Natural-Resource Depletion and Optimal Fiscal Policy: Lessons from Mexico

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Abstract

In a number of oil-exporting countries, oil revenue represents an important share of government revenue. These countries face a challenge from the fact that oil revenue is exhaustible. In this context, fiscal policy represents a key instrument for an optimal wealth distribution between current and future generations. Models based on Friedman's (1957) permanent-income hypothesis (PIH) provide a possible path to ensure a fair intergenerational use of resource wealth. However, although the main insights of these models are sound, they ignore essential features of resource rich countries. In this paper further realism is added by including productive government spending and Dutch disease effects. We find that a higher share of oil revenue should be spend upfront when government spending effects overcome Dutch disease effects. The approach is applied to Mexico.

JEL classification: E6, F43, H5, Q3
Keywords: Resource wealth, optimal saving, endogenous growth, Dutch disease, productive government spending, permanent-income hypothesis

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1 Introduction

When oil prices are high, oil producing countries are characterized by overall fiscal surpluses and non-oil deficits. Large oil revenues generate political pressures to spend a larger share of current income. However, given that oil resources are exhaustible, non-oil deficits may not be sustainable in the long-run. In this context, policy makers face the challenge to adopt a fiscal policy to keep intergenerational equity. Given that oil revenue is exhaustible, it looks optimal to save part of oil revenue for future generations. But, how much should be saved?

The literature on optimal fiscal policy in countries endowed with exhaustible natural resources has typically been based on Friedman's (1957) permanent-income hypothesis. Within this framework, government consumption should be limited to the permanent income [1]. Thus, given that oil is exhaustible, goverment should accumulate enough assets to finance the non-oil deficit once oil revenue dries up. Decisions on the non-oil deficit should be based on assesments of government wealth (including oil wealth), rather than on current oil income. Although the main insights of these models are sound, they ignore essential problems of resource rich countries.

The aim of this paper is to enrich previous models adding particular features of rich resource countries. To be precise, we include productive government spending and Dutch disease effects. We assume that government consumption not only yields utility but also increases productivity. Thus, non-oil GDP will be positively affected by higher government spending. This interpretation of government spending is consistent with the broadly shared view that government spending on social (e.g., health and education) and physical infrastructure raises productivity[2]. This is also the basis for the claim by the governments in resource-rich developing countries that they should spend more of the resource endowment upfront, when the marginal benefit of government spending is likely to be higher than the return from external financial assets.

On the other hand, we also consider Dutch disease effects. The idea behind the Dutch disease is that the exploitation of natural resources shifts production factors from the traded to the non-traded sector. If we consider that most of economic growth is caused by technological progress acquired through learning-by-doing (LBD) which is mainly present in the traded sector, a decline in that sector may lower growth. This has been the most widespread argument for the poor economic performance of resource rich

[1] See, for instance, Davids et al. (2002), Barnett and Ossowski (2003), Segura (2006), Leigh and Olters (2006), Basdevant (2008)

[2] Evidence of a growth-enhancing effect of government spending can be found in Cashin (1995), Miller and Tsoukis (2001), Gupta, et al. (2002), and Kneller, Bleaney and Gemmel (2000).

countries[3]. Thus, the literature based on the Dutch disease argues that the optimal share of national wealth consumed in each period should be adjusted downwards.

To analyze the optimal fiscal policy in a resource-rich country with productive government spending and Dutch disease effects, we follow a similar framework developed by Matsen and Torvik (2005). Government objective is to maximize households' utility, yielded by both households and governemnt consumption, subject to the national wealth. In contrast to Matsen and Torvik (2005), we consider that the dynamics of productivity are not only driven by the traded sector but also by the government spending.

The present model is relevant for a current debate on the need for fiscal rules in resource-rich countries. There is a general agreement on the desirability of accumulating funds to avoid sharp declines in government consumption. Including endogenous effects on productivity growth, our model prescribes a different spending path from what the permanent income hypothesis would imply. On the one hand, productive government spending induces higher spending in the first periods. On the other hand, when LBD is present in the traded sector, it is optimal to postpone the use of oil revenue. Therefore, we find that the optimal spending path will depend on which of these two effects is stronger.

We apply the model to Mexico's economy, where oil revenue is an important share of government revenue. In the last years, oil revenue has accounted for around 35 percent of total government revenue. Thanks to high oil prices, the primary balance of Mexican government reached a surplus of 2 percent of GDP in 2007. However, the non-oil primary balance (the primary balance minus oil revenue) showed a deficit of 3 percent. Given that, if new reserves are not found, oil reserves are to run out in 20 years, is the non-oil deficit sustainable in the long-run? We show that under the permanent-income hypothesis Mexican government should cut the non-oil deficit to around 0.6 percent of non-oil GDP. However, when we analyze Mexican economy in a model with endogenous growth we draw different conclusions. If we consider that LBD is specially present in the Mexican traded sector and public goods are not an important mean for productivity growth, non-oil deficit should be cut more sharply. On the other hand, if there is not LBD differences between the traded and non-traded sector and public goods boost productivity growth, the current non-oil deficit is optimal.

The outline of the paper is as follows. Section 2 presents the main features of Mexican oil sector. Section 3 presents the benchmark model based on the standard permanent income hypothesis. Once the model is

[3]Studies by van Wijnbergen (1984), Sachs and Warner (1995) and Gylfason et. al. (1999) all find that a windfall of natural resource revenue shrinks the traded sector, LBD and thus productivity growth is reduced

solved, it is shown how the economy adjusts to the optimal path when we include habit persistence. We calibrate the model for the Mexico's economy. Section 4 enriches the analysis including endogenous productivity growth. Government consumption and the traded sector drive productivity growth. We also calibrate the model for the Mexico's economy. Section 5 concludes.

2 Oil sector in Mexico

The oil sector is crucial to Mexican economy, oil revenue generates over 10 percent of Mexico's export earnings and accounts for 35 percent of government revenue. Mexico is the sixth largest oil producer in the world and the tenth largest in terms of net exports. However, oil production has declined in the last years. During 2007 oil production averaged 3.08 million barrels per day, 5 percent less than the average production recorded in 2006. The decline is driven mainly by the fall of proven reserves.

Pemex, the state-owned oil company, estimates proven reserves of 14.717 billion barrels of oil. This means that, given current oil production, oil reserves will be over in 10 years. This would provoke a downturn in government revenue, very reliant on oil revenue. Hence, it is highly important to analyze whether current government spending path is both sustainable and optimal in the long-run.

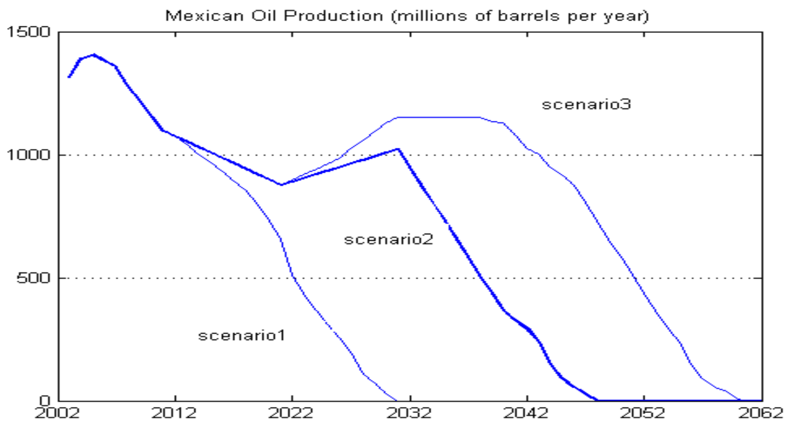
Pemex faces a variety of challenges in its efforts to stem Mexico's oil production decline. Pemex sends a large share of its revenues to the government, this makes difficult to increase spending on exploration and production. In September 2007, Mexico's Congress approved some reforms, including a reduction in the tax rate levied on Pemex, which will allow Pemex increase resources for deepwater exploration. However, even if new oil fields are discovered, oil production could not recover until 2025.

Figure 1 shows three different scenarios for oil production depending on oil reserves. The source is Pemex's annual statistics 2008[4], which based on Securities and Exchange Commission (SEC) divides oil reserves in three categories. In the first scenario only proven reserves are included (14717.2 million barrels). In the second scenario oil fields with a probability of at least 50 percent to be recoverable are added (29861.6 million barrels). In the last scenario less probable reserves are included (44482.8 million barrels). Production path is based on EIA's *International Energy Outlook 2008*, which estimates a decline of oil production until 2025, thereafter, a recovery of production if new reserves are discovered.

Even if new reserves are discovered and oil production can be prolonged 50 years more, given the importance of oil revenue in Mexican economy, it is crucial to analyze how oil revenue should be managed.

[4]Oil reserves statistics can be found on the website www.pemex.com

Figure 1:



3 Benchmark: A Model of Permanent Income and Habit Formation

Following Barnett and Ossowski (2003), we construct a model where the government chooses the optimal size of the primary deficit (the problem is expressed solely in terms of spending, treating the tax rate as exogenous). Government maximizes a social welfare function subject to an intertemporal budget constraint and a transversality condition. The government's problem can thus be written as follows:

$$\max_{G_t} \sum_{s=t}^{\infty} \left(\frac{1}{1+\delta} \right)^{s-t} U(G_s) \tag{1}$$

$$\text{s.t.} \qquad B_t = RB_{t-1} + G_t - T_t - Z_t \tag{2}$$

$$\lim_{s \to \infty} B_{t+s} = 0 \tag{3}$$

where B is government debt, $R = 1 + r$, with r being the long-run interest rate (assumed to be constant) and G_t government expenditure. Non-oil revenue is denoted by T_t and oil revenue by Z_t. The parameter δ is the discount factor. It is assumed that there is not uncertainty about the future.

The first order condition of government's problem yields the following Euler equation:

$$U'(G_t) = \left(\frac{1+r}{1+\delta} \right) U'(G_{t+1}) \tag{4}$$

where $U'(G)$ denotes the marginal utility of government consumption. Assuming that $\delta = r$, it follows that $U'(G_t) = U'(G_{t+1})$. This implies that government spending is constant: $G_t = G_{t+1} = G$. Combining equation (4) with equations (2) and (3) yields the optimal level of government spending:

$$G = T + \frac{r}{R} \sum_{s=t}^{N} \left(\frac{1}{R} \right)^{s-t} Z_s - rB_{t-1} \tag{5}$$

where N is the date at which oil revenue is exhausted. Equation (5) implies that the optimal policy is to smooth government consumption over time.

Introducing non-oil growth does not change the essential form of the solution. Non-oil GDP is now assumed to grow at the exogenous rate $\gamma > 0$. The government's problem is expressed in terms of non-oil GDP. Therefore, $g = \frac{G}{Y}$ is the ratio of spending to non-oil GDP, and the budget constraint becomes

$$b_t = \frac{R}{1+\gamma} b_{t-1} + g_t - \tau_t - z_t \tag{6}$$

where τ denotes the ratio of non-oil revenue to non-oil GDP, and z and b the ratios to non-oil GDP of oil revenue and debt, respectively. Utility is also expressed in terms of non-oil GDP, so that $U = U(g)$. The standard assumption that the interest rate is higher than the non-oil growth rate $(r > \gamma)$ is imposed to keep the sustainability question interesting. Solving the model with non-oil growth, and assuming that $\frac{1}{1+\delta} = \frac{1+\gamma}{1+r}$, government spending path is analogous to the one in equation (5), that is a constant spending level in terms of non-oil GDP:

$$g = \tau + \frac{r-\gamma}{R} \sum_{s=t}^{N} \left(\frac{1+\gamma}{R} \right)^{s-t} z_s - \frac{r-\gamma}{1+\gamma} b_{t-1} \tag{7}$$

Equation (7) implies that the optimal ratio of government spending to non-oil GDP must be constant over time.

As Leigh and Olters (2006), we also look for the consequences of introducing habit persistence into the model. Introducing habits has the advantage of greater realism with regard to the speed at which fiscal policy can adjust. We introduce habits altering the utility function so that current-period utility depends positively on current consumption and negatively on how much was consumed in the previous period. Thus, the utility function becomes $U(g_t, h_t)$, where h_t represents the current stock of habits. Solving the government's problem yields the following Euler equation

$$U^g(g_t, h_t) + \frac{1}{1+\delta} U^h(g_{t+1}, h_{t+1}) = \frac{R}{(1+\gamma)(1+\delta)} \left[U^g(g_{t+1}, h_{t+1}) + \frac{1}{1+\delta} U^h(g_{t+2}, h_{t+2}) \right] \tag{8}$$

where $U^g(g_t, h_t)$ denotes the marginal utility of an additional unit of spending in period t and $U^h(g_{t+1}, h_{t+1})$ the marginal utility of stronger habits in the next period (due to higher spending today). A popular formulation of habit formation in the literature is the "subtractive formulation"[5]

$$U(g_t, g_{t-1}) = V(g_t - \alpha g_{t-1}) \tag{9}$$

where $\alpha \in [0,1]$ denotes habit strength, and the current-period spending, g_t, yields lower utility the stronger the habits, g_{t-1}, i.e. previous spending. Combining the Euler equation (8) with the intertemporal budget constraint yields the following optimal path for government spending:

$$g_t = \left(1 - \frac{(1+\gamma)\,\alpha}{R}\right)\left[\tau + \frac{r-\gamma}{R}\sum_{s=t}^{N}\left(\frac{1+\gamma}{R}\right)^{s-t} z_s - \frac{r-\gamma}{1+\gamma}b_{t-1}\right] + \frac{\alpha}{R}g_{t-1} \tag{10}$$

Equation (10) shows that spending is a linear combination of the last period's level and the one that is permanently sustainable. The higher last period spending, higher will be current-period spending.

3.1 Model Calibration

To simulate the optimal government spending path, we calibrate the model to fit the relevant features of Mexico's economy. To establish the baseline projection for future real oil revenue requires projections for the real oil price and the volume of oil production. The projection for oil prices is based on U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2008*(AEO), which presents two scenarios. In the reference case, real oil price[6] is expected to decline until 2020, thereafter, to increase to 71.7 US dollars per barrel by 2030. In the high price scenario, real oil price is expected to increase continuously, reaching 117.7 US dollars per barrel by 2030 (Figure 2).

For future oil output, we consider the three scenarios explained in the previous section. We take the second scenario as the reference case. The second scenario includes proven reserves and oil fields with a probability of at least 50 percent to be recoverable.

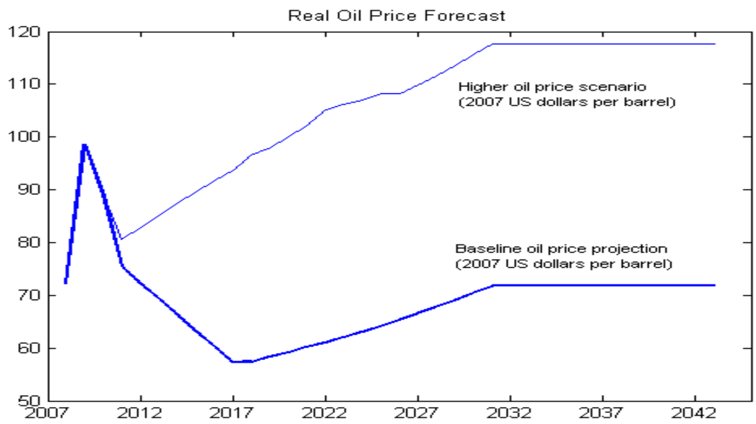
Real oil GDP is obtained multiplying the predicted production volumes by the real price path, net of intermediate consumption (which is assumed to remain constant at level of 22 percent of oil production, which is the average of the period 2000-07[7]). These calculations include a discount for Mexican crude oil relative to the WTI crude price, which is also to remain

[5]see Constantinides (1990), Campbell and Cochrane (1999).

[6]An inflation rate of 2 percent per year is used to convert the oil prices into real terms

[7]Intermediate consumption level is obtained from INEGI's *El Sector Energetico en Mexico 2007*

Figure 2:



constant at 23 percent (equivalent to discount factor averaged in the period 2000-2007). Exchange rate forecasts are based on the Economists outlook for Mexico, which foresees a rate of 12.45 pesos per US dollar in 2008 and 13.14 in 2009; afterwards, the exchange rate is held constant at 13.14 pesos per US dollar. Fiscal oil revenue is based on the Pemex's new tax regime, which estimates a tax rate of around 79 percent of oil GDP[8]. The non-oil tax rate is kept constant at the 2007 level of 17 percent. The real interest rate is set at a standard value of 3 percent. The non-oil growth rate, γ, is set at 2 percent. The habit parameter, α, is set at 0.7, which is within the range of estimates in the literature.

3.2 Results

In this section we simulate the optimal spending path from the 2008. Figure 3 shows the optimal path when there is not habit persistence, and the optimal path for different values of habit persistence. Table 1 presents a range of sensitivity tests on the main parameters in the model.

The main result from the PIH model is that the present non-oil primary deficit is not sustainable in the long-run. In 2007 the non-oil primary deficit was 3.55 percent of non-oil GDP. Under the baseline assumptions, the permanently sustainable non-oil primary deficit is estimated to be 0.60 percent of non-oil GDP. Even if we assume higher oil reserves (scenario 3) and the highest oil price scenario, the sustainable deficit would rise to 1.47 percent of non-oil GDP, still well bellow 2007 level.

[8]For a complete analysis of the new tax regime, see www.pemex.com

Figure 3 shows the optimal path without habit persistence. In order to keep a sustainable spending path in the long-run, Mexico's government should pay off debt and accumulate sufficient financial assets during the oil period. The present 2 percent overall primary surplus should increase to around 6 percent. As oil reserves are exhausted, the primary surpluses decline and converge to the permanently sustainable level of 0.70 percent of GDP.

Figure 3 also shows the optimal path for three alternative values of the habit strength parameter. Strong habits implies a slower adjustment to the permanently sustainable level, however it leads to lower long-run deficits. When we consider a habit strength of 0.8 the government requires 15 years to adjust the primary balance. On the other hand, a habit strength of 0.6 requires 5 years.

Figure 3: Optimal Adjustment Path

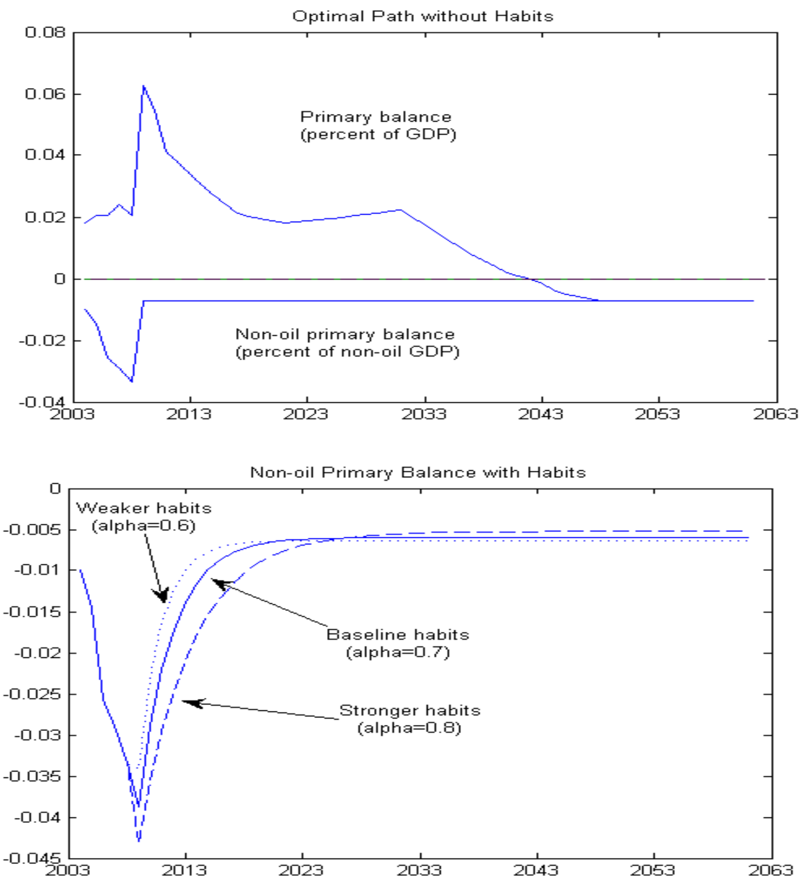


Table 1: Sensivity Analysis

Variable		Value	Sustainable Non-oil Primary Deficit (Percent of non-oil GDP)	
			Baseline Prices	High Prices
Baseline parameters			0.60	1.05
Oil reserves	baseline	Scenario 2	0.60	1.05
	High	Scenario 3	0.84	1.47
	Low	Scenario 1	0.26	0.45
Real interest rate	baseline	$r = 0.03$	0.60	1.05
	high	$r = 0.035$	1.08	1.71
	low	$r = 0.025$	0.07	0.3
Real growth rate	baseline	$\gamma = 0.02$	0.60	1.05
	high	$\gamma = 0.025$	0.32	0.57
	low	$\gamma = 0.015$	0.84	1.46
Habit strenght	baseline	$\alpha = 0.7$	0.60	1.05
	No habits	$\alpha = 0$	0.70	1.14
	high	$\alpha = 0.8$	0.52	0.99
	low	$\alpha = 0.6$	0.64	1.08

4 A model of productive government consumption and Dutch disease effects

4.1 Production

We consider a small open economy that produces four types of goods: non-traded (C_N) and traded (C_T) consumption goods, public good (G) and oil (O). Oil production requires no inputs, and total oil revenue (Z) is appropriated by the government. Consumption and public goods only require labor for production, which is inelastically supplied by households and normalize to unity. Thus the production function of the three goods is given by

$$X_{Nt} = H_t \left(1 - \eta_t - \lambda_t\right) \tag{11}$$

$$X_{Tt} = H_t \eta_t \tag{12}$$

$$X_{Gt} = H_t \lambda_t \tag{13}$$

where X_{N_t}, X_{T_t} and X_{G_t} represent production of non-traded, traded and public goods, respectively. H_t denotes productivity which is equal in all sectors and, η_t and λ_t are the share of labor employed in the traded and public sector, respectively.

The most important assumption in this model concerns what drives productivity growth. Following other models of the Dutch disease as Sachs and Warner (1995), we assume that the labor force employed in the traded sector affects positively productivity. However, we add a second parameter to productivity growth. We consider that public spending has also positive effects on productivity. Thus, the dynamics of productivity H are

$$\frac{H_{t+1} - H_t}{H_t} = \alpha \eta_t + \chi \lambda_t \tag{14}$$

where the parameters $\alpha, \chi \geq 0$ measure the effect of traded and public sector on productivity. The equal productivity in all sectors implies a relative price equal to 1. Plugging (11), (12) and (13) we obtain total production (non-oil GDP):

$$X_t = X_{Nt} + X_{Tt} + X_{Gt} = H_t \tag{15}$$

4.2 Households

The representative household has not access to the capital market, so she consumes all her income. She can neither lend nor borrow. Household's income (Y_t) is composed of after tax labor income and government transfer (R_t),

$$Y_t = (1 - \tau) H_t + R_t = C_t \tag{16}$$

where $C_t = C_{Nt} + C_{Tt}$ is total household consumption which includes non-traded C_N and traded goods C_T. The representative household allocates spending on non-traded and traded goods according to a Cobb-Douglas utility function. Let $\gamma \in (0, 1)$ be the weight on traded goods in the utility function. The demand for non-traded goods is

$$C_{Nt} = (1 - \gamma) Y_t = X_{Nt} \tag{17}$$

the last equality shows that in equilibrium domestic demand of non-traded goods must match the domestic production of such goods.

4.3 Government

The government is the only agent in the economy that has access to the international capital market, so foreign debt B corresponds to public debt. Consequently, the economy's current account matches government budget constraint

$$CA_t = B_{t+1} - B_t = rB_t - X_{Gt} + G_t - X_{Tt} + C_{Tt} - X_{Nt} + C_{Nt} - Z_t$$
$$= rB_t - H_t + G_t + C_t - Z_t = rB_t - \tau H_t + G_t - Z_t + R_t \tag{18}$$

where r is a constant exogenous real interest rate. The first equality in the second row follows from using (15), and the last equality is obtained using (16). Notice that the last equality is the government budget constraint. Government finances public goods (G_t) and tranfers (R_t) through income taxes (τ), oil revnue (Z_t) and debt.

The government role in the economy is to allocate public goods and lump-sum transfers over time. We assume a benevolent government, whose horizon is M periods. When government takes a decision, it considers the effects on future productivity. The objective is to maximize the following households' utility function

$$\max_{G_t, R_t} \sum_{t=1}^{M} \left(\frac{1}{1+\delta} \right)^{t-1} (\Psi \log G_t + \log C_t) \tag{19}$$

subject to the economy's current account (18) and the dynamics of productivity (14). Where the parameter, $\Psi \geq 0$, measures the relative importance of both public and consumption goods.

Following Matsen and Torvik (2005), the problem is more easily analyzed by merging (14) and (18) into one constraint, describing the dynamics of national wealth. At the start of period $t+1$, the national wealth NW is

$$NW_{t+1} = -(1+r)B_{t+1} + \sum_{s=t+1}^{M} \left(\frac{1}{1+r} \right)^{s-(t+1)} H_s + \sum_{s=t+1}^{M} \left(\frac{1}{1+r} \right)^{s-(t+1)} Z_s \tag{20}$$

It includes debt B accumulated through period t plus the present value of current and future income, both non-oil GDP and oil wealth. For later use, we rewrite (20) as

$$NW_{t+1} = -(1+r)\left[(1+r)B_t + G_t + C_t - H_t - Z_t\right] + (1+r)\sum_{s=t}^{M} \left(\tfrac{1}{1+r} \right)^{s-t} H_s - (1+r)H_t$$
$$+(1+r)\sum_{s=t}^{M} \left(\tfrac{1}{1+r} \right)^{s-t} Z_s - (1+r)Z_t = (1+r)(NW_t - G_t - C_t) \tag{21}$$

In choosing the optimal path, government takes into account that the labor employed in the traded and public sector affects future productivity. Using (11), (16) and (17), we find that the traded sector employment is given by

$$\eta_t = 1 - (1-\gamma)(1-\tau) - (1-\gamma)\frac{R_t}{H_t} - \frac{G_t}{H_t} \tag{22}$$

We assume that the public good is non-tradable, so production equals consumption $X_{Gt} = G_t$. Thus, making use of (22), the dynamics of productivity can be written as follows

$$H_{t+1} = aH_t - bR_t + cG_t \tag{23}$$

where

$$a = 1 + \alpha\left[1 - (1-\gamma)(1-\tau)\right]; \quad b = \alpha(1-\gamma); \quad c = \chi - \alpha$$

Equation (23) shows the effects of both government spending and transfers on productivity. On the one hand, government transfers to households have a negative impact on productivity. This effect is the one associated with the Dutch disease. When households enjoy higher income, they raise consumption of traded and non-traded goods. In order to increase the production of non-traded goods, labor must shift from the traded to the non traded sector. Employment in the traded sector is reduced, and thus, productivity growth. The effect is stronger the more important are the non-traded goods in consumers' preference. On the other hand, government spending has an ambiguous effect on productivity. There is a positive effect due to an increase in public spending, and thus, productivity growth. However, this also implies lower employment in the traded sector, and therefore, lower productivity growth. The effect of government spending on productivity will depend on which of the two effects is stronger.

Iterating equation (23), we can write non-oil GDP (or productivity) in period $s > t$ as

$$H_s = a^{s-t}H_t - b\sum_{i=t}^{s-1} a^{s-i-1}R_i + c\sum_{i=t}^{s-1} a^{s-i-1}G_i \tag{24}$$

Combining equations (18), (20) and (24), we can express government wealth in period $t+1$ as

$$\begin{aligned} NW_{t+1} = &-(1+r)\left[(1+r)B_t + G_t + R_t - \tau H_t - Z_t\right] + aH_t \textstyle\sum_{s=t+1}^{M}\left(\frac{a}{1+r}\right)^{s-(t+1)} \\ &-b\textstyle\sum_{s=t+1}^{M}\left(\frac{1}{1+r}\right)^{s-(t+1)}\left[a^{s-(t+1)}R_t + \sum_{i=t+1}^{s-1} a^{s-i-1}R_i\right] \\ &+c\textstyle\sum_{s=t+1}^{M}\left(\frac{1}{1+r}\right)^{s-(t+1)}\left[a^{s-(t+1)}G_t + \sum_{i=t+1}^{s-1} a^{s-i-1}G_i\right] \\ &+\textstyle\sum_{s=t+1}^{M}\left(\frac{1}{1+r}\right)^{s-(t+1)} Z_s \end{aligned} \tag{25}$$

This equation replaces the two constraints (14) and (18) in the government's maximization problem. Notice that government transfers in period t have two effects on national wealth. On the one hand, there is the ordinary effect of lower future wealth; on the other hand, there is a negative effect on future income through lower productivity growth. Similarly, government spending in period t has two effects on national wealth. First, government spending lowers wealth in the next period. Second, there is a positive effect on future wealth through higher productivity growth.

4.4 Optimal government consumption

In this section, we present the optimal solution for the government problem. The government chooses the amount of public good (G_t) and transfer (R_t) to maximize the utility of the representative household (19) subject to the wealth constraint (25).

Proposition 1 *Let*

$$J(NW_t) = \max_{G_t, R_t} \sum_{t=1}^{M} \left(\frac{1}{1+\delta} \right)^{t-1} \left[\log G_t + \Psi \log \left((1-\tau) H_t + R_t \right) \right]$$

subject to (25) and the terminal condition $B_{M+1} = 0$. *Then*

$$J(NW_t) = \phi_t + \Theta_t \log NW_t$$

where

$$\Theta_t = (1+\Psi) \left(\frac{1+\delta}{\delta} \right) \left(1 - \left(\frac{1}{1+\delta} \right)^{M-t+1} \right)$$

and ϕ_t *is an inessential function of time only. Optimal government and household consumption is*

$$G_t = q_t C_t \qquad\qquad C_t = h_t NW_t \tag{26}$$

where

$$q_t = \Psi \frac{1 + \frac{b}{a-(1+r)} \left[\left(\frac{a}{1+r} \right)^{M-t} - 1 \right]}{1 - \frac{c}{a-(1+r)} \left[\left(\frac{a}{1+r} \right)^{M-t} - 1 \right]} \tag{27}$$

$$h_t = \frac{1}{1 + q_t + (\Theta_t - 1 - \Psi) \left[1 + \frac{b}{a-(1+r)} \left(\left(\frac{a}{1+r} \right)^{M-t} - 1 \right) \right]} \tag{28}$$

Proof. See Appendix

Equation (26) relates consumption and public goods. We observe that the ratio of consumption and public goods is mainly determined by three parameters. First, the relative importance of consumption and public goods in the utility function, Ψ. It is clear that when the public good has more weight in the utility function (i.e., higher Ψ), it will be optimal to consume more public goods. Second, the effect of public spending on productivity, χ. A higher share of public goods is consumed when future productivity is positively affected by the public sector. Third, the effect of the traded sector on productivity, α. Combining equations (16) and (23), we observe that households' consumption has a negative impact on productivity. It is optimal to increase the share of public goods with respect to consumption goods for high values of α, that is, when households' consumption has a higher effect on productivity.

Combining equations (21) and (26) it is straightforward to demonstrate that aggregate consumption grows according to

$$\frac{C_{t+1}}{C_t} = (1+r)\, h_{t+1} \left(\frac{1}{h_t} - 1 - q_t \right) \tag{29}$$

in optimum. The optimal consumption growth is time-varying.

Corollary 1 *When the government has an infinite time horizon, $M \to \infty$, and in absence of endogenous growth, $\alpha, \chi = 0$, the optimal consumption growth equals the one of the PIH model, $\frac{C_{t+1}}{C_t} = \frac{1+r}{1+\delta}$.*

Proof. For $\alpha, \chi = 0$ it is straightforward to demonstrate that $q_t = \Psi$. When $M \to \infty$, $\Theta_t = (1+\Psi)\left(\frac{1+\delta}{\delta}\right)$, and thus, h_t is given by

$$h_t = \frac{\delta}{(1+\Psi)(1+\delta)} \tag{30}$$

which is a constant. Plugging this value into equation (29), and simplifying gives

$$\frac{C_{t+1}}{C_t} = \frac{1+r}{1+\delta} \tag{31}$$

4.5 Model Calibration

To simulate the optimal government spending and transfer path, we calibrate the model to fit the relevant features of Mexico's economy. Oil revenue is calculated as in section 3. In the benchmark simulation, we consider the baseline oil price projection and the second scenario of oil production. The real interest rate (r) and the discount factor (δ) are set at a standard value of 3 percent. The non-oil tax rate (τ) is kept constant at the 2007 level of 17 percent.

The parameter Ψ is set at 0.15. This implies that, in absence of endogenous growth, households' consumption is around 6.5 times government consumption, which matches the observed values in Mexico's economy. Similarly, we set γ at 0.46, which corresponds to the share of non-traded goods in consumption expenditures in the Mexican CPI basket.

In the benchmark simulation, we start with a moderate effect of the public and traded sector on productivity, setting α and χ at 0.4 percent.

Finally, each time period is one year and the government has a planning horizon of 100 years, i.e., $M = 100$.

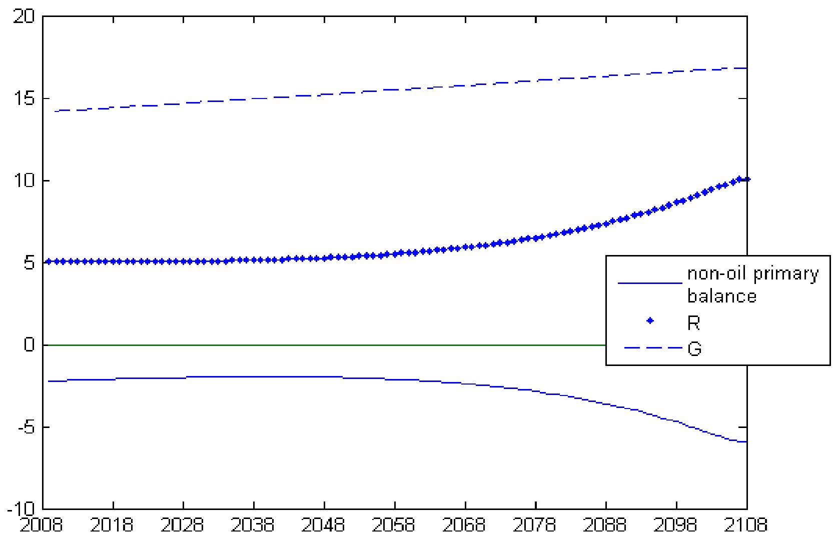
4.6 Results

In this section, we simulate the optimal path under different growth scenarios. We analyze how government decisions are influenced by the growth parameters α and χ. We observe that high values of α lead to postpone the use of national wealth, in order to avoid the Dutch disease. On the other hand, high values of χ lead to make use of national wealth upfront, and thus, benefit from the productive government spending.

4.6.1 Benchmark simulation

Figure 4 shows the optimal path of government spending, transfers and the non-oil primary balance, given the baseline parameters ($\alpha, \chi = 0.4\%$). Simulating the optimal path, three main results emerge.

Figure 4: Optimal paths under baseline parameters



First, government transfers to households grow over time, particularly in the last periods. It is optimal to transfer part of the resource wealth to households, however this is lower in the first periods. This result is the optimal respond to the Dutch disease. Government transfers imply higher demand (and supply) of non-traded goods, and thus, a movement of labor from the traded to the non-traded sector. In order to avoid large productivity falls due to a smaller traded sector, transfers are kept low in the first periods. The negative impact of transfers on future productivity is lower over time, hence we observe an increase of transfers in the last periods.

Second, government spending grows over time. Given that government spending affects positively productivity growth, we could expect higher spending upfront, so households would benefit from higher productivity in the future. However, government spending also has a negative effect; it lowers employment in the traded sector, and thus, productivity growth. Under the baseline parameters this two effects counteract. Equation (23) shows the dynamics of productivity growth. When the parameters α and χ have the same value, the effect of government spending on productivity is null.

Third, given the baseline scenario, Mexican economy can afford non-oil primary deficits in the next 100 years. It is optimal to spend relatively little of the resource wealth while oil production is active, and thus, accumulate enough foreign assets to keep the non-oil deficit once oil revenue dries up. Given that government spending has not effect on productivity, it is optimal to save a share of the resource wealth for the future, and thus avoid the Dutch disease.

4.6.2 Without Growth

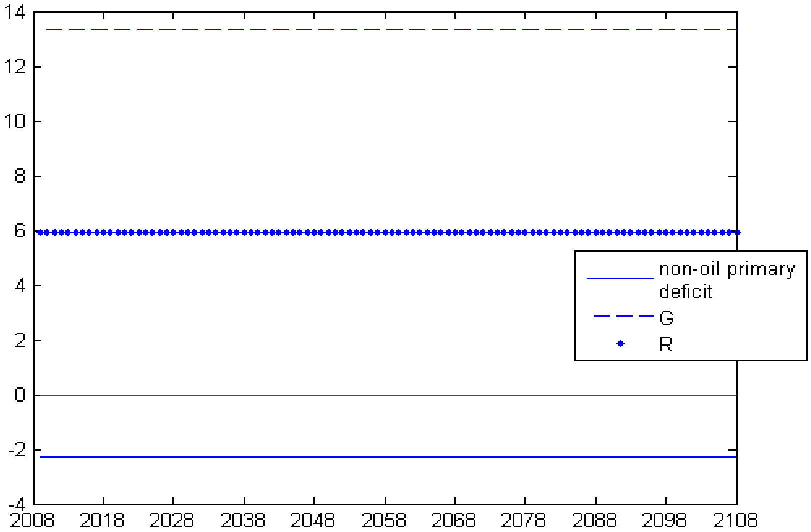
To put these results into perspective, we display the corresponding paths in a non-growing economy ($\alpha, \chi = 0$) in Figure 5. Without growth, government distributes national wealth homogeneously over time. This implies that a share of oil revenue has to be saved while oil production runs on. Given baseline oil projections, the optimal non-oil primary deficit is slightly above 2 percent of non-oil GDP[9].

In contrast with the baseline simulation, where transfers grow over time, the non-growing economy shows constant transfers from the government to households. Without a productive traded sector, there is no need to avoid the Dutch disease, so transfers are kept constant at 6 percent of non-oil GDP.

Without endogenous growth, the choice between consumption and public goods depends solely on the marginal utility of both goods. The optimal share of consumption and public goods is, thus, determined by the parameter Ψ.

[9] Notice that the non-oil primary deficit is higher than in the PIH model. This is because the time horizon is 100 years instead of infinity

Figure 5: Optimal paths without growth



4.6.3 Only one source of growth

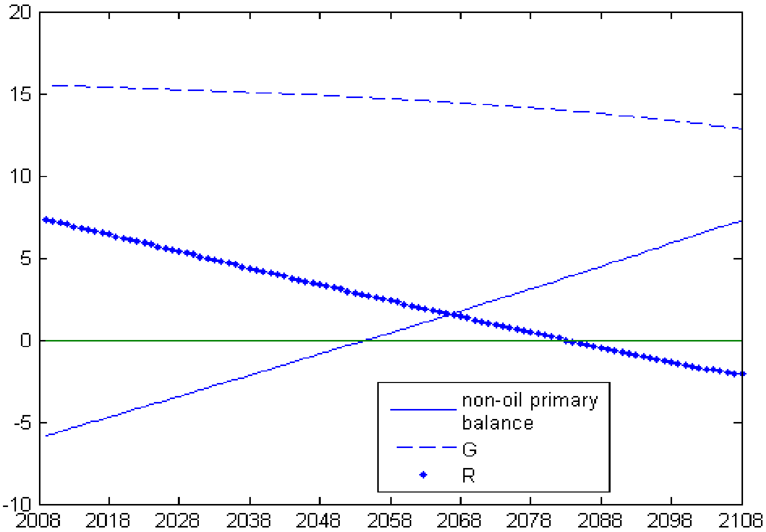
We now analyze the optimal paths when productivity growth is driven by either public sector or traded sector. The first case implies $\alpha = 0$ and $\chi = 0.4\%$, and it is showed in Figure 6. The second case implies $\alpha = 0.4\%$ and $\chi = 0$, and it is showed in Figure 7.

When government spending has a positive effect on productivity growth, the government has incentives to spend national wealth upfront (Figure 6). In this case, there are not negative consequences from a smaller traded sector, since this does not affect productivity. The government raises spending in public goods in the first periods, and thus, households benefit longer from higher productivity in the future. The increase in public goods leads to a rise in transfers. In order to keep equal the marginal utility of consumption and public goods (Equation 26), the government transfers a share of the national wealth to households, so that, they can raise consumption.

The implications for the non-oil primary balance are straightforward. The economy shows large deficits in the first periods, which are repaid in the last periods, when productivity is higher.

Figure 7 displays the case where productivity growth is only driven by the traded sector. Under this scenario, the government has incentives to reduce both government spending and transfers in the first periods. As we

Figure 6: Optimal path with productive government spending



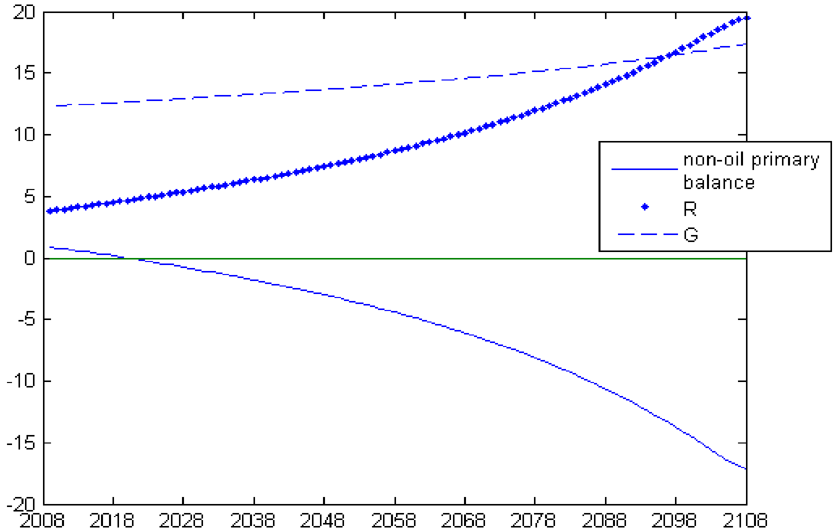
have explained above, government transfers to households lead to higher demand of the non-traded goods, and thus, a decline of the traded sector. Similarly, government spending moves employment from the traded to the public sector. In order to avoid a decline of the traded sector in the first periods, and therefore, lower productivity levels in the future, government save a large share of national wealth, and spends it in the last periods, when the effect on productivity is shorter.

The consequences are that the optimal non-oil balance path exhibits a surplus in the first 10 periods. The largest share of national wealth is spend in the last periods, when there is shorter impact on productivity. The economy would reach a deficit of 17 percent of the non-oil GDP in the last period.

5 Conclusion

The literature on the optimal use of exhaustible resources is mainly based on the permanent-income hypothesis. Little attention has been drawn to two important aspects of resource rich countries. First, the fact that resource abundance may shift factors of production away from sector generating learning by doing (Dutch disease). Second, the claim that government

Figure 7: Optimal path with Dutch disease effects



spending enhances productivity growth, particularly in developing countries, so that a larger share of the resource endowment should be spent upfront. In this paper, we have included these two aspects to add more realism to the normative analysis. In contrast with previous models based on the permanent-income hypothesis, we find that a constant government spending rule is not always optimal. When public goods are the main factor which drives productivity growth, we find that the optimal spending path decreases over time. In opposition of PIH models, a higher share of natural wealth should be use in the first periods, and thus, households would benefit from higher productivity in the future. On the other hand, when the traded sector is the main factor which drives productivity growth, the optimal spending path grows over time. In order to avoid a large shift of production away from the traded sector, government saves a higher share of natural wealth in the first periods.

Our analysis is applied to Mexican economy. Firstly we have analyzed Mexican economy under a PIH model. We find that the 2007 non-oil deficit (3 percent of the non-oil GDP) is above the optimal level prescribed by the PIH model (0.7 percent of the non-oil GDP). Consequently, there is a need to adjust the economy to a sustainable level. However, it does not look optimal to adjust the spending path in one period under the realistic assumption that there exist adjustment costs (or habits). Hence, we enrich the PIH model including habits, and find that the optimal policy involves an adjustment over 5 to 10 years.

Analyzing the Mexican economy under a model with endogenous growth, different conclusions are drawn with respect to the PIH model. Currently, Mexico can afford a non-oil deficit higher than the level prescribed by the PIH, when we consider that government spending is the main factor driving productivity growth. Mexico should spend a large share of its oil revenue, and consequently do not save it for future generations, since these will benefit from higher productivity. We reach opposite results when we consider that the traded sector is the main factor driving productivity growth. A higher share of oil revenue should be saved for future generations not only to benefit them from current oil revenue but also to avoid a decline in productivity. Therefore, in order to draw a final conclusion about the optimal non-oil balance path in Mexico, it would be necessary to know the real impact of the public and the traded sector on the Mexican economy.

In assessing the optimal fiscal policy we have focused on the fact that oil revenue is exhaustible. We have not taken into consideration an important feature of oil revenue, volatility. Uncertainty about future income would imply higher savings, what is known as precautionary saving. We could consider two sources of uncertainty, oil reserves and prices. One avenue for future research would involve considering this feature.

References

[1] Auty, R. M. (2001a), "The political economy of resource-driven growth", European Economic Review, 46, 839-846.

[2] Barnett, S. and R. Ossowski (2003), "Operational Aspects of Fiscal Policy in Oil-Producing Countries", in Fiscal Policy Formulation and Implementation in Oil-Producing Countries ed. by J. Davis, R. Ossowsky and A. Fedelino, Washington: International Monetary Fund, pp.45-81.

[3] Basevant, O. (2008), "Are diamonds forever? Using the permanent income hypothesis to analyze Botswana's reliance on diamond revenue", Working Paper No. 08/80, International Monetary Fund, Washington D.C.

[] Campbell, J. and J. Cochrane (1999), "By Force of Habit: A Cosumption Based Explanation of Aggregate Stock Market Behavior", Journal of Political Economy, 107(2), pp. 205-251.

[] Constantinides, G. (1990), "Habit Formation: A Resolution of the Equity Premium Puzzle", Journal of Political Economy, Vol. 9, pp. 519-543.

[4] Cashin, P. (1995), "Government Spending, Taxes, and Economic Growth", IMF Staff Papers, Vol. 42(2), pp. 237-269.

[5] Corden, W.M., J.P. Neary (1982), "Booming Sector and de-industrialisation in a small open economy", Economic Journal 92, 825-848.

[6] Davis, J., R. Ossowski, J., Daniel and S. Barnett (2002), "Stabilization and Saving Funds for Non-Renewable Resources: Experience and Fiscal Policy Implicaions", IMF Occasional Paper No. 205, International Monetary Fund, Washington D.C.

[7] Friedman, M. (1957), "A Theory of the Consumption Function", Princeton University Press.

[8] Gupta, S., B. Clements, E. Baldacci and C. Mulas-Granados (2002), "Expenditure Composition, Fiscal Adjustment, and Growth in Low-Income Countries", IMF Working Paper No. 02/77, International Monetary Fund, Washington D.C.

[9] Gylfason, T. (2001), " Natural resources, education, and economic development", European Economic Review 45, 847-859.

[10] Gylfason, T., T. T. Hebertsson and G. Zoega (199), "A mixed blessing: natural resources and economic growth", Macroeconomic Dynamics, 3, 204-225.

[11] Hartwick, J. (1977), "Intergenerational equity and the investing of rents from exhaustible resources", American Economic Review 67, 972-991.

[12] Kneller, R., M. Bleaney and N. Gemmell (1999), "Fiscal Policy and Growth: Evidence from OECD Countries", Journal of Public Economics, Vol. 74, pp. 171-190.

[13] Leigh, D. and J. Olters (2006), "Natural resource depletion, habit formation, and sustainable fiscal policy: lessons from Gabon", IMF Working Paper WP/06/193, International Monetary Fund, Washington D.C.

[14] Matsen, E. and Torvik (2005), "Optimal Dutch Disease", Journal of Development Economics, 78, 494-515.

[15] Miller, N.J. and C. Tsoukis (2001), "On the Optimality of Public Capital for Long-run Economic Growth: Evidence from Panel Data", Applied Economics, Vol. 33, pp. 1117-1129.

[16] Obstfeld, M., and K. Rogoff (1996), "Foundations of International Macroeconomics" MIT Press, Cambridge, MA.

[17] Sachs, J. and A. Warner (1995), "Natural resource abundance and economic growth", NBER Working Paper no. 5398.

[18] Sachs, J. and A. Warner (2001), "The curse of national resources", European Economic Review, 45, 827-838.

[19] Segura, A. (2006), "Management of oil wealth under the permanent income hypothesis: the case of Sao Tom and Prncipe", Working Paper No. 06/183, International Monetary Fund, Washington D.C.

[20] Takizawa, H., E. Gardner and K. Ueda (2004), "Are Developing Countries Better Off Spending Their Oil Wealth Upfront?" IMF Working Paper 04/141, International Monetary Fund, Washington D.C.

[21] Van Wijnbergen, S. (1984), "The Dutch Disease: A Disease After All?", The Economic Journal, vol. 94, no. 373, pp.41-55.

6 Appendix

Proof. For the proposed value function J_t, the Bellman optimality equation is

$$\phi_t + \Theta_t \log NW_t = \max_{G_t, R_t} \left[\log\left((1-\tau) H_t + R_t\right) + \Psi \log G_t + \frac{1}{1+\delta} \left(\phi_{t+1} + \Theta_{t+1} \log NW_{t+1}\right) \right] \tag{32}$$

subject to (25). The first-order conditions can be written as

$$R_t: \qquad C_t^{-1} = \frac{\Theta_{t+1}}{1+\delta} \left[(1+r) + b \sum_{s=t+1}^{M} \left(\frac{a}{1+r} \right)^{s-(t+1)} \right] NW_{t+1}^{-1} \tag{33}$$

$$G_t: \qquad \Psi G_t^{-1} = \frac{\Theta_{t+1}}{1+\delta} \left[(1+r) - c \sum_{s=t+1}^{M} \left(\frac{a}{1+r} \right)^{s-(t+1)} \right] NW_{t+1}^{-1} \tag{34}$$

Dividing equation (30) by (31), we obtain the optimal ratio of consumption and public goods

$$\frac{G_t}{C_t} = \Psi \frac{(1+r) + b\sum_{s=t+1}^{M}\left(\frac{a}{1+r}\right)^{s-(t+1)}}{(1+r) - c\sum_{s=t+1}^{M}\left(\frac{a}{1+r}\right)^{s-(t+1)}} = \Psi \frac{1 + \frac{b}{a-(1+r)}\left[\left(\frac{a}{1+r}\right)^{M-t} - 1\right]}{1 - \frac{c}{a-(1+r)}\left[\left(\frac{a}{1+r}\right)^{M-t} - 1\right]} \equiv q_t \tag{35}$$

Making use of this expression and substituting for NW_{t+1} from equation (21), we rewrite equation (30) as

$$C_t = \frac{1}{1 + q_t + (\Theta_t - 1 - \Psi)\left[1 + \frac{b}{a-(1+r)}\left(\left(\frac{a}{1+r}\right)^{M-t} - 1\right)\right]} NW_t \equiv h_t NW_t \tag{36}$$

Substituting for C and G in (29) gives

$$\begin{aligned}
&\phi_t + \Theta_t \log NW_t = \\
&\log(h_t NW_t) + \Psi \log(q_t h_t NW_t) + \tfrac{1}{1+\delta}\left\{\phi_{t+1} + \Theta_{t+1} \log\left[(1+r)(1 - h_t - h_t q_t)NW_t\right]\right\} \\
&= \left(1 + \Psi + \tfrac{\Theta_{t+1}}{1+\delta}\right) \log NW_t + \log h_t + \Psi \log(q_t h_t) + \tfrac{\phi_{t+1}}{1+\delta} \\
&+ \tfrac{\Theta_{t+1}}{1+\delta} \log\left[(1+r)(1 - h_t - h_t q_t)\right]
\end{aligned} \tag{37}$$

Thus, the values for Θ_t and ϕ of the proposed value function are

$$\Theta_t = 1 + \Psi + \frac{\Theta_{t+1}}{1+\delta} \tag{38}$$

and

$$\phi_t = \log h_t + \Psi \log(q_t h_t) + \frac{\phi_{t+1}}{1+\delta} + \frac{\Theta_{t+1}}{1+\delta} \log\left[(1+r)(1 - h_t - h_t q_t)\right]$$

A general value for Θ can be obtained observing that $Theta_{M+1} = 0$. Thus, $Theta_M = 1 + \Psi$, $\Theta_{M-1} = 1 + \Psi + \frac{\Theta_M}{1+\delta}$, etc. Iterating equation (35) we obtain

$$\Theta_t = (1+\Psi)\left(\frac{1+\delta}{\delta}\right)\left(1 - \left(\frac{1}{1+\delta}\right)^{M-t+1}\right) \tag{39}$$

Applying in (33) gives

$$h_t = \frac{1}{1 + q_t + (\Theta_t - 1 - \Psi)\left[1 + \frac{b}{a-(1+r)}\left(\left(\frac{a}{1+r}\right)^{M-t} - 1\right)\right]} \tag{40}$$