OPB_t, is defined as,

$$OPB_t = T_t^O + T_t^{NO} + T_t^L - G_t. \tag{38}$$

G. World Interest Rate and Risk Premium

The market cost of foreign borrowing, r_t^W, depends on the world risk-free (constant) rate, $r^{W,R}$, and a risk premium, PR_t,

$$r_t^W = (1 + r^{W,R})(1 + PR_t) - 1. \tag{39}$$

In line with the literature on sovereign debt spreads for developing countries (see Agénor and Montiel (2015)), the premium is positively related to the government net debt to total output ratio,

$$PR_t = (\frac{D_t^G}{Y_t})^{pr1}, \tag{40}$$

where $pr1 > 0$. Therefore, an increase in total output lowers the risk premium.

H. Market-Clearing Conditions

The market-clearing condition of the nontradable sector is,

$$Y_t^N = C_t^N + C_t^G + I_t^{G,N}. \tag{41}$$

[10] In the calibration, I assume the government does not issue additional debt to finance its deficit.

The labour market equilibrium condition is,[11]

$$L_t = L_t^N + L_t^T. \tag{42}$$

The CES aggregator for total private capital is given by,

$$K_{t-1}^P = [\zeta_K (K_t^T)^{(\eta_K - 1)/\eta_K} + (1-\zeta_K)(K_t^N)^{(\eta_K-1)/\eta_K}]^{\eta_K/(\eta_K-1)}. \tag{43}$$

The aggregate rental rate of capital is,

$$r_t^K = [(\zeta_K)^{\eta_K} (r_t^{K,T})^{1-\eta_K} + (1-\zeta_K)^{\eta_K} (r_t^{K,N})^{1-\eta_K}]^{1/(1-\eta_K)}. \tag{44}$$

The asset accumulation rule is,

$$F_{t+1} = (1-\phi^F)F_t + \chi T_t^O, \tag{45}$$

where $\phi^F \in (0,1)$ represents a management fee levied on the stock of assets held in the sovereign wealth fund and $\chi \in (0,1)$ is the fraction of the resource windfall saved in the sovereign wealth fund.

The current account balance is given by,

$$D_{t+1} - F_{t+1} = (1 + r_t^W)D_t - Y_t^T + C_t^T + I_t^P + I_t^{G,T} \tag{46}$$

$$-(1 + r_t^F - \{1-\nu\}\,\phi^F)F_t - \left[\psi^O + (1-\psi^O)\tau^O\right] P_t^O Y_t^O,$$

where $D_t = D_t^P + D_t^G$ denotes total debt and $\nu \in (0,1)$ is the fraction of the management fee that goes to domestic agents.

As in Agénor (2016), the competitive equilibrium in this framework consists of sequences of allocations $\{C_t^N, C_t^T, I_t^P, D_t, F_t, L_t^N, L_t^T, K_t^P, K_t^N, K_t^T, G_t\}_{t=0}^{\infty}$, final good and factor prices, $\{w_t, r_t^K, r_t^{K,T}, r_t^{K,N}\}_{t=0}^{\infty}$, such that, taking as given K_{-1}^P, K_{-1}^G, D_{-1}, F_{-1}, the exogenous processes $\{P_t^O, Y_t^O\}_{t=0}^{\infty}$, constant policy parameters χ, τ^O, τ^{NO}, υ^G, and $\upsilon^{G,N}$, and constant public debt,

a) $\{C_t, C_t^N, C_t^T, L_t, I_t^P, D_t^P, K_t^P\}_{t=0}^{\infty}$ solve households' optimization problem;

b) $\{L_t^N, K_t^N\}$ solve the nontradable good firm's optimization problem;

c) $\{L_t^T, K_t^T\}$ solve the nonresource tradable good firm's optimization problem;

[11] I assume that total labour is allocated between the nonresource tradable and nontradable production sectors only. This is realistic because employment in the resource sector is usually small, due to (as noted earlier) the capital intensive nature of that sector.

d) the government sets a sequence of total spending $\{G_t\}_{t=0}^{\infty}$, its components $\{C_t^G, I_t^G\}_{t=0}^{\infty}$; a sequence of lump-sum taxes $\{T_t^L\}_{t=0}^{\infty}$; and a sequence of assets $\{F_t\}_{t=0}^{\infty}$, held in the sovereign wealth fund so that its flow and lifetime budget constraints are satisfied; and

e) market-clearing conditions for nontradable goods, labour, private capital, and nonresource tradable goods are satisfied.

IV. Steady State and Log-Linearization

This section presents some of the key steady-state and log-linearized equations of the model.

Total consumption in the steady state is,

$$C = \frac{1}{(1-\theta)}[Y^T - r^W D - I^P - I^{G,T} + r^F F$$
$$- \{1-\nu\}\phi^F F + \left[\psi^O + (1-\psi^O)\tau^O\right] P^O Y^O].$$

The steady-state world interest rate is given by the standard equation,

$$r^W = \frac{1}{\Lambda} - 1.$$

The real exchange rate is solved from the equilibrium condition between supply and demand of nontradables,

$$z = \frac{1}{\theta C}\left[Y^N - C^G - I^{G,N}\right].$$

In the steady state, the risk premium is given by,

$$(1 + PR)\left(1 + r^{W,R}\right) = 1 + r^W.$$

The model is solved by log-linearizing each variable around the steady state. Variables with a hat represent percentage point deviations for interest rate variables from the steady state, and log-deviations around a non-stochastic steady state for the other variables.

Total output in log-linear form is given by,

$$\hat{Y}_t = \frac{1}{Y}\left[Y^T\hat{Y}_t^T + z^{-1}Y^N(\hat{Y}_t^N - \hat{z}_t) + P^O Y^O(\hat{P}_t^O + \hat{Y}_t^O)\right].$$

The resource price and resource production are,

$$\hat{P}_t^O = \rho^{PO}\hat{P}_{t-1}^O + \epsilon_t^{PO},$$

$$\hat{Y}_t^O = \rho^{YO}\hat{Y}_{t-1}^O + \epsilon_t^{YO}.$$

Total consumption is given by the standard equation,

$$E_t\hat{C}_{t+1} = \hat{C}_t + \varsigma\hat{r}_t^W.$$

Log-linearizing private investment gives,

$$\hat{I}_t^P = \frac{1}{I^P}\{D^P\hat{D}_{t+1}^P - F\hat{F}_{t+1} - (1+r^W)D^P(\hat{r}_t^W + \hat{D}_t^P) + Y^T\hat{Y}_t^T$$
$$-C^T\hat{C}_t^T - I^{G,T}\hat{I}_t^{G,T} + (1+r^F)F(\hat{r}_t^F + \hat{F}_t) - \{1-\nu\}\,\phi^F F\hat{F}_t$$
$$+\left[\psi^O + (1-\psi^O)\tau^O\right]P^OY^O(\hat{P}_t^O + \hat{Y}_t^O)\}.$$

The overall primary balance represents total revenues less noninterest government spending,

$$\widehat{OPB}_t = \frac{1}{OPB}\left[T^O\hat{T}_t^O + T^{NO}\hat{T}_t^{NO} + T^L\hat{T}_t^L - G\hat{G}_t\right].$$

Public capital is,

$$\hat{K}_t^G = (1-\delta^G)\hat{K}_{t-1}^G + \frac{\varphi I^G}{K^G}\left(\hat{\varphi}_{t-1} + \hat{I}_{t-1}^G\right).$$

Efficiency of public investment depends positively on the public capital stock and is negatively related with public investment,

$$\hat{\varphi}_t = \varphi_1\left[\hat{K}_t^G - \hat{I}_t^G\right].$$

V. Calibration

The model is calibrated using data for Trinidad and Tobago because of the importance of the resource sector to the economy, and the critical need to determine how resource windfalls should be managed—as highlighted in Section II. The main data sources are The Central Bank of Trinidad and Tobago, The Central Statistical Office of Trinidad and Tobago, The Ministry of Energy and Energy Affairs of Trinidad and Tobago, and The Ministry of Finance of Trinidad and Tobago. In cases where data and country-specific parameters are not available, estimates from other studies are used.

A summary of the benchmark set of parameters is provided in Table 2. Considering the parameters characterizing the household behaviour, the intertemporal discount factor, Λ, is set at 0.972 based on estimates of real interest rates.[12] The intertemporal elasticity of substitution, ς, is 0.2 (Agénor and Montiel (2015)), and the preference parameter for labour, η_L, is set at a low value of 0.2. The Frisch elasticity of labour supply, ψ, is calibrated at 12, implying an inelastic labour supply. The share of nontradables in total private consumption, θ, is set at 0.55. This is the same value used in Pieschacón (2012), and it is in line with the share of nontradable goods reported in the Household Budget Survey (HBS) for Trinidad and Tobago.[13] Using data from the HBS, the share of household spending on oil and gas products in total tradable consumption, θ^T, is calculated to be 0.06. The adjustment cost parameter for private investment, κ, is set at 30, whereas the depreciation rate for private capital, δ^P, is 0.045, in line with estimates in the literature. The share of capital in the nonresource tradable sector, ζ_K, is calibrated at 0.6, to reflect the fact that the nonresource tradable sector is more capital intensive. Furthermore, the elasticity of substitution between nonresource traded and nontraded goods, η_K, is set to 0.5. The share of the nontaxed resource windfall that domestic households receive, ψ^O, is set as 88.4 percent, given that the profits repatriated by nonresidents for the period 2007-2010, $(1 - \psi^O)$, is 11.6 percent.

Given that the resource commodities are oil and natural gas, the degree of persistence in resource production is calculated similar to Agénor (2016). Therefore, assuming that proven oil and natural gas reserves may last about 15 years, ρ^{YO} is calibrated at 0.912.[14,15] For energy prices, the degree of persistence (ρ^{PO}) is 0.93, in line with empirical estimates (see Maliszewski (2009)).[16] Also, in the nonresource sector, as production in the nontradable sector is more labour intensive, the elasticity of production with respect to labour in that sector, η, is set at a value of 0.65; this is greater than the elasticity of production in the tradable sector, β, which is equal to 0.6. The elasticities with respect to public capital, ω_T and ω_N, both take a value of 0.17.

Moreover, for the government, revenue from the oil and gas sector represents 17.9 percent of GDP on average for the period 2009-2012. Given that the value of oil and gas production for the

[12] The world real interest rate, r^W, is 2.875 percent. Using the standard formula $r^W = \Lambda^{-1} - 1$ gives $\Lambda = 0.972$.

[13] The Household Budget Survey (HBS) is carried out to collect data on income and expenditure of private households for the Retail Price Index (see Central Statistical Office of Trinidad and Tobago n.d.).

[14] In Trinidad and Tobago, the exact period before oil and gas reserves are fully depleted is unknown. Given the economy's resource base, there are a lot of gas reserves to be discovered via increased exploration (see Trinidad and Tobago Newsday (January 2012)). With regard to oil production, Krishna Persad noted that there are at least 3.5 billion barrels of crude oil remaining. He also pointed out that because primary recovery has already yielded 3.5 billion over 104 years, the economy still has a lot of oil remaining (see Trinidad and Tobago Express Newspapers (November 2012)). This is consistent with a study by Hosein et al. (2010) which found that only 20 percent of the heavy oil onshore in Trinidad and Tobago has been recovered.

[15] Assuming that proven energy reserves will last approximately 15 years, the formula yields $(\rho^{YO})^{7.5} = 0.5$; therefore $\rho^{YO} = 0.912$. It should be noted that changing the period that proven reserves are expected to last does not alter the results.

[16] Maliszewski's study focuses on oil prices; however, because natural gas prices comove with crude oil prices, the same number is used for energy prices.

same period is 44 percent of GDP, then the tax rate on energy income, τ^O, is calculated as 41 percent.[17] Using data for the period 2009-2012 on the tax revenue-to-GDP ratio, the tax rate on non-energy income, τ^{NO}, is calibrated at 14.7 percent. Furthermore, data for the same period reveal that government spending is 13.8 percent of total output; hence this value is used for ψ^G. Using information from the Ministry of Planning and Sustainable Development (2012), the actual amount the government spent on infrastructure investment during the fiscal year 2012 was used to estimate the initial share of infrastructure investment in government spending, υ^G, to be 0.151. The parameter that captures the allocation of investment in infrastructure to nontraded goods, $\upsilon^{G,N}$, is set at 0.41 based on the estimate of the share of nontradables in total investment reported in Bems (2008) for Trinidad and Tobago. In addition, the efficiency parameter for public investment, φ, is 0.275 based on the value reported in Dabla-Norris (2012) for Trinidad and Tobago, whereas the absorption constraint elasticity for public investment, $\varphi_{1,}$ is set at a low value of 0.05. The rate of depreciation of public capital, δ^G, is equal to 0.035, in line with Dagher et al. (2012).

To calculate the average interest rate earned by the country's sovereign fund, r^F, data from the Heritage and Stabilisation Fund Quarterly Investment Report were used.[18] The nominal interest rate for 2009-2012 was 5.1 percent on average. Given that in the same period, inflation in the U.S. was 1.6 percent on average, the real return on the sovereign wealth fund is set at 3.5 percent. The risk-free world interest rate, $r^{W,R}$, is computed as 1.0 percent, based on the real yields on U.S. treasury bonds issued in 2014. To calculate the world interest rate, r^W, I used the nominal yield on recent sovereign bonds issued by Trinidad and Tobago on the international financial market in December 2013. Given that the bonds had a yield of 4.375 percent, the real bond rate is 2.875—accounting for a 1.5 percent average U.S. inflation rate for 2013. Therefore, from (39), the risk premium (in foreign-currency terms) is calculated as 1.86 percent. The elasticity of the risk premium with respect to the debt to output ratio, $pr1$, is set at a low value of 0.25. Furthermore, to manage the assets in the Heritage and Stabilisation Fund, a fee—which is set as a fraction of the assets in the Fund—is paid to the external fund managers and to the Central Bank of Trinidad and Tobago, who is the manager of the Fund. In line with the recent data on sovereign wealth funds, the total fee paid for managing the Fund, ϕ^F, is set at 1.10 percent; whereas, the share of the management fee that goes to residents, ν, is 0.80 percent.

[17] Similar to Pieschacón (2012), the identity $T^O/Y = \tau^O \left(P^O Y^O\right)/Y$ is used to compute the resource tax rate.

[18] See Trinidad and Tobago Heritage and Stabilisation Fund, Quarterly Investment Report (various years).

VI. Dynamics of Resource Price Shocks

This section examines the transmission of a positive temporary shock to commodity prices under two "extreme" fiscal rules: the first fiscal rule considers the case where the government spends all the excess revenue from the windfall; and in the second fiscal rule, all the resource windfall is saved in a sovereign wealth fund. The simulations show the percent deviation of the variables from their steady-state values, with the exception of the risk premium and the rental rate of capital, which are expressed in percentage points. In the first fiscal rule, the government spends all the excess revenue from the windfall. This is quite common in many resource-rich countries that have not established a sovereign wealth fund, or any other formal mechanism to manage the proceeds from natural resources. In the second fiscal rule, all the resource windfall is saved in a sovereign wealth fund. Under both rules, it is assumed that public debt is constant and lump-sum taxes adjust to clear the government budget.

A. Full Spending of Resource Windfall

The full spending experiment corresponds to the *Hand-to-Mouth* policy. This experiment is consistent with the view that governments in developing countries should use natural resource revenue to address their development needs. This is particularly important in capital scare economies that have infrastructure deficits, and poor education and health care services. Hence, under this rule, the government spends all the windfall on consumption and investment, so government spending rises by the amount of the windfall, and there is no asset accumulation in the sovereign wealth fund. Formally,

$$G\hat{G}_t = T^O\hat{T}_t^O, \tag{47}$$

$$\hat{F}_t = 0, \tag{48}$$

where (48) corresponds to $\chi = 0$ in (45).

Lump-sum taxes are solved residually from the government budget constraint, (37), using (28),

$$\hat{T}_t^L = \frac{1}{T^L}[-T^{NO}\hat{T}_t^{NO} - T^O\hat{T}_t^O - (1+r^F)F(\hat{r}_t^F + \hat{F}_t) \\ +F\hat{F}_t + G\hat{G}_t + \left(1+r^W\right)D^G\hat{r}_t^W].$$

Using (47) and (48), and with $\hat{r}_t^F = 0$, lump-sum taxes are given by,

$$\hat{T}_t^L = \frac{1}{T^L}[-T^{NO}\hat{T}_t^{NO} + \left(1+r^W\right)D^G\hat{r}_t^W]. \tag{49}$$

Figure 3 shows the general equilibrium effects of a 5 percent temporary increase in resource prices. On impact of the shock, there is a fiscal effect, which causes an immediate increase in government resource revenues, and in turn leads to higher government spending, as well as a rise in public investment. The rise in government spending dominates the increase in resource revenues, thereby reducing the overall primary balance and the nonresource primary balance. Also, on impact of the shock, there is a temporary wealth effect created by higher income to household. The wealth effect causes households to increase total private consumption. The higher level of current consumption increases the demand for leisure and lowers labour supply. Thus, employment falls in the tradable and the nontradable sectors. The expansion in aggregate demand for nontradable goods leads to a real appreciation and causes the product wage in that sector to increase. The nonresource tradable sector shrinks because of the resource movement effect, as well as a result of the real appreciation which reduces the competitiveness of the nonresource tradable goods. Overall, under the full spending experiment, Dutch disease effects are significant. The expansion in demand for nontradable goods increases production of nontradables, as well as nonresource revenues.

Upon impact of the shock, total output increases which in turn reduces the risk premium and the world interest rate. The drop in the interest rate exerts downward pressure on the aggregate rental rate of capital and increases private investment and the total stock of physical capital. The lower interest rate also amplifies the increase in private consumption today, through the intertemporal effect. Initially, there is also a temporary reallocation of capital from the tradable sector to the nontradable sector. This can be attributed to the real appreciation which dampens the effect of the increase in the rental rate of capital in the nontradable sector, bringing about a higher stock of capital in that sector. However, over time the increase in capital in the nontraded goods sector quickly dissipates.

Due to absorption constraints, the higher level of public investment reduces the efficiency of public investment and leads to a marginal increase in the public capital stock.[19] The slow rate of accumulation of both private and public capital causes the public-private capital ratio to remain unchanged for a while before falling overtime.

B. Full Saving of Resource Windfall in Sovereign Wealth Fund

The full saving rule corresponds to the *Bird-in-Hand* policy, which has been discussed in the literature. In this case all the resource revenue is accumulated in a sovereign wealth fund and only the interest income generated from the fund is used to finance government spending on consumption and investment, in proportion of initial spending allocations. A key point to note is that saving from natural resource rents can be used as a stabilization buffer to smooth

[19] Further experiments (which are not reported here) show that if absorption capacity constraints reduce, the efficiency of public investment and public capital would increase.

fluctuations that can emanate from future resource revenue shocks. In this experiment, which corresponds to $\chi = 1$ in (45), government spending is,

$$\hat{G}_t = \frac{1}{G}\left[(1+r^F)F(\hat{r}_t^F + \hat{F}_t) - F\hat{F}_t\right], \tag{50}$$

and the accumulation rule for the stock of assets is given by,

$$\hat{F}_t = \frac{1}{F}\left[(1-\phi^F)F\hat{F}_{t-1} + \chi T^O\hat{T}_{t-1}^O\right]. \tag{51}$$

The equation for lump-sum taxes, which excludes resource revenues, can be written as,

$$\begin{aligned}\hat{T}_t^L = \frac{1}{T^L}[&-T^{NO}\hat{T}_t^{NO} - (1+r^F)F(\hat{r}_t^F + \hat{F}_t) \\ &+F\hat{F}_t + G\hat{G}_t + \left(1+r^W\right)D^G\hat{r}_t^W],\end{aligned} \tag{52}$$

where using (50), lump-sum taxes are also determined by (49).

Figure 4 shows the simulations of a 5 percent temporary shock to resource prices under the full saving rule—compared to the full spending rule. Notably, if all the resource windfall is saved, Dutch disease effects are eliminated, and volatility in the fiscal variables is reduced. In comparison to the full spending rule, under the full saving rule government spending rises slowly, causing public investment to increase at a slower pace and government consumption to fall. The marginal and gradual rise in public investment reduces the absorption pressures; hence the efficiency of public investment falls by substantially less compared to the full spending experiment. The overall primary balance records a surplus in this case, and as a fraction of output the drop in the balance is mitigated. The sovereign fund assets as a fraction of output increases to around 30 percent of output.

Also, with the full saving rule, the increase in total output—which is less than the full spending case—causes the risk premium to fall, thereby lowering the cost of borrowing abroad, which in turn raises consumption today but by less than the previous case. The positive effect on consumption raises the demand for leisure and lowers labour supply but by less than the full spending case. The overall impact on aggregate demand is mitigated so the appreciation of the exchange rate is less significant. In comparison to the full spending experiment, the rental rate of capital in the tradable sector falls by substantially less before increasing marginally. However, the drop in private capital in the nontradable sector is more substantial under the full saving experiment. The aggregate private capital stock rises because of the higher level of private investment. Overall, the fall in both employment and capital in the nontradable sector causes a contraction in the production of nontradables, which in turn lowers the product wage in the nontradable sector. Also, the drop in the nonresource tradable output is slightly less when all the windfall is saved. The contraction in the production of both nonresource tradables and nontradables lowers the increase in nonresource tax revenues, and mitigates the rise in total output. Given the lower increase in total output, volatility in the risk premium is lower, which in turn reduces fluctuations in the world interest rate and consumption.

VII. Optimal Allocation of Resource Windfalls

An important practical issue for Trinidad and Tobago is how to determine the optimal allocation of the resource windfall between spending on consumption and investment, and saving in a sovereign wealth fund. Because of the volatility of resource revenue flows, it is necessary for some of the windfall to be set aside as a precautionary liquidity buffer. To examine this issue, a partial spending rule is considered whereby a fraction of the resource windfall, χ, is saved—when there is a 5 percent temporary increase in resource prices. Under the partial spending approach, the asset accumulation rule is given by (51), and government spending and lump-sum taxes are adjusted to account for the share of the windfall that should be allocated to spending, $1-\chi$. Thus,

$$\hat{G}_t = \frac{1}{G}\left[(1-\chi)T^O\hat{T}_t^O + (1+r^F)F(\hat{r}_t^F + \hat{F}_t) - F\hat{F}_t\right], \tag{53}$$

$$\hat{T}_t^L = \frac{1}{T^L}[-T^{NO}\hat{T}_t^{NO} - (1-\chi)T^O\hat{T}_t^O + \left(1+r^W\right)D^G\hat{r}_t^W]. \tag{54}$$

A. Social Loss Function

Using a similar approach to Agénor (2016), to determine the optimal level of resource windfalls that should be saved, χ, the partial spending rule is applied to minimize a social loss function defined as a weighted geometric average of the volatility of private consumption, σ_C^χ, normalized to its steady-state value, C^{SS}, and the volatility of the overall primary balance to output ratio, σ_{OPBY}^χ, normalized to its steady-state value, $OPBY^{SS}$.[20] The criterion used therefore accounts for both household welfare, which is affected by volatility of private consumption, and fiscal stability. Owing to the fact that in Trinidad and Tobago consumption is highly volatile, an important concern to policymakers is to minimize welfare losses. The overall primary balance is used as the fiscal indicator because Trinidad and Tobago has a long reserve horizon; therefore,

[20] The specification of the social loss function (as well as the generalized loss function, discussed later) differs slightly from Agénor (2016) who used the nonresource primary balance instead of the overall primary balance to output ratio.

the aim is to manage revenue volatility.[21,22] The social loss function is given by,

$$\mathcal{L}_t^S(\chi) = (\frac{\sigma_C^{\chi}}{C^{SS}})^{\mu}(\frac{\sigma_{OPBY}^{\chi}}{OPBY^{SS}})^{1-\mu}, \tag{55}$$

where $\mu \in (0,1)$. The loss is calculated using the asymptotic variances, for μ and χ both varying between 0 and 1 with a grid of 0.1. If the government is mainly concerned about fiscal stability then $\mu = 0$; whereas, if the government sets policy only on the basis of household welfare, $\mu = 1$.

Table 3 presents the results of the social loss function, with the optimal values in red. The results reveal that if the government is mainly concerned about fiscal stability, then all the excess revenue should be saved ($\chi = 1$). In the case where there are equal weights on consumption volatility and fiscal volatility ($\mu = 0.5$), then $\chi = 0.8$ which implies that 80 percent of the resource windfall should be saved. If the government is only concerned about consumption volatility ($\mu = 1$), then $\chi = 0.6$. Contrary to Agénor (2016), these findings indicate that if the government is concerned more about household welfare, a greater fraction of the excess revenue should be spent, as this can help to improve welfare. An analysis of the data for Trinidad and Tobago shows that as the share of revenues from the energy sector increases, the share of social expenditure rises. Similarly, Spatafora and Samake (2012) found that commodity price shocks are associated with a significant increase in social expenditure in commodity-exporting developing countries.

B. Alternative Specification of Loss Function

This section extends the social loss function given in (55) to obtain a generalized loss function similar to Agénor (2016). In addition to the volatility of private consumption, the generalized loss function includes a broader measure of macroeconomic volatility defined in terms of a weighted average of the volatility of the overall primary balance to output ratio and the volatility of the real exchange rate, σ_Z^{χ}, scaled to their respective steady-state values. The generalized loss function is given as,[23]

[21] Baunsgaard et al. (2012) and International Monetary Fund (2012a) use the threshold of less than or greater than 35 years to distinguish between short and long reserve horizons. These studies also recommend that the nonresource primary balance be used in countries with a short reserve horizon. If the proven, possible, probable and explorative resources are considered, oil and gas reserves in Trinidad and Tobago exceed 35 years. This therefore means that the economy is considered to have a long reserve horizon. In addition, as mentioned previously, the economy is a mature energy producer.

[22] Le Fort (2013) pointed out that because the government of Trinidad and Tobago obtains significant revenues from the resource sector, the overall (primary) balance is a better indicator of the fiscal policy stance.

[23] A main concern for policymakers is to minimize losses in household welfare (as indicated earlier). In light of this, the generalized loss function is specified to capture the trade-off between household welfare only, and macroeconomic volatility.

$$\mathcal{L}_t^G(\chi) = (\frac{\sigma_C^\chi}{C^{SS}})^\mu [(\frac{\sigma_{OPBY}^\chi}{OPBY^{SS}})^{0.8} (\frac{\sigma_Z^\chi}{Z^{SS}})^{0.2}]^{1-\mu}, \tag{56}$$

where Z^{SS} represents the steady-state value for the real exchange rate.

Table 4 illustrates the results of the optimal value of χ, using weights of 0.8 and 0.2 on the fiscal indicator and the real exchange rate, respectively, when the generalized loss function is used. These weights were chosen to consider a government that—while being concerned with real exchange rate volatility—remains mainly focused on mitigating fiscal instability as a source of macroeconomic instability. The findings show that the optimal allocation parameter is lower in general. Therefore, if the government is concerned solely about macroeconomic stability, $\mu = 0$, 80 percent of the windfall should be saved, whereas if the main focus is on consumer welfare, $\mu = 1$, 60 percent of the excess revenue should be saved.

Figure 5 shows the volatility of consumption, the overall primary balance to output ratio and the real exchange rate, with χ varying between 0 and 1. In the case where $\chi = 0$ (the full spending rule) the overall primary balance to output ratio is highly volatile, but as more of the windfall is saved (as χ tends to 1) fiscal volatility is consistently reduced. In a similar way, consumption is more volatile under the full spending rule, but as the proportion of resource revenue saved in the sovereign fund increases volatility is reduced. However, because the interest income from the assets held in the sovereign fund increases, more resources are injected back into the economy. This leads to higher spending on consumption and investment over time and increases volatility once again. As noted earlier, this is the main insight from Agénor's (2016) contribution and it explains why consumption volatility takes a convex shape. With regard to the real exchange rate, there is a gradual increase in volatility initially, but as more of the windfall is saved volatility rises because the higher interest income from the assets in the fund increases spending and creates pressure on the exchange rate.

VIII. Sensitivity Analysis

This section tests the robustness of the results for the optimal value calculated for χ using the social loss function in Section VII (A)—which is the benchmark case. To conduct this exercise, I consider changes in some parameter values to assess: a higher degree of capital mobility; less resources to domestic residents via a lower share of the management fee; and tighter absorption constraints. I also examine an alternative specification of the risk premium and an investment-only spending rule.

A. Higher Degree of Capital Mobility

Table 5 shows the optimal values for the social loss function when there is an increase in the elasticity of substitution between K_t^N and K_t^T, η_K, from 0.5 to 0.8. If private capital is more mobile across sectors then it is much easier to shift resources between the production of traded and nontraded goods. A higher degree of capital mobility will increase the volatility of a commodity price shock on output and consumption, and should therefore require a higher optimal χ. The results presented in Table 5 show that if $\mu = 0.5$ the optimal value is 0.9 compared to 0.8 in the benchmark case (Table 3). If more emphasis is placed on fiscal stability ($\mu = 0$ or $\mu = 0.1$), the optimal value for χ is 1.0—which is the same value in Table 3. Hence, to better distinguish these results, a smaller grid of 0.01 was done for χ varying between 0.9 and 1.0. The results (which are not reported) show that if $\mu = 0.1$ a higher optimal value of 1.0 is required compared to a value 0.97 under the benchmark case.

B. Lower Share of Management Fee to Residents

If residents receive a lower share of the management fee, it means that a larger proportion of the windfall will leave the country to nonresidents. This therefore reduces the wealth effect to household and lowers aggregate demand, thereby reducing on impact volatility in consumption, the real exchange rate and output, so less (given the form of the loss function and the nature of the government's optimization problem) of the windfall should be saved. The results, which are reported in Table 6, show that as the share of the management fee that goes to residents, ν, is reduced from 0.8 percent to 0.5 percent, the optimal value for χ is lower. For example, if the sole concern is about fiscal stability, the optimal χ is 0.9 compared to 1.0 under the benchmark case (see Table 3). Also, if the government is concerned about consumption volatility and fiscal volatility equally ($\mu = 0.5$), then the optimal value for χ is 0.7 as compared to 0.8. But when the focus shifts more towards household welfare, the results show that more of the windfall should be spent. Thus, if $\mu = 0.8$, the optimal value is 0.4 as compared to 0.7 in Table 3. Intuitively, because households have less income the magnitude of the wealth effect is smaller, so consumption increases by less, which in turn reduces volatility. Because a higher weight is attached to consumption volatility (or household welfare), then the government can afford to spend more and save less.

C. Higher Incidence of Absorption Constraints

Due to absorption constraints in developing countries, an increase in public investment causes efficiency to fall. A lower efficiency of public investment should therefore reduce the volatility of the public capital stock, which in turn will reduce fluctuations in macroeconomic variables, and hence require a lower optimal χ. The results from this experiment (which are not reported here to save space) show that when φ_1 increases from 0.05 to 0.06 the optimal values are the same as the benchmark case (Table 3). To examine this closer I calculate the optimal values using a finer grid of 0.01 for χ varying between 0.9 and 1.0. The results show that with $\mu = 0.2$, the optimal value is 0.94 compared with 0.95 in the benchmark case, thereby implying a lower optimal value with a higher absorption constraint. However, this effect is not very strong in the present case.

D. Alternative Specification of the Risk Premium

Consider now a different specification of the risk premium, where government debt is scaled by total nonresource output, instead of total output. Thus, equation (40) is now specified as,

$$PR_t = (\frac{D_t^G}{Y_t^T + z_t^{-1} Y_t^N})^{pr1}. \tag{57}$$

Given the inherent volatility and uncertainty of resource revenues, they can be seen as a weakness and may not be considered by markets in determining the premium countries pay on international capital markets. Therefore, by using (57), the effect of the shock on the risk premium and the world interest rate will be mitigated. Thus, volatility in the interest rate will be reduced, which in turn, will lower volatility in total output and consumption—thereby implying a lower optimal χ.

Table 7 shows that under the new specification for the risk premium, the optimal value for χ is reduced. If the government is concerned about fiscal volatility, the optimal value is 0.9 compared to 1.0 in Table 3. Also, as more emphasis is placed on household welfare, the optimal value falls. For example, if $\mu = 0.9$, then 50 percent of the windfall should be saved compared to 70 percent in Table 3.

E. Public Investment of Resource Windfalls

In the previous analysis, it was assumed that the government spent the resource windfall or interest income accrued on the assets in the sovereign fund on consumption and investment, and based on this the social loss function was used to determine the optimal allocation that should be saved and spent. This section examines the case where instead the resource windfall or interest income is used for investment purposes only. Therefore, the social loss function is used to calculate the optimal share of the windfall that should be saved, χ, and the fraction that should be spent on infrastructure investment $(1-\chi)$. In this case, public investment and government spending are given by,

$$\hat{I}_t^G = \frac{1}{I^G}\left[(1-\chi)T^O\hat{T}_t^O + (1+r^F)F(\hat{r}_t^F + \hat{F}_t) - F\hat{F}_t\right], \tag{58}$$

$$G\hat{G}_t = I^G\hat{I}_t^G + z^{-1}C^G(\hat{C}_t^G - \hat{z}_t). \tag{59}$$

Combining (58) and (59) and then inserting the result in (52), lump-sum taxes are,

$$\hat{T}_t^L = \frac{1}{T^L}\left[-T^{NO}\hat{T}_t^{NO} + z^{-1}C^G(\hat{C}_t^G - \hat{z}_t) + \left(1+r^W\right)D^G\hat{r}_t^W\right]. \tag{60}$$

The results, which are presented in Table 8, show lower optimal values for χ, implying therefore that if the resource windfall is used for investment, a smaller share should be saved. For instance, if the concern is about fiscal stability the optimal $\chi = 0.4$ compared with $\chi = 1$ in Table 3. Interestingly, for $\mu = 0.2$ to $\mu = 1$, the optimal rule recommends that all the windfall be spent on investment. Depending on an economy's development needs, it can therefore be optimal to use all the excess resource revenue to reduce infrastructure deficits.

IX. Resource Production Shock

A resource windfall can also occur if there is an increase in resource production, created by the discovery of new reserves. This experiment examines the transmission of a temporary positive shock to resource production under the full spending and full saving rules, as well as the optimal allocation between spending (on consumption and investment) and saving.

Figure 6 shows the simulations for a 5 percent shock to resource production under the full spending rule, compared to the results from the 5 percent price shock. The simulations show that in most cases, the dynamics of the resource production shock under the full spending rule follow the same pattern as the resource price shock. A key difference to note is that on impact of the production shock, the rental rate of capital in the nontraded goods sector declines, thereby amplifying the increase in private capital and output in the nontradable sector. Furthermore, the real exchange rate appreciates by substantially less, reducing the volatility in private consumption and total output—in comparison to the shock to resource prices. Also, volatility in the fiscal variables is slightly lower but fluctuations in private investment are more notable when there is an increase in natural resource production.

The results for the 5 percent resource production shock under the full saving rule (compared to the 5 percent shock to resource prices) are shown in Figure 7. Similar to the full spending experiment, although the appreciation of the real exchange rate is less significant under the production shock, the marginal drop in the rental rate of capital in the nontradable sector leads to a higher private capital stock in that sector and in turn a greater expansion in nontradable production. In addition, primarily owing to the slight reduction in the volatility of total output, fluctuations in the risk premium and the world interest rate are reduced. This in turn reduces volatility in consumption and private investment under the output shock—in comparison to the price shock.

The results for the optimal values of χ when the social loss function (55) is applied under the resource production shock are presented in Table 9. In general, when compared to the price shock, the optimal values appear the same in most cases under the output shock—with the exception of the case where the government is only concerned about household welfare. Therefore, if there is a resource windfall, as a result of a production shock, the optimal allocation rule provides a similar suggestion to the case where the windfall is emanated from a price shock—that is, a greater share of the excess revenue should be saved if the government is concerned about fiscal stability. However, if $\mu = 1$, the optimal value under the output shock is 0.5 compared with 0.6 under the price shock in Table 3, which implies that more of the windfall should be spent if the aim is to reduce consumption volatility.

X. Summary and Policy Implications

This paper applied a three-sector Dynamic Stochastic General Equilibrium model to determine the transmission of a temporary resource price shock and a production shock under two fiscal rules: a full spending rule and a full saving rule. The model was calibrated for Trinidad and Tobago—a resource-rich developing country that faces the challenge of prudent management of resource windfalls. The paper also examined an optimal allocation rule between spending today and saving in a sovereign wealth fund. Thus, an important contribution of this research has been to determine the fraction of the resource windfall that should be deposited into the country's sovereign wealth fund. The allocation rule used to determine the optimal share is defined to minimize a social loss function, that is specified in terms of the volatility of private consumption—which is used to capture household welfare—and fiscal stability.

The results show that spending all the resource windfall on consumption and investment creates a lot of volatility, in general, and amplifies Dutch disease effects—whereas if all the windfall is saved, the contraction in the nonresource tradable sector, as well as the real appreciation, is mitigated. Also, under the full saving rule, the expansion in the nontraded sector is eliminated. This implies that because the level of government spending is lower when all the resource windfall is saved, aggregate demand pressures are substantially reduced in the economy, which in turn lowers demand for production of nontradables.

Furthermore, similar to Agénor (2016), the results from the social loss function show that under the optimal allocation rule of resource windfalls, there is a dynamic volatility trade-off (overall) between spending today and tomorrow. In addition, the findings from this study reveal that there is a trade-off between each volatility measure in the loss function; this trade-off is more apparent for consumption. Thus, as the share of the windfall saved in the sovereign wealth fund increases overtime, the interest income accumulated from the assets rises, causing an increase in spending, which in turn raises consumption volatility once again. By contrast, saving a larger proportion of the resource windfall does not increase fiscal volatility but rather lowers fluctuations in the overall primary balance to output ratio. Also, although spending all the resource windfall on consumption and investment creates a lot of volatility in both consumption and the overall primary balance to output ratio, fluctuations in consumption are greater, in general, than fiscal volatility.

It is important to note that if the government is equally concerned about household welfare and fiscal stability, neither the full spending rule nor the full saving rule is the optimal fiscal response to resource windfalls. Saving a fraction of the windfall in a sovereign wealth fund can help to reduce the impact of an increase in resource prices on welfare, and lower fiscal volatility. The share that should be saved will depend on whether the government is concerned about consumption volatility or fiscal stability. In addition, the findings reveal that an increase in new reserves, or a resource production shock, can have similar effects as a temporary rise in commodity prices.[24] This is because both types of shock translate into higher government resource revenues and a wealth effect to the private sector. Therefore, following a resource production shock, it is also optimal for a larger share of the excess revenues to be saved, if the focus is more towards fiscal stability.

According to the optimal rule, if the government of Trinidad and Tobago is relatively more concerned about fiscal stability than household welfare, a larger proportion of the resource windfall should be deposited in the Heritage and Stabilisation Fund. In the case where the government is equally concerned about fiscal stability and household welfare, the optimal rule suggests that about 80 percent of the windfall should be saved—which is greater than the fraction of the excess revenue that the government is mandated to save according to the deposit rule for the Heritage and Stabilisation Fund.[25] Also, considerations should be given for the excess revenue to be deposited into the Fund on an annual (or semi-annual) basis, rather than on a quarterly basis as specified by the Heritage and Stabilisation Fund Act; and the excess revenue should be related to the *actual* rather than estimated petroleum revenue for the period. Furthermore, similar to the deposit rule for the Heritage and Stabilisation Fund, the optimal

[24] This result is similar to a study by Pieschacón (2012) that found new oil discoveries have the same effects as an increase in oil prices and therefore requires a similar fiscal policy response.

[25] The Parliament Republic of Trinidad and Tobago established the Heritage and Stabilisation Fund by an Act in 2007. In practice, implementing this optimal rule requires an amendment to the Heritage and Stabilisation Fund Act, which must be approved by the Parliament.

rule can be applied if actual energy revenues exceed budgeted revenues by at least 10 percent. In the case where the actual revenues exceed the budgeted revenues by less than 10 percent, the authorities can consider the current economic conditions to determine the fraction of the excess revenue (if any) to be saved.

Overall, these findings indicate that fiscal policy can help to mitigate the effects of shocks to resource prices and production. Also, the government of Trinidad and Tobago should review its policy so that a larger proportion of the proceeds from the energy sector is saved. Thus, as posited by van den Bremer and van der Ploeg (2013), in countries where resource income make up a larger share of total income—as in Trinidad and Tobago—it is critical for the size of the liquidity fund (or the stabilization buffer) to be larger.[26] Furthermore, owing to the fact that increases in commodity prices and non-renewable reserves are temporary, the government should (gradually) reduce dependence on surplus resource inflows. This is necessary because of the recent fall in resource revenue—which resulted from both a fall in energy reserves and a decline in world oil prices.

Moreover, the efficiency of public investment spending in Trinidad and Tobago was estimated to be 27.5 percent—which is substantially low for a high-income country (see Dabla-Norris et al. (2012)). In light of the low quality of government investment spending, it can therefore be optimal to save a larger proportion of the windfall gains. Put differently, saving more of the windfall until the efficiency of government spending improves, can help to reduce wastage of the country's natural resource wealth.[27] This finding underscores the importance of governance reforms to improve the efficiency of investment spending, before optimum benefits can be gained from spending a larger proportion of the resource windfall.

Although there have been similar attempts by other researchers to determine the optimal fiscal response of temporary resource windfalls, this study departs from those in the literature because it uses the Dynamic Stochastic General Equilibrium methodology. Nonetheless, the overall findings of this research can be compared to other studies. Similar to Collier et al. (2010) and van der Ploeg (2012), the results show that spending all the revenue from a temporary resource windfall leads to an increase in aggregate demand pressures on the nontraded sector and an appreciation of the real exchange rate. However, van der Ploeg and Venables (2011) found that if the excess resource revenue is not spent on nontradables, the real exchange appreciation and the contraction in the nonresource tradable sector are avoided. In addition, van der Ploeg and Venables (2013) found that optimal revenue management of a resource windfall requires investing in the nonresource tradable sector and building up consumption slowly.

[26] Similarly, the International Monetary Fund (2012a) suggested that resource-rich developing countries should save a high proportion of their resource revenues. This is necessary to delink spending from the dynamics of resource revenue to avoid boom-bust cycles.

[27] If indeed the government were to improve the quality of spending, then it would be optimal to save less. This is corroborated by simulations (which are not reported here) with a higher value for the efficiency of public investment.

This is contrary to the results in this study which show that the optimal fiscal response requires reducing the share of the windfall spent on both consumption and investment, while simultaneously increasing savings.

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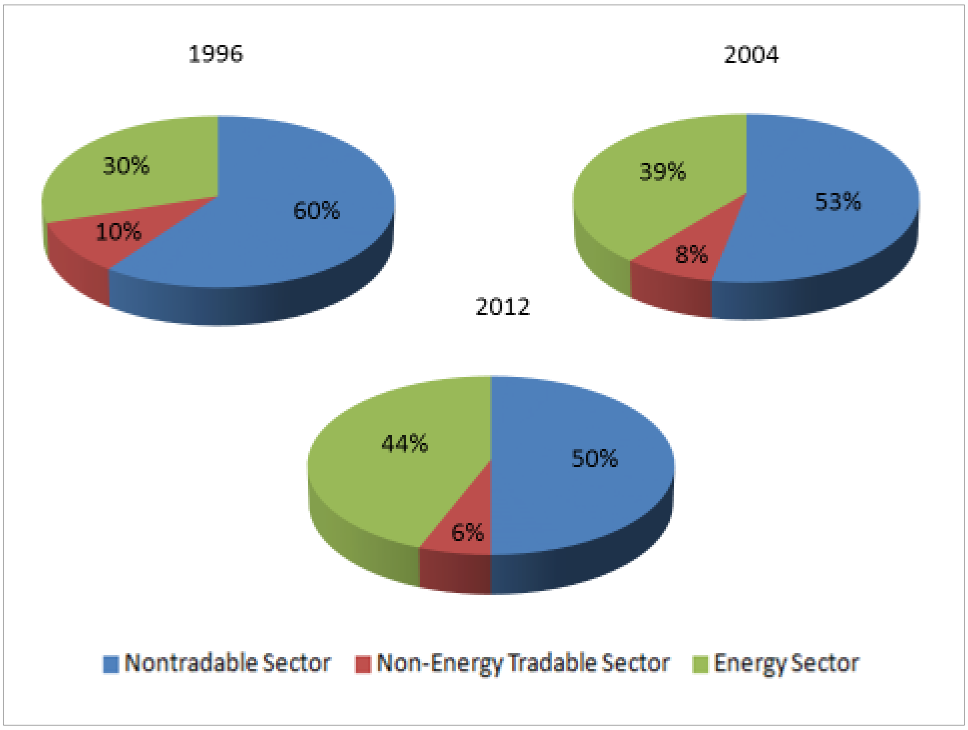
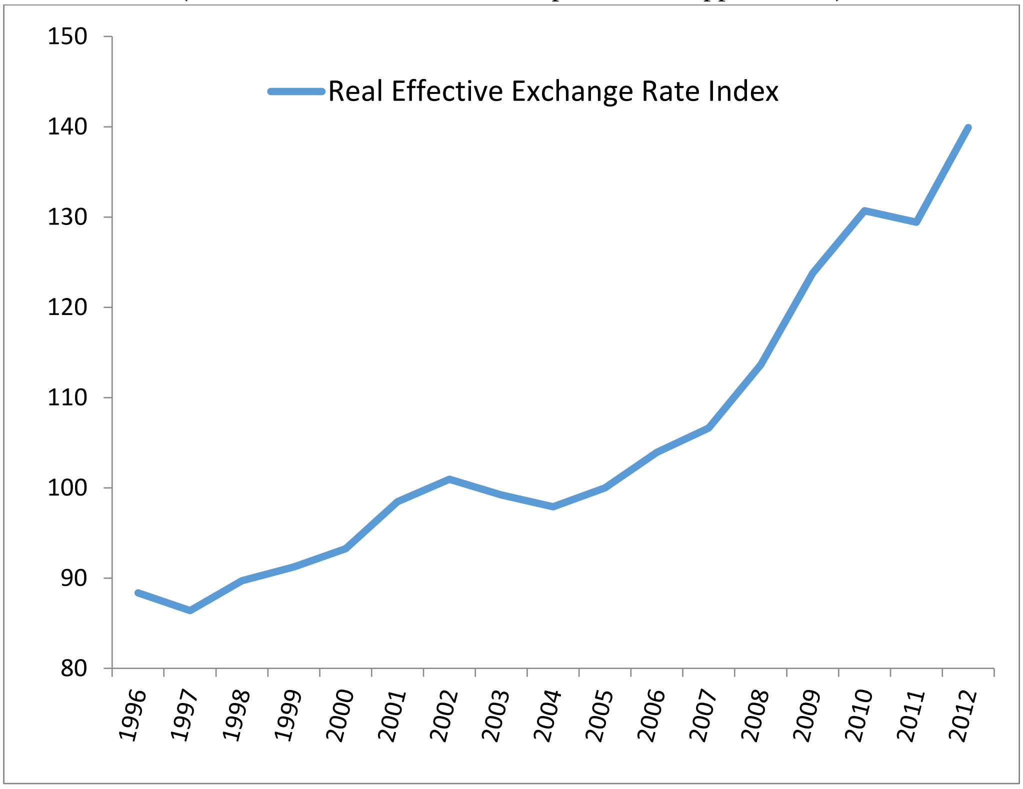
Figure 1. Production Structure in Trinidad and Tobago



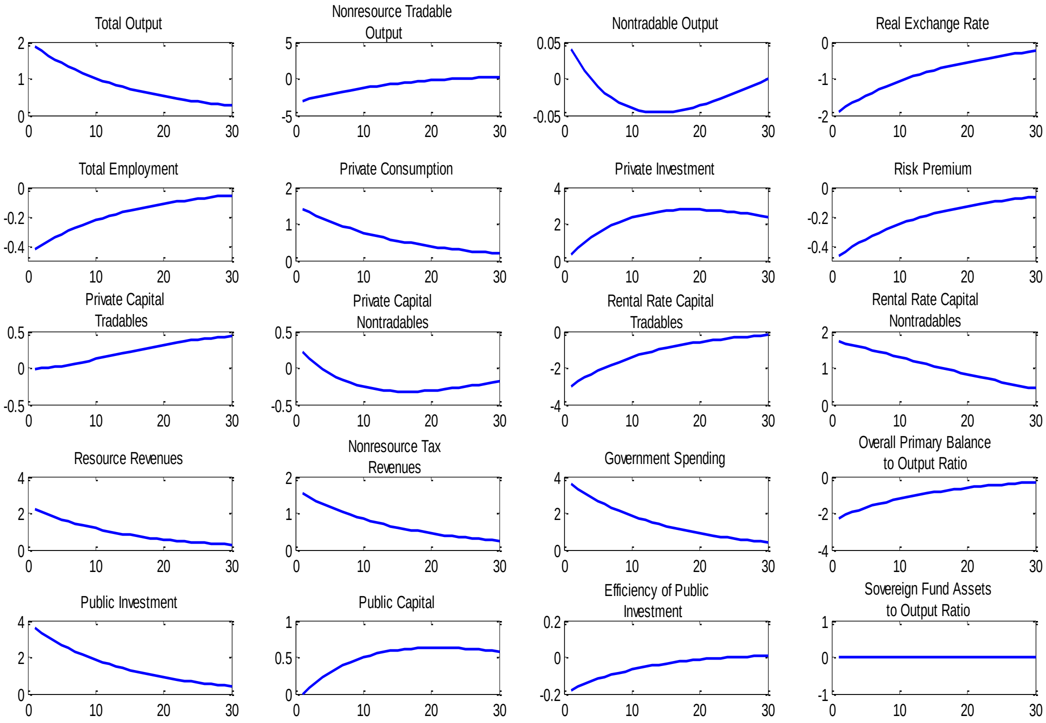
Source: Central Statistical Office of Trinidad and Tobago.

Figure 2. Trinidad and Tobago's Real Effective Exchange Rate
(2005=100; increase in index represents an appreciation)



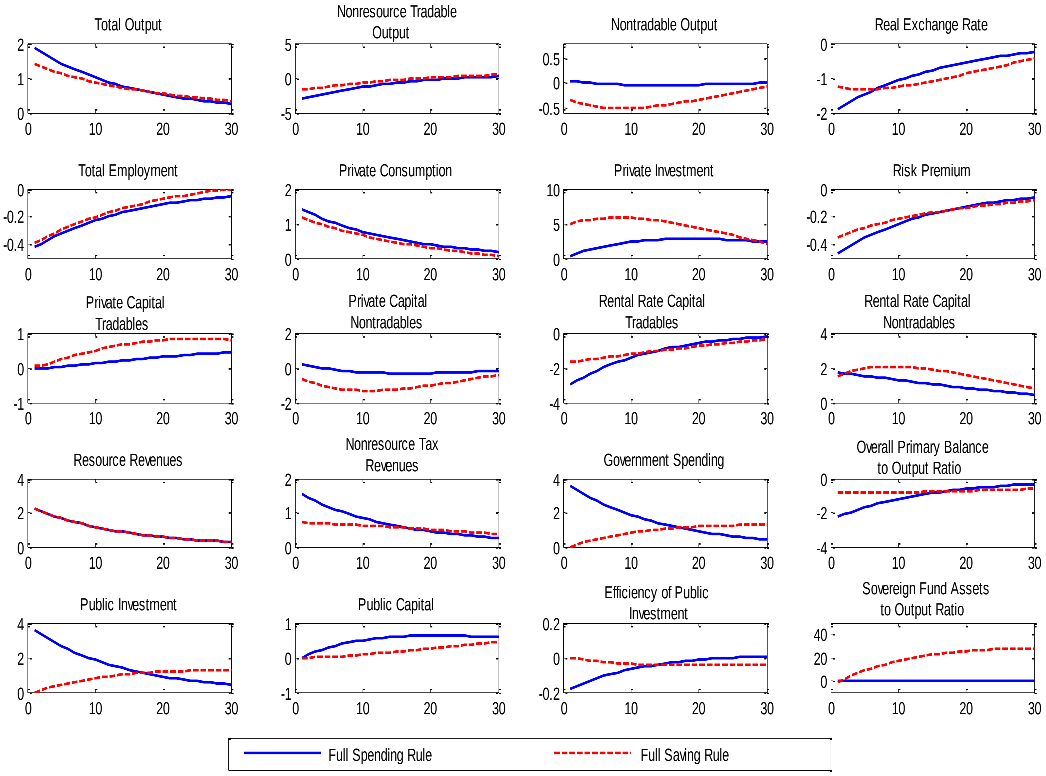
Source: International Monetary Fund Database.

Figure 3. Full Spending of Resource Windfall



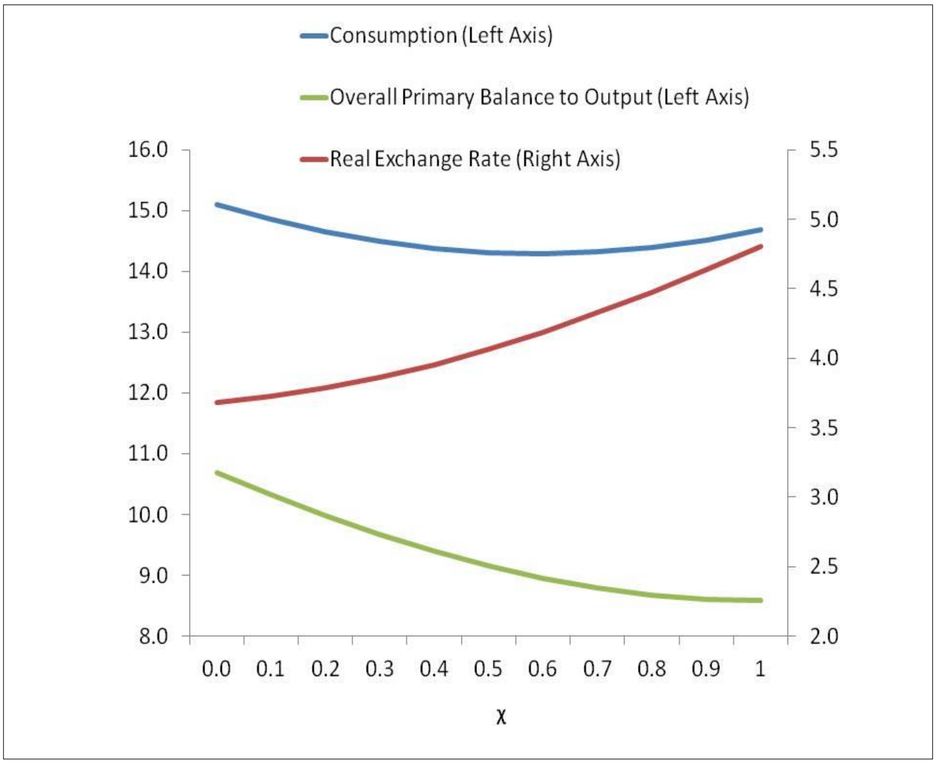
Absolute deviations from baseline, unless otherwise indicated.

Figure 4. Full Saving Experiment versus Full Spending Experiment



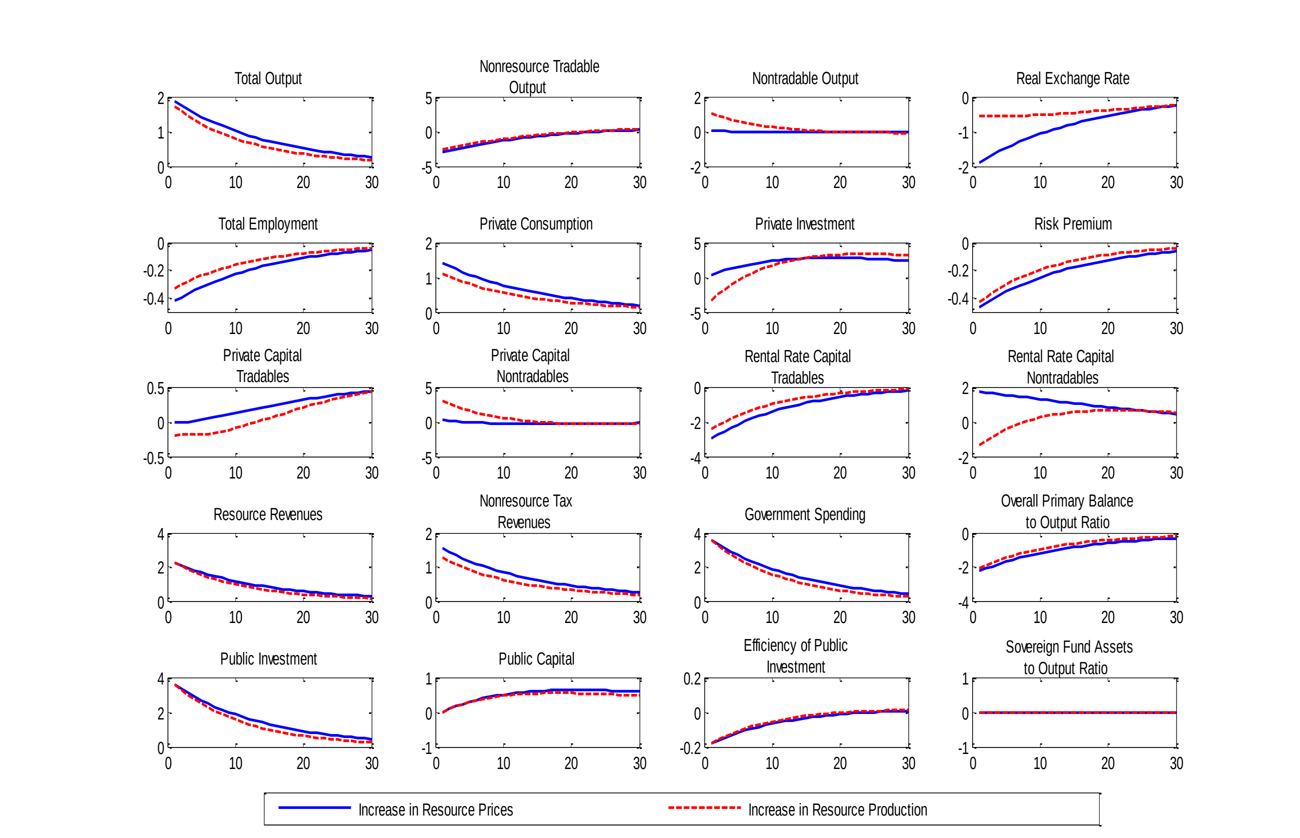
Absolute deviations from baseline, unless otherwise indicated.

Figure 5. Volatility of Consumption, the Real Exchange Rate and the Overall Primary Balance to Output Ratio as a Fraction of the Resource Windfall Saved



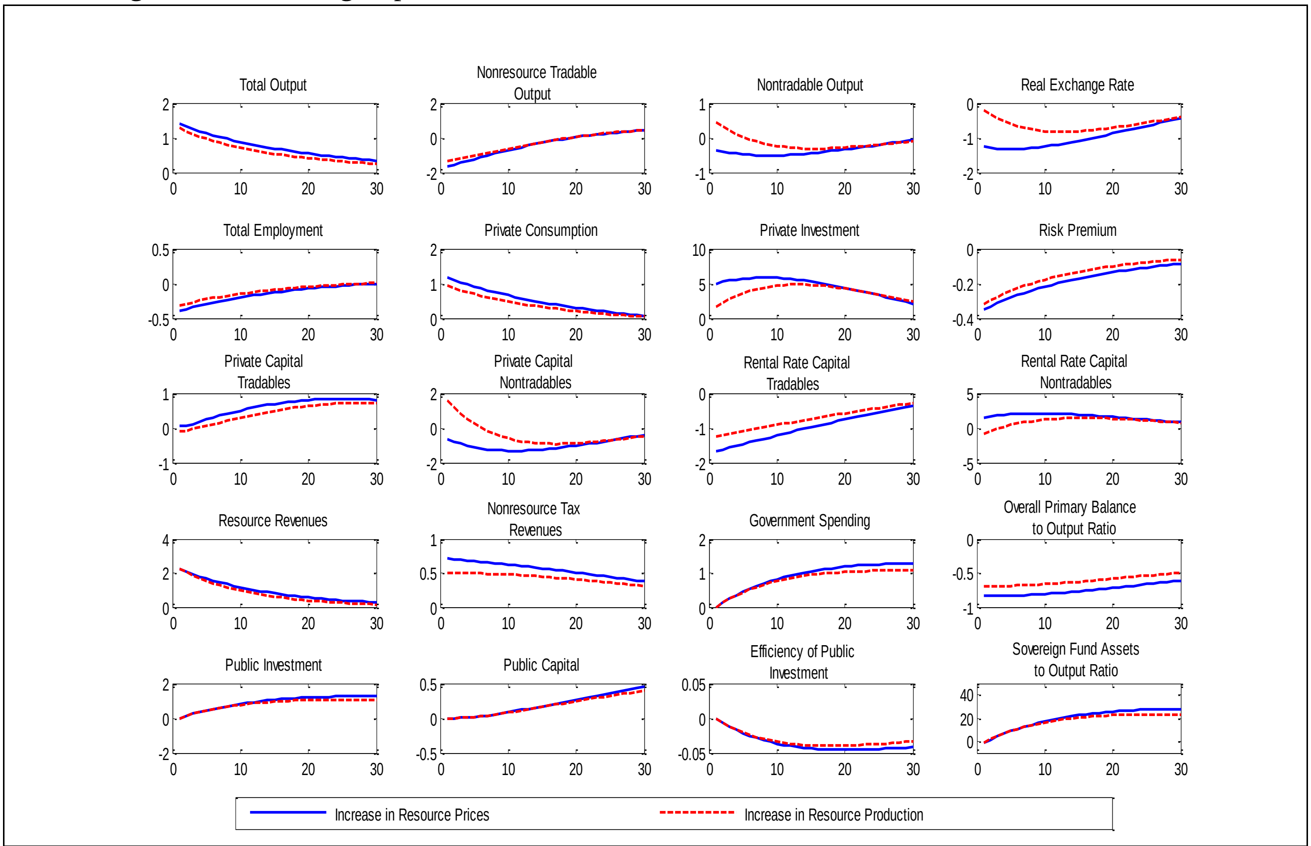
Note: χ represents the share of the resource windfall saved in the Sovereign Wealth Fund.

Figure 6. Full Spending Experiment: Resource Price Shock versus Resource Production Shock



Absolute deviations from baseline, unless otherwise indicated.

Figure 7. Full Saving Experiment: Resource Price Shock versus Resource Production Shock



Absolute deviations from baseline, unless otherwise indicated.

Table 1. Economic Contribution of the Energy Sector (percent, 2000 − 2012)

Item	2000	2003	2006	2009	2012
Energy GDP to Total GDP	31.3	36.0	47.0	34.6	43.7
Energy Revenue to Total Government Revenues*	30.2	42.8	61.9	49.5	54.3
Energy Exports to Total Exports	81.2	83.3	91.1	86.1	81.4
Energy Sector Employment to Total Employment	3.2	3.2	3.5	3.3	3.5

Note: Government revenues only include taxes and royalties paid by companies in the exploration and production business and the refinery business.

Source: Central Bank of Trinidad and Tobago.

Table 2. Calibrated Parameter Values: Benchmark Case

Parameter	Value	Description
Households		
Λ	0.972	Discount factor
ς	0.2	Intertemporal elasticity of substitution
η_L	0.2	Preference parameter, labour in utility function
ψ	12	Inverse of labour supply elasticity
θ	0.55	Share of nontradables in total private consumption
θ^T	0.06	Share of energy products in total tradable consumption
κ	30	Adjustment cost parameter, private investment
δ^P	0.045	Depreciation rate, private capital
ζ_K	0.6	Share of capital in the traded sector
η_K	0.5	Elasticity of substitution between K_t^N and K_t^T
ψ^O	0.884	Share of resource windfall households receive
Resource sector		
ρ^{YO}	0.912	Persistence parameter, resource output
ρ^{PO}	0.93	Persistence parameter, world resource price
Nonresource production		
β, η	0.6,0.65	Labour shares, tradable and nontradable sectors
$\omega_T = \omega_N$	0.17	Elasticity of output with respect to public capital
Government		
τ^O	0.41	Effective tax rate on resource income
τ^{NO}	0.147	Effective tax rate on nonresource income
ψ^G	0.138	Share of government spending on output
υ^G	0.151	Share of spending on infrastructure investment
$\upsilon^{G,N}$	0.41	Share of infrastructure investment on nontraded goods
φ	0.275	Investment efficiency parameter
φ_1	0.05	Absorption constraint parameter, public investment
δ^G	0.035	Depreciation rate, public capital
ϕ_F	0.0110	Management fee on sovereign assets
ν	0.80	Share of management fee paid to residents
World interest rate		
$r^{W,R}$	0.01	World risk-free interest rate
Risk premium		
pr_1	0.25	Elasticity with respect to the debt to output ratio

Table 3. Optimal Allocation of Resource Windfalls under Social Loss Function

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	15.1069	10.6870	11.0633	11.4530	11.8563	12.2739	12.7062	13.1537	13.6169	14.0965	14.5930	15.1069
OPB/Y	10.6870											
χ = 0.1												
C	14.8603	10.3195	10.7027	11.1002	11.5125	11.9400	12.3835	12.8434	13.3204	13.8151	14.3281	14.8603
OPB/Y	10.3195											
χ = 0.2												
C	14.6558	9.9793	10.3703	10.7766	11.1989	11.6376	12.0936	12.5674	13.0598	13.5715	14.1032	14.6558
OPB/Y	9.9793											
χ = 0.3												
C	14.4961	9.6693	10.0689	10.4849	10.9182	11.3694	11.8392	12.3284	12.8379	13.3684	13.9208	14.4961
OPB/Y	9.6693											
χ = 0.4												
C	14.3820	9.3927	9.8015	10.2281	10.6733	11.1379	11.6226	12.1285	12.6564	13.2073	13.7821	14.3820
OPB/Y	9.3927											
χ = 0.5												
C	14.3146	9.1523	9.5709	10.0087	10.4666	10.9453	11.4460	11.9696	12.5171	13.0897	13.6884	14.3146
OPB/Y	9.1523											
χ = 0.6												
C	14.2950	8.9510	9.3800	9.8295	10.3007	10.7943	11.3117	11.8538	12.4220	13.0173	13.6412	14.2950
OPB/Y	8.9510											
χ = 0.7												
C	14.3234	8.7916	9.2314	9.6931	10.1780	10.6871	11.2217	11.7830	12.3724	12.9912	13.6411	14.3234
OPB/Y	8.7916											
χ = 0.8												
C	14.3992	8.6764	9.1273	9.6015	10.1004	10.6253	11.1774	11.7582	12.3691	13.0118	13.6880	14.3992
OPB/Y	8.6764											
χ = 0.9												
C	14.5218	8.6073	9.0694	9.5564	10.0696	10.6103	11.1800	11.7803	12.4129	13.0794	13.7817	14.5218
OPB/Y	8.6073											
χ = 1.0												
C	14.6899	8.5850	9.0588	9.5586	10.0861	10.6427	11.2300	11.8497	12.5036	13.1936	13.9216	14.6899
OPB/Y	8.5850											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; and Rel SD is the Relative Standard Deviation.

Table 4. Optimal Allocation of Resource Windfalls under Generalized Loss Function

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	15.1069	8.6368	9.1335	9.6587	10.2141	10.8015	11.4226	12.0794	12.7741	13.5086	14.2854	15.1069
OPB/Y	10.6870											
Z	3.6843											
χ = 0.1												
C	14.8603	8.4167	8.9091	9.4302	9.9818	10.5657	11.1837	11.8379	12.5303	13.2633	14.0391	14.8603
OPB/Y	10.3195											
Z	3.7247											
χ = 0.2												
C	14.6558	8.2199	8.7093	9.2277	9.7771	10.3591	10.9758	11.6293	12.3216	13.0551	13.8323	14.6558
OPB/Y	9.9793											
Z	3.7838											
χ = 0.3												
C	14.4961	8.0474	8.5352	9.0526	9.6014	10.1834	10.8007	11.4554	12.1499	12.8864	13.6676	14.4961
OPB/Y	9.6693											
Z	3.8609											
χ = 0.4												
C	14.3820	7.9006	8.3884	8.9062	9.4560	10.0398	10.6596	11.3176	12.0163	12.7581	13.5457	14.3820
OPB/Y	9.3927											
Z	3.9550											
χ = 0.5												
C	14.3146	7.7809	8.2700	8.7898	9.3423	9.9296	10.5537	11.2171	11.9221	12.6715	13.4680	14.3146
OPB/Y	9.1523											
Z	4.0647											
χ = 0.6												
C	14.2950	7.6899	8.1817	8.7051	9.2619	9.8543	10.4846	11.1552	11.8688	12.6279	13.4357	14.2950
OPB/Y	8.9510											
Z	4.1890											
χ = 0.7												
C	14.3234	7.6292	8.1253	8.6536	9.2162	9.8154	10.4535	11.1332	11.8570	12.6279	13.4490	14.3234
OPB/Y	8.7916											
Z	4.3265											
χ = 0.8												
C	14.3992	7.6007	8.1022	8.6367	9.2066	9.8140	10.4615	11.1518	11.8876	12.6719	13.5080	14.3992
OPB/Y	8.6764											
Z	4.4761											
χ = 0.9												
C	14.5218	7.6055	8.1137	8.6558	9.2342	9.8511	10.5093	11.2115	11.9606	12.7597	13.6123	14.5218
OPB/Y	8.6073											
Z	4.6365											
χ = 1.0												
C	14.6899	7.6447	8.1607	8.7115	9.2995	9.9271	10.5972	11.3124	12.0759	12.8910	13.7611	14.6899
OPB/Y	8.5850											
Z	4.8067											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Z is the real exchange rate; Rel SD is the Relative Standard Deviation.

Table 5. Social Loss Function: Higher Degree of Capital Mobility [η_K from 0.5 to 0.8]

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	17.8944	11.8762	12.3732	12.8910	13.4304	13.9925	14.5780	15.1880	15.8236	16.4858	17.1756	17.8944
OPB/Y	11.8762											
χ = 0.1												
C	17.6324	11.5393	12.0391	12.5605	13.1045	13.6720	14.2642	14.8819	15.5265	16.1989	16.9005	17.6324
OPB/Y	11.5393											
χ = 0.2												
C	17.4061	11.2271	11.7303	12.2561	12.8055	13.3795	13.9793	14.6059	15.2606	15.9446	16.6594	17.4061
OPB/Y	11.2271											
χ = 0.3												
C	17.2169	10.9416	11.4491	11.9800	12.5356	13.1169	13.7252	14.3617	15.0277	15.7247	16.4539	17.2169
OPB/Y	10.9416											
χ = 0.4												
C	17.0664	10.6851	11.1973	11.7341	12.2967	12.8862	13.5039	14.1513	14.8297	15.5407	16.2857	17.0664
OPB/Y	10.6851											
χ = 0.5												
C	16.9550	10.4596	10.9773	11.5205	12.0907	12.6891	13.3170	13.9761	14.6678	15.3936	16.1555	16.9550
OPB/Y	10.4596											
χ = 0.6												
C	16.8842	10.2672	10.7908	11.3411	11.9195	12.5274	13.1663	13.8378	14.5436	15.2853	16.0648	16.8842
OPB/Y	10.2672											
χ = 0.7												
C	16.8543	10.1098	10.6400	11.1979	11.7851	12.4031	13.0535	13.7380	14.4584	15.2166	16.0145	16.8543
OPB/Y	10.1098											
χ = 0.8												
C	16.8650	9.9892	10.5263	11.0923	11.6887	12.3172	12.9795	13.6774	14.4128	15.1878	16.0045	16.8650
OPB/Y	9.9892											
χ = 0.9												
C	16.9167	9.9065	10.4510	11.0255	11.6316	12.2709	12.9455	13.6571	14.4078	15.1997	16.0353	16.9167
OPB/Y	9.9065											
χ = 1.0												
C	17.0090	9.8626	10.4150	10.9984	11.6144	12.2650	12.9520	13.6774	14.4435	15.2525	16.1068	17.0090
OPB/Y	9.8626											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.

Table 6. Social Loss Function: Lower Share of Management Fee to Residents [ν from 0.8 to 0.5]

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	15.1069	10.6870	11.0633	11.4530	11.8563	12.2739	12.7062	13.1537	13.6169	14.0965	14.5930	15.1069
OPB/Y	10.6870											
χ = 0.1												
C	15.0958	10.3818	10.7779	11.1890	11.6158	12.0589	12.5189	12.9964	13.4922	14.0068	14.5411	15.0958
OPB/Y	10.3818											
χ = 0.2												
C	15.1061	10.1058	10.5203	10.9518	11.4010	11.8687	12.3555	12.8623	13.3899	13.9391	14.5109	15.1061
OPB/Y	10.1058											
χ = 0.3												
C	15.1379	9.8613	10.2931	10.7438	11.2143	11.7054	12.2180	12.7530	13.3115	13.8944	14.5028	15.1379
OPB/Y	9.8613											
χ = 0.4												
C	15.1911	9.6509	10.0988	10.5675	11.0580	11.5712	12.1082	12.6702	13.2582	13.8735	14.5174	15.1911
OPB/Y	9.6509											
χ = 0.5												
C	15.2654	9.4768	9.9395	10.4249	10.9339	11.4678	12.0278	12.6151	13.2311	13.8771	14.5547	15.2654
OPB/Y	9.4768											
χ = 0.6												
C	15.3604	9.3409	9.8172	10.3179	10.8441	11.3971	11.9783	12.5892	13.2312	13.9059	14.6151	15.3604
OPB/Y	9.3409											
χ = 0.7												
C	15.4757	9.2451	9.7338	10.2484	10.7903	11.3607	11.9613	12.5937	13.2595	13.9605	14.6986	15.4757
OPB/Y	9.2451											
χ = 0.8												
C	15.6109	9.1905	9.6906	10.2178	10.7737	11.3599	11.9780	12.6297	13.3168	14.0414	14.8053	15.6109
OPB/Y	9.1905											
χ = 0.9												
C	15.7656	9.1779	9.6882	10.2268	10.7953	11.3954	12.0289	12.6977	13.4036	14.1487	14.9353	15.7656
OPB/Y	9.1779											
χ = 1.0												
C	15.9390	9.2075	9.7269	10.2756	10.8552	11.4675	12.1144	12.7978	13.5197	14.2823	15.0879	15.9390
OPB/Y	9.2075											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.

Table 7. Social Loss Function: Alternative Specification of the Risk Premium

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	12.8598	9.9598	10.2176	10.4821	10.7534	11.0317	11.3173	11.6102	11.9107	12.2190	12.5353	12.8598
OPB/Y	9.9598											
χ = 0.1												
C	12.6499	9.6063	9.8743	10.1499	10.4331	10.7243	11.0235	11.3312	11.6474	11.9724	12.3065	12.6499
OPB/Y	9.6063											
χ = 0.2												
C	12.4906	9.2833	9.5629	9.8509	10.1477	10.4533	10.7682	11.0925	11.4266	11.7708	12.1254	12.4906
OPB/Y	9.2833											
χ = 0.3												
C	12.3838	8.9941	9.2864	9.5882	9.8998	10.2215	10.5537	10.8967	11.2508	11.6165	11.9940	12.3838
OPB/Y	8.9941											
χ = 0.4												
C	12.3309	8.7425	9.0484	9.3650	9.6927	10.0318	10.3828	10.7461	11.1221	11.5113	11.9140	12.3309
OPB/Y	8.7425											
χ = 0.5												
C	12.3324	8.5313	8.8516	9.1838	9.5285	9.8862	10.2573	10.6423	11.0418	11.4563	11.8863	12.3324
OPB/Y	8.5313											
χ = 0.6												
C	12.3884	8.3640	8.6991	9.0476	9.4101	9.7871	10.1792	10.5870	11.0112	11.4523	11.9111	12.3884
OPB/Y	8.3640											
χ = 0.7												
C	12.4983	8.2428	8.5932	8.9584	9.3392	9.7361	10.1499	10.5813	11.0311	11.4999	11.9887	12.4983
OPB/Y	8.2428											
χ = 0.8												
C	12.6606	8.1701	8.5359	8.9181	9.3174	9.7346	10.1705	10.6259	11.1016	11.5987	12.1180	12.6606
OPB/Y	8.1701											
χ = 0.9												
C	12.8732	8.1472	8.5286	8.9278	9.3457	9.7832	10.2411	10.7205	11.2223	11.7476	12.2975	12.8732
OPB/Y	8.1472											
χ = 1.0												
C	13.1339	8.1745	8.5715	8.9877	9.4242	9.8818	10.3617	10.8648	11.3924	11.9456	12.5257	13.1339
OPB/Y	8.1745											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.

Table 8. Social Loss Function: Public Investment of Resource Windfalls

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	27.7916	22.2701	22.7689	23.2788	23.8002	24.3332	24.8782	25.4353	26.0050	26.5874	27.1829	27.7916
OPB/Y	22.2701											
χ = 0.1												
C	29.6041	22.0331	22.6936	23.3739	24.0746	24.7963	25.5396	26.3052	27.0938	27.9060	28.7425	29.6041
OPB/Y	22.0331											
χ = 0.2												
C	31.4967	21.8716	22.6839	23.5265	24.4003	25.3066	26.2465	27.2214	28.2325	29.2811	30.3687	31.4967
OPB/Y	21.8716											
χ = 0.3												
C	33.4551	21.7866	22.7414	23.7380	24.7783	25.8642	26.9976	28.1808	29.4158	30.7049	32.0505	33.4551
OPB/Y	21.7866											
χ = 0.4												
C	35.4690	21.7796	22.8681	24.0110	25.2110	26.4710	27.7939	29.1830	30.6414	32.1728	33.7807	35.4690
OPB/Y	21.7796											
χ = 0.5												
C	37.5292	21.8503	23.0648	24.3467	25.6999	27.1283	28.6361	30.2277	31.9077	33.6812	35.5532	37.5292
OPB/Y	21.8503											
χ = 0.6												
C	39.6286	21.9981	23.3318	24.7463	26.2466	27.8378	29.5255	31.3155	33.2140	35.22765	37.3634	39.6286
OPB/Y	21.9981											
χ = 0.7												
C	41.7612	22.2215	23.6687	25.2101	26.8518	28.6005	30.4631	32.4469	34.5600	36.81062	39.2078	41.7612
OPB/Y	22.2215											
χ = 0.8												
C	43.9222	22.5182	24.0740	25.7373	27.5156	29.4167	31.4491	33.6220	35.9450	38.4285	41.0836	43.9222
OPB/Y	22.5182											
χ = 0.9												
C	46.1076	22.8853	24.5459	26.3269	28.2372	30.2861	32.4837	34.8407	37.3687	40.0802	42.9884	46.1076
OPB/Y	22.8853											
χ = 1.0												
C	48.3142	23.3196	25.0817	26.9769	29.0153	31.2077	33.5659	36.1022	38.8301	41.7642	44.9199	48.3142
OPB/Y	23.3196											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.

Table 9. Social Loss Function: Resource Production Shock

		μ										
VARIABLE	Rel SD	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
χ = 0.0												
C	11.3004	8.9032	9.1181	9.3381	9.5634	9.7941	10.0305	10.2725	10.5203	10.7742	11.0342	11.3004
OPB/Y	8.9032											
χ = 0.1												
C	11.1262	8.5617	8.7890	9.0223	9.2618	9.5077	9.7601	10.0192	10.2851	10.5582	10.8384	11.1262
OPB/Y	8.5617											
χ = 0.2												
C	10.9875	8.2447	8.4849	8.7321	8.9865	9.2484	9.5178	9.7951	10.0805	10.3742	10.6765	10.9875
OPB/Y	8.2447											
χ = 0.3												
C	10.8868	7.9552	8.2087	8.4704	8.7403	9.0189	9.3063	9.6029	9.9089	10.2247	10.5506	10.8868
OPB/Y	7.9552											
χ = 0.4												
C	10.8248	7.6963	7.9633	8.2397	8.5256	8.8214	9.1275	9.4442	9.7719	10.1109	10.4618	10.8248
OPB/Y	7.6963											
χ = 0.5												
C	10.8018	7.4710	7.7516	8.0427	8.3448	8.6582	8.9833	9.3207	9.6708	10.0340	10.4108	10.8018
OPB/Y	7.4710											
χ = 0.6												
C	10.8183	7.2828	7.5767	7.8826	8.2008	8.5318	8.8762	9.2345	9.6073	9.9951	10.3985	10.8183
OPB/Y	7.2828											
χ = 0.7												
C	10.8742	7.1343	7.4414	7.7617	8.0959	8.4444	8.8079	9.1871	9.5826	9.9951	10.4254	10.8742
OPB/Y	7.1343											
χ = 0.8												
C	10.9691	7.0283	7.3482	7.6827	8.0324	8.3980	8.7803	9.1800	9.5979	10.0348	10.4916	10.9691
OPB/Y	7.0283											
χ = 0.9												
C	11.1016	6.9664	7.2987	7.6469	8.0117	8.3938	8.7942	9.2137	9.6533	10.1137	10.5962	11.1016
OPB/Y	6.9664											
χ = 1.0												
C	11.2705	6.9499	7.2942	7.6555	8.0347	8.4327	8.8504	9.2888	9.7489	10.2318	10.7386	11.2705
OPB/Y	6.9499											

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.