WPS6597

Policy Research Working Paper 6597

Efficiency and Equity Implications of Oil Windfalls in Brazil

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Latin America and the Caribbean Region
Poverty Reduction and Economic Management Unit
September 2013

Abstract

Large oil reserves off the coast of Brazil may substantially increase the country's oil revenue in the future. A natural resource "curse" could be the consequence if an appropriate share of the oil revenue is not invested. This issue is addressed in this paper for Brazil both theoretically and empirically by focusing on (i) the *efficient allocation* of oil revenue between investment and consumption; and (ii) because it may be efficient to consume a certain share of the oil revenue, the *distributional implications* across generations of higher public consumption. The main finding is that, if the Pre-Salt oil revenue brings the aggregate oil revenue in Brazil above 10 percent of gross domestic product, there will be scope for consuming a certain share of it while still maintaining efficiency. But unless oil revenue reaches 10 percent or more of gross domestic product, then all of it should be invested in order for the economy to approach the efficient investment level. If oil revenue as a share of gross domestic product was 10 percent, then the achievable growth in gross domestic product could reach 9.0 percent. The distributional implications are positive for all generations, but vary across generations depending on how much of the oil revenue is invested. As a result, transfer policies could be adjusted to ensure equality in its distribution.

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EFFICIENCY AND EQUITY IMPLICATIONS OF OIL WINDFALLS IN BRAZIL[1]

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JEL Classification: E22, O13, O31, Q33.

Keywords: Brazil; Natural Resources; Oil Revenue; Efficiency; Equity; Population Aging; Saving.

[1] This paper was written for the World Bank Study *Pre-Salt Oil Discoveries and the Long-Term Development of Brazil* by Pablo Fajnzylber and Daniel Lederman. The main parts of the paper were written when the author worked for Economic Policy, PREM in the World Bank. Insightful comments to this and the other papers prepared for the report *Pre-Salt Oil Discoveries and the Long-Term Development of Brazil* was provided at the authors' workshop in Washington D.C. on March 25, 2011. The author is grateful for valuable comments to the paper provided by Eduardo Engel, Norman Loayza, Pablo Fajnzylber, Daniel Lederman, Tito Cordella, Eduardo Haddad, Constantino Hevia, and Guilherme Lichand. Those comments have been incorporated in the paper. Michiel Paris and Tammy Pertillar provided valuable research and assistance. The views in this paper are entirely those of the author and do not necessarily represent the views of the World Bank, its executive directors, or the countries they represent.

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1 Introduction

The 2006 discovery of large oil reserves off the coast of Brazil may substantially increase the country's oil revenue. A natural resource "curse" could be the consequence if the oil revenue is consumed, because that could crowd out the capital stock. It is possible, however, to achieve a resource "blessing" if an appropriate share of oil revenue is invested. This issue is addressed in this paper for Brazil both theoretically and empirically by focusing on two main questions: (i) What is the *efficient allocation* of oil revenue between investment and consumption? And (ii), since it may be efficient to consume a certain share of the oil revenue, what are the *distributional implications* across generations?

Most mineral producing countries fail to maintain incentives for savings and investment after positive resource shocks. As Sachs and Warner (2001) argue, the resource curse is most likely associated with the crowding-out effects of natural resources on several growth determinants. There are at least four main areas of explanation in the literature of why resource dependency has resulted in sluggish economic performance: (i) Dutch disease; (ii) institutions; (iii) investment; and, (iv) policy failures. A large body of literature, by now, focuses on the disappointing economic performance of resource affluent countries across the world — a tendency that became renowned as the "resource curse" hypothesis (Gylfason, 2000, 2001; Leite and Weidmann, 1999; Papyrakis and Gerlagh, 2004; Rodriguez and Sachs, 1999; Sachs and Warner, 1995, 1997, 1999, 2001).

The first branch of the literature argues that countries rich in natural capital such as oil, minerals, fish banks and agriculture tend to grow at a slower pace compared to resource-scarce countries (Papyrakis and Gerlagh, 2006). The second branch of the literature argues that resource abundance negatively affects long-term income by crowding out several of its determinants. Resource windfalls may for instance decrease entrepreneurial activity (Torvik, 2002; Mehlum et al., 2006), private employment (Robinson et al., 2006), and formal labor (Olsson, 2007). The innovative work in this area by Lederman and Maloney (2010) relative to trade patterns has also been influential.

Corden (1984) also suggests that resource rich countries tend to suffer from currency overvaluations and loss of competitiveness, enhanced corruption, and rent-seeking (Krueger, 1974; Torvik, 2002); bad-decision making (Sachs and Warner, 1999; Auty, 2001)' political instability (Collier and Hoeffler, 1998); low levels of educational quality (Gylfason, 2001); and low capital investment (Atkinson and Hamilton, 2003). Papyrakis and Gerlagh (2004) claims that the last-mentioned channel is most important in explaining the resource curse phenomenon. In Papyrakis and Gerlagh (2006), and in this paper, we describe a mechanism to explain this transmission channel, focusing on the role of resource abundance in crowding-out savings by enhancing future income.

The positive role of investment in economic development has been well documented in the literature (Grier and Tullock, 1989, Kormendi and Meguire, 1985, Levine and Renelt, 1992, Sachs and Warner, 1997). Natural resource wealth is believed to decrease the need for savings and investment, since natural resources provide a continuous stream of income wealth that makes future welfare less dependent on capital accumulation (Papyrakis and Gerlagh, 2004). Furthermore, recent empirical research has identified the crowding out impact of resource abundance on investment rates and consequently on economic growth. Papyrakis and Gerlagh (2004) estimated that 40 percent of the total negative impact of mineral income on economic growth is attributed to the investment channel.

Papyrakis and Gerlagh (2006) developed a simple mechanism to explain why resource windfalls are likely to lower income levels in the long run. They provided a theoretical justification to the empirical observation that resource-dependent countries generally do not reinvest resource rents in other forms. In that way, the decline in income may more than offset the increase in resource revenues, when we take account of the decrease in savings and the responsiveness of technology to investment. Their analysis focuses on the savings-investment transmission channel through which resource rents affect welfare. They use an overlapping generations (OLG) model to study the mechanism, where savings adjust downwards to income from natural resources, investments adjust to savings, and subsequently the level of overall productivity falls.

Natural resources are not harmful to growth or income per se but they tend to crowd out several income-supporting activities. Countries that maintain such activities are likely to convert the resource impact from a curse to a blessing. Norway, for instance, managed to catch up with its richer Scandinavian neighbors in the 1970s–1980s following its oil discoveries and maintained faster growth for most of the period thereafter (Røed Larsen, 2005). Usui (1997), on the other hand, claims that Mexico's underperformance after its oil boom was related to the policy bias towards current spending rather than capital investment. Resource booms also reallocate factors of production from the manufacturing sector to the primary sector. Since it is often the manufacturing sector that is characterized by increasing returns to scale and positive externalities, this shift in production factors reduces productivity and profitability of investments (Sachs and Warner, 1995, 1999; Gillis et al., 1996).

As another mechanism, Atkinson and Hamilton (2003) show that governments often spend resource rents on public consumption. The few countries that use resource rents for public investment projects are those that have avoided the resource curse. Lange (2004), for example, claims that Namibia — and the majority of resource-abundant countries — liquidate rather than reinvest their resource revenues and therefore find themselves on a development path of declining welfare. On the other hand, in a few cases where a prudent investment of resource revenues takes place (as in the case of Botswana), people relish a higher level of wealth over time (Lange and Wright, 2004).

The first regression of Table 1 (taken from Papyrakis and Gerlagh, 2006) illustrates the negative relationship between natural resources and income for a sample of 82 countries. The dependent variable is the natural logarithm of GDP per capita in 2002 (LnY2002), while we use the share of natural capital in total wealth in 1994 (NatK94) as a proxy for resource abundance. There is a significant negative statistical association between the two variables. A 1 percent share of natural resources in the total capital stock is associated with a 7 percent lower income level. An increase in the natural capital share by a standard deviation (0.11) is associated with a decrease of the natural log of income by 0.84, which implies a decrease in income of 57 percent.

Table 1 depicts how natural capital is strongly and negatively associated with both savings and investment in physical capital. Regression (2) depicts the strong negative correlation between natural capital and savings. Regression (5) extends the correlation to investment. Indeed, countries that save less tend to invest less, as regressions (8) and (9) demonstrate. The former regression shows the positive correlation between investment and saving for the largest sample available of 141 countries, while the latter regression leaves out small countries with less than one million inhabitants. These small countries are atypical, as they need to be more open to foreign investments and often have a larger share of public investment in GDP to support basic infrastructure in telecommunications, airports, etc., which are needed irrespective of the size of the economy.

Table 1. Natural Wealth is Crowding Out Saving and Investment Leading To a Resource Curse

	Dependent Variables								
	Ln Y_{2002}	Savings (Sav_{94})			Investment (Inv_{94})				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$NatK_{94}$ (0.11)	-7.62***	-0.39***		-0.22***	-0.18***		-0.19***		
	(-7.86)	(-5.20)		(-2.29)	(-3.40)		(-2.70)		
Aid_{94} (0.17, 0.18, 0.17, 0.18)			-0.27***	-0.19***		0.04	-0.02		
			(-5.61)	(-3.11)		(0.73)	(-0.46)		
Sav_{94} (0.09)								0.24***	0.38***
								(3.26)	(7.13)
Constant	9.29	0.23	0.21	0.23	0.23	0.23	0.24	0.18	0.15
R^2 adjusted	0.43	0.24	0.21	0.3	0.11	0	0.13	0.06	0.29
N	82	83	115	63	83	110	63	141	121

Source: Papyrakis and Gerlagh (2006). Note: Standard deviations for independent variables in parentheses. For Aid variable, standard deviations refer to regressions (3), (4), (6) and (7), respectively; t-statistics for coefficients in parentheses. Superscripts *, **, *** correspond to a 10%, 5% and 1% level of significance. Data on natural capital and GDP per capita are provided by the World Bank.

Motivated by existing literature and the recent discoveries of the Pre-Salt oil fields in Brazil, this paper aims to contribute to the literature by adding the possibility, in the context of Brazil, for government to choose how much of the oil revenue it will devote to public investment and public consumption, respectively. This has not before been attempted, to our knowledge, in the literature.

Existing literature has assumed that all oil revenue has been consumed by the government — which therefore, naturally, leads to a resource curse since capital is crowded out. However, maybe by investing merely a relatively small fraction of oil revenue the government can escape the resource curse; maybe by investing the full amount of oil revenue can even promote growth and welfare; and, finally, maybe the effect on different generations could be positive at the same time if oil revenue to some extent is invested. These are crucial questions that have not before been formally addressed in the economic literature.

A dynamic OLG model is developed in this paper that is capable of analyzing the *efficiency–equity* implications. A key policy relevant relationship is stressed: The efficient investment-share depends endogenously to the manner in which the government chooses to consume whichever share that is not invested. The model incorporates natural resource revenues in a new way, by combining existing approaches with an approach of public investments of revenues that directly stimulates capital accumulation. This framework will be combined with a version of the model that features population growth, productivity growth, and life expectancy

The distribution across generations is complicated by a crucial long term factor — namely the macroeconomic implications of population aging. Aging will disrupt the efficient allocation of natural resources since the capital-labor ratio is bound to increase and saving rates will change endogenously. As a result, the distribution of natural resource revenues will also change endogenously. Given that Brazil is operating relatively generous social security system, this further influences these allocations, and policies would need to balance efficiency with equity when facing the opportunity of natural resource windfalls and the challenge of population aging.

It is the aim of this paper to addresses mainly two questions: (i) What is the *efficient allocation* of oil revenue between investment and consumption in Brazil? And (ii), since it may be efficient to consume a certain share of the oil revenue, what are the *distributional implications* across generations? While addressing these questions, the paper also provides strong insights to the implications of the (Pre-Salt) oil revenue on how to escape the resource curse; on income growth; and on how these dynamics are affected by population aging in shaping Brazil's macroeconomic future.

A key finding is that, if the Pre-Salt oil revenue brings the aggregate oil revenue in Brazil up to, or above, 10 percent of GDP, there will be scope for consuming a certain share of it. In fact, if oil revenue increases to 10 (12) percent of GDP, then 2 (13) percent of oil revenue can be used for public consumption while still maintaining efficiency. However, if the Pre-Salt discoveries drive aggregate oil revenue to a level below 10 percent of GDP, then 100 percent of the oil revenue should be invested — leaving nothing for public consumption. The higher oil revenue is, the larger the increase in the income growth rate — provided that the efficient share of oil revenue is invested. For example, if oil revenue as a share of GDP was 5 (10) percent, then the additional achievable income growth would be 4.9 (9.0) percent. Furthermore, it is found that investing merely 1 percent or more of aggregate oil revenue could lead to a resource blessing.

In terms of the distributional implications across generations, the increased oil revenue, and the subsequent investments, could drive the capital stock towards its efficient level — and reach it if oil revenue reaches 9.7 percent (almost 10 percent) of GDP — but that would also alter factor prices. Depending on the size and openness of Brazil's economy, the wage and interest rates could change and affect the consumption and welfare of the population. It is found that if no oil revenue is invested, but rather fully used for public consumption distributed equally across generations, then retirees would tend to gain more than workers; but both generations gain from such a transfer policy. On the other hand, if some of the oil revenue is invested, then workers would gain more than retirees. As a result, there are social implications of the public policy adopted to allocate oil revenue — but the transfer policy could always be adjusted to ensure equity in its distribution.

The paper proceeds as follows: Section 2 presents the OLG model that is extended from existing literature to include the potential choice between investing vs. consuming the aggregate oil revenue — combined with the actual presence of oil revenue and population dynamics in one unified framework. Section 3 reveals the empirical (comparative statics) results in the context of Brazil, focusing on the drivers of a potential resource blessing rather than a curse; the thresholds that oil revenue must reach in order to leave efficient room for public consumption out of oil revenue; the growth implications of different policies for investing or consuming oil revenue given how much oil revenue might be available according to different scenarios for Pre-Salt oil production; the distributional implications across generations; and, finally, the consequences of studying these macroeconomic effects of changes in stocks of natural resources in the context of an aging population. Section 4 concludes.

2 The Model

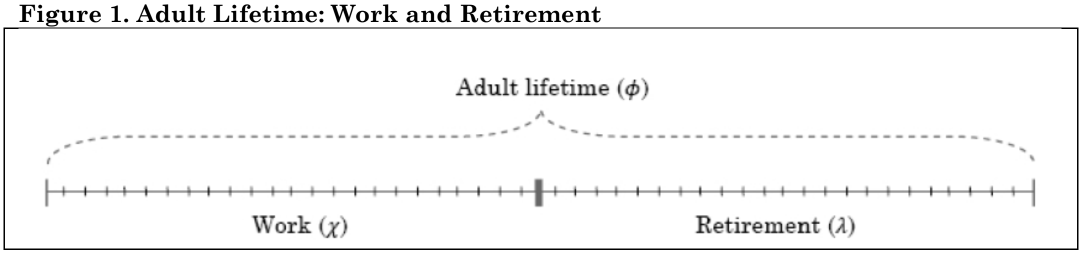
In this section the analytical framework is presented. The model is a general equilibrium model with overlapping generations (OLG) in line with Jorgensen and Jensen (2010) and Jorgensen (2011), but here augmented by two features that, in combination, deliver novel economic dynamics. The model consists of different building blocks: Exogenous natural resource (oil) revenue, demographics, households, production, as well as a public sector that has two functions: (i) to manage a PAYG pension system, and (ii) to efficiently and equitably allocate oil revenue between investment and consumption.

The model will illustrate the economic dynamics in the context of Brazil when the economy experiences exogenous shocks to oil revenue and population aging — since, over the long term, these two developments are likely to coexist and jointly give rise to changes in households" economic behavior and call for policy responses from the government. Each block of the model is first described, after which the solution method is outlined.[3]

2.1 Demographics

Individuals are assumed to be identical across cohorts, and to live for two periods: as adults and elderly, respectively. Workers in period t is denoted as N_t, where the growth rate of the labor force is defined as is standard, $N_t = (1+n_t)N_{t-1}$ where $n_t > 0$ is the population growth rate (i.e. the growth rate of the labor force is therefore given by the fertility rate in the previous period). Workers are assumed to exogenously supply labor for the full length of period t. During period $t+1$ they are retired with no supply of labor whatsoever. A fall in the fertility rate in the previous period thus implies a shrinking labor force in the present period. Figure 1 illustrates how adult lifetime is divided between work and retirement periods, respectively.

Figure 1. Adult Lifetime: Work and Retirement



Source: Jorgensen (2010)

In a standard OLG framework, the working period, t, and the retirement period, $t+1$, are assumed to be equally long. In reality, however, the length of the two periods might differ considerably. For example, if the statutory retirement age increases, the share of life spent working goes up, provided that the total lifetime is unchanged. In order to allow for such a difference in the length of the two generational periods, we follow the standard practice of considering the overall time periods, t and $t+1$, as aggregate "supra-periods" divided into fractional "sub-periods".

[3] For more details on the derivations, I refer to the appendix which is available upon request.

A similar technique has been applied by Auerbach and Hassett (2007), Bohn (2001, 2002), Chakraborty (2004), Jorgensen and Jensen (2010), and Jorgensen (2011), The supra-periods are assumed to adjust to have the same lengths as the generational periods of work and retirement; the sub-periods of the total length of life, ϕ, merely may not be distributed equally across supra-periods, but consists of an unchanged total number of sub-periods.[4]

The separation point between supra-period t and supra-period $t+1$ is interpreted as an exogenous (statutory) retirement age where an agent changes status from having completed χ working sub-periods in supra-period t to entering a retirement supra-period $t+1$ consisting of λ sub-periods. Since this paper will not deal with changes in the statutory retirement age (in order to keep the focus on other government policies) the value of χ is assumed to be of unity ($\chi \equiv 1$). As a result, χ is not presented in the derivations below. Changes to the longevity (i.e. life expectancy) is equivalent to changing the value of ϕ, indicating that the change in ϕ would fall entirely on the length of the retirement period. As a result, $\Delta\lambda_t = \Delta\phi_t$, and I will use λ to denote the length of life in the following.

Since the model will be solved for steady state dynamics only — for the purpose of comparative statics analyses for Brazil — the length of life and population growth rate are assumed to be deterministic.

2.2 Public Sector

In a rather unorthodox manner, the model description will already at this stage describe the government sector since the appearance of oil revenue in this sector will determine much of the subsequent model presentation. The government is assumed to have two main functions:

1) To allocate revenues from the sale of natural resources, such as oil, between capital investments and consumption. The capital investments are assumed to be injected straight into the capital stock while the share of oil revenue that is prioritized for consumption is divided among the population according to the type and scale of distribution the government finds more efficient and equitable.

2) To manage the PAYG pension system by collecting contributions from workers and paying benefits to retirees. The system must balance contributions with benefits, but the government is assumed to operate with a fixed benefit rate and a flexible contributions rate which is under government control. Each of the two systems embodies more details which will be described in the following two subsections.

[4] A supra-period could be defined to include any given number of smaller sub-periods without loss of consistency with the overall OLG model structure (Figure 1); all sub-periods remain of exactly the same length. Alternatively, the whole life could be considered as one single supra-period consisting of a number of sub-periods. The categorization into supra-periods is merely necessary in order to match the differential behavior of generations in their working and retirement periods with equivalent lengths of period *t* and *t+1* irrespective of how many sub-periods each supra-period consists of. A change in the length of a generational period will, therefore, be accompanied by an equivalent change in the supra-period by simply changing the number of sub-periods a given supra-period consists of. This implies that two generations could be on the labor market simultaneously, which extends the extensive margin of labor supply as we structure the model.

2.2.1 Natural Resource Revenue

Natural resource revenues are henceforth called oil revenue – even though natural resource revenues could come from any type of natural resource thinkable. Oil revenue, O_t, is assumed to equal a share q_t of national non-oil income, Y_t, and 100 percent of the revenue is assumed to accrue to the government as oil revenue in line with (1).[5]

$$O_t = q_t Y_t \tag{1}$$

The government is assumed to have to choice for how to spend its oil revenue: It can either invest it or consume it. The investments are assumed to be "injected" directly into the physical capital stock, which could be thought of as investments in infrastructure or capital spending on schools, hospitals, or the like. The remaining share of the oil revenue is assumed to be consumed by transferring the income to the population, i.e. workers and retirees at a given point in time.

In case the government wants to transfer the income in an unequal manner across workers and retirees, the share of oil revenue that accrues to workers is κ, while retirees receive $1-\kappa$. However, κ signifies that if $\kappa = 1$ then there is complete equality in the transfers across generations; if $\kappa > (<)\ 1$, then workers (retirees) receive a larger share than retirees (workers). In that way, the government can adjust for any other economic effects that may alter the equity of government transfers to each generation. In case, the government wishes to distribute the income equally across generations, then each person, workers and retirees alike, will receive the same amount.

The share of investment in oil revenue is γ, while the share of investment that goes to consumption is $1-\gamma$, according to (2) and (3) where (4) ensures that all oil revenue is accounted for.

$$G_t^I = S_t^G = \gamma O_t \tag{2}$$

$$G_t^T = (1-\gamma) O_t \tag{3}$$

$$O_t = G_t^I + G_t^T \tag{4}$$

In addition, the public investments is also their capital saving, S^G, in the given period, which will become important in the aggregation of privately and publicly accumulated capital in section 2.4. In order to distribute the transfers across generations (equally or not) depends on the population growth rate, n. Taking population growth into consideration yields the transfers by generation in (5)-(7):

$$T_{1t} = \left(\frac{\kappa + n}{2+n}\right) G_t^T \tag{5}$$

[5] For example, 2 percent of non-oil national income could be oil revenue. In reality, it is not always the case that 100 percent of oil revenue accrues to the government, but this is assumed for simplification purposes. Alternatively, the share q could merely be interpreted as the oil revenue that accrue to the government while the remaining revenue, *1-q*, is absorbed as revenue by private firms.

$$T_{2t} = \left(\frac{1+(1-\kappa)}{2+n} \right) G_t^T \tag{6}$$

$$G_t^T = \left(\frac{\kappa + n}{2+n} \right)(1-\gamma)O_t + \left(\frac{1+(1-\kappa)}{2+n} \right)(1-\gamma)O_t = (1-\gamma)O_t \tag{7}$$

which collapses to $G_t^T = (1+n)/(2+n)G_t^T + G_t^T/(2+n) = (1-\gamma)O_t$ if transfers are made equally to each member of the population, where the reason why workers are scaled by $1+n$ while retirees are only weighted *one-to-one* is due to the fact the population, i.e. the labor force, is growing at the rate *n*.

Importantly, the manner in which oil revenues are distributed across generations is not trivial. In Papyrakis and Gerlagh (2006), for example, oil revenue could only be consumed (i.e. transferred to) by generations who then consume it. In their main illustration, all the revenue was transferred to retirees, who did not save and fraction of it. Thereby, no capital accumulation was generated by the transfer of oil revenue; in fact, quite the opposite happened since current workers now anticipated such transfers in old age, so they subsequently reduced their savings to optimize consumption over their lifetime. This means that Papyrakis and Gerlagh (2006) indirectly assumed that none of the oil revenue was invested – which naturally crowds out the capital stocks and leads to a "resource curse".

Papyrakis and Gerlagh's alternative transfer-scheme, illustrated in their appendix, showed how a completely equal distribution across generations led to savings by workers. However, they still did not combine this scenario with either the possibility for public investments of some of the oil revenue and nor the possibility of the government to distribute the royalties unevenly across generations in case other simultaneous shocks would affected the wellbeing of different generations differentially.

A more appropriate approach, in my opinion, is to combine the different choices of the government — especially since the literature clearly states that consumption of oil revenues may lead to rent seeking and corruption and, this, crowding out of public saving. And, also because other shocks – possibly several others – occur in economies simultaneously, so an adjustment factor in the distribution of transfers is important as an instrument for intergenerational redistribution.

This paper offers an approach that can encompass the dynamics of the "full-consumption of oil revenue" approach that Papyrakis and Gerlagh (2006) offers, but also incorporates the possibility for the government to invest some of the oil revenue and transfer the rest with whichever weight on different generations it deems appropriate and efficient. The novel approach offered here facilitates an analysis of these elements:

- *Which allocation of oil revenue is (dynamically) efficient?* The share, γ, of oil revenue that is invested can be derived given the economy's characteristics. In the case of Brazil, the decentralized optimal capital stock per efficient worker can be compared to the golden rule capital stock per efficient worker, and γ can be adjusted such that the economy will reach the optimal level of capital stock per efficient worker which optimizes consumption and welfare. As an example, a country may turn out to be very close to the optimal capital stock, in which case it might be efficient to spend 90 percent of oil revenue on consumption. However, the opposite may also be the case; that the country is so far away from its optimal capital stock that 100 percent of the oil revenue should be invested. The model facilitates such an analysis on a country-by-country basis — focusing on Brazil.

- *What are the distributional implications across generations of higher oil revenue?* The manner in which the government transfers the oil revenue across generations affects the economic dynamics – including capital accumulation. As a result, wages and interest rates may change in a somewhat less open economy, leading to distributional effects on the different generations. The model offers a possibility of accounting for various transfer mechanisms and other simultaneous shocks, such as population aging. The main feature of the model will be on how the different generations are affected by higher oil revenue depending on how much of that revenue is transferred across generations for consumption and how much is invested. This model tackles this issue in the case of Brazil.

The role of public policy in allocating royalties is one of two tasks the government is charged with in this model. The provision of social security is important in the case of Brazil because the pension system is relative generous and accounts for some of the crowding out of private saving which has to analyzed together with the crowding out caused by the presence of exogenous incomes from oil revenue that also tend to crowd out private saving if such oil revenues are consumed in a non-efficient extent.

2.2.2 Social Security

The economy is assumed to operate with a PAYG pension system, given by the following identity,

$$B_t N_{t-1} = D_t N_t$$

$$\lambda_t \tau_t w_t N_{t-1} = \theta_t w_t N_t \tag{8}$$

where B is pension benefits per retiree, D is pension contributions per worker, θ_t is the pension contribution rate and τ_t is the pension replacement rate.

The left (right) hand side illustrates the pension benefits (contributions). Neither θ nor τ need to be fixed, so the PAYG system can in principle display either defined benefits (DB) or defined contributions (DC) schemes. To reflect the empirical fact that the DB system is the approximation of the system in Brazil, I assume that benefits are held constant whereas the contribution rate may vary. Note that the longevity of retirees increases, λ, then pension savings would need to be spread over a longer period of time, which means that either the replacement rate would need to fall or the contribution rate must increase to ensure balance in the PAYG system.

In a DB system, if the longevity of current retirees increases, the retirement period would increase, given that the statutory retirement age remains unchanged. This would call for a higher contribution rate. If fertility falls so will the growth in the number of workers and contributions need to rise to balance the PAYG budget:

$$\theta_t = \tau\left(\frac{\lambda_t}{1+n_t}\right) \tag{9}$$

2.2.3 Aggregate Government Budget Constraint

By including the social security PAYG system into the government's budget constraint (4), and collecting terms, the consolidated government budget constraint is derived in (10).

$$B_t + G_t^I + G_t^T = D_t + O_t$$

$$\lambda_t \tau_t w_t N_{t-1} + \gamma q_t Y_t + \left(\frac{\kappa + n}{2+n}\right)(1-\gamma) q_t Y_t + \left(\frac{1-(1-\kappa)}{2+n}\right)(1-\gamma) q_t Y_t = \theta_t w_t N_t + q_t Y_t \tag{10}$$

It is clear from (10), that the left hand side illustrates government spending on pension benefits, public investments in physical capital, and public transfers, while the right hand side shows government revenue from pension contribution (tax) collection and oil revenue. The budget is assumed to balance over time since the model abstracts from the possibility of issuing debt.

2.3 Households

I adopt a log-utility function, displaying homothetic preferences over consumption, bearing in mind the well-known limitations of the log-specification.

$$u_t = \ln c_{1t} + \lambda_{t+1} \beta \ln c_{2t+1} \tag{11}$$

I denote c_{1t} and c_{2t+1} as first and second period consumption in efficiency units, respectively. The discount rate on c_{2t+1} is $\beta > -1$. Decisions about consumption for children are implicitly assumed to be made by parents, so children make no economic decisions and the intertemporal optimization by parents implicitly collapses to a two-period setting. Second period consumption is scaled by the length of the retirement period.[6] The higher is λ, the longer period of time retirees can enjoy consumption. The restrictions on c_{1t} and c_{2t+1} are presented in (12) and (13),

$$c_{1t} = (1-\theta_t) w_t + t_{1t} - S_t^P \tag{12}$$

$$c_{2t+1} = \frac{R_{t+1}}{\lambda_{t+1}} S_t + \tau_{t+1} w_{t+1} + t_{2t+1} \tag{13}$$

where S_t^P is the level of private savings (as opposed to the government's saving, S^G). In terms of income in the working period, the wage rate is denoted by w_t. The gross return to the savings of

[6] Auerbach and Hassett (2007), Bohn (2001), Chakraborty (2004), Jorgensen and Jensen (2010) and Jorgensen (2011), have incorporated the length of the retirement period (sometimes alternatively referred to as survival probabilities) into the utility function, but neither have incorporated the length of the working period. This is a novelty of our approach. Furthermore, in Bohn (2001), λ does not depend negatively to the retirement age and in Chakraborty (2004), λ is endogenous to health expenditure and is incorporated so it encompasses both the discount rate and at the same time the length of total life.

retirees, $R_t = (1+r_t)$, is scaled by λ to account for the fact that savings must be spread across a given length of the retirement period—which increases when life longevity increases. Combining c_{1t} and c_{2t+1} over S_t^P yields the intertemporal budget constraint:

$$c_{1t} + \frac{\lambda_{t+1}}{R_{t+1}} c_{2t+1} = (1-\theta_t)w_t + t_{1t} + \tau_{t+1}w_{t+1} + \frac{\lambda_{t+1}}{R_{t+1}} t_{2t+1} \tag{14}$$

Note the role of λ as an implicit price on second period consumption: consumption must be spread across the lengths of working and retirement periods, respectively. Utility is therefore increasing in λ, but so is the implicit price on second period consumption. By maximizing lifetime utility (11) subject to the intertemporal budget constraint (14), the first order (Euler) condition is derived in (15),

$$c_{1t} = \frac{1}{\beta} E_t \left\{ \frac{c_{2t+1}}{R_{t+1}} \right\} \tag{15}$$

The increase in utility of a longer retirement period – in case longevity increases – is offset by a corresponding increase in the implicit prices of consumption and leisure in the intertemporal budget constraint. Note that the optimality condition does not depend on the inclusion of exogenous oil revenue in income since this does not affect intertemporal prices on consumption.

2.4 Technology and Resources

By assuming that firms are identical, privately accumulated capital will be through the savings of workers, i.e. $K_{t+1}^P = N_t S_t^P$. However, there is also the publicly accumulated capital through the investments of the government: $K_{t+1}^G = S_t^G = \gamma q_t Y_t$. The total capital stock is therefore, $K_{t+1} = K_{t+1}^P + K_{t+1}^G$, where it is clear that the government investments are simply injected directly into the capital stock. Output, Y_t, is assumed to be produced by firms with a Cobb-Douglas technology in terms of capital, K_t, and labor, N_t in (16):

$$Y_t = K_t^\alpha (A_t N_t)^{1-\alpha} \tag{16}$$

Productivity is denoted by A_t and is assumed to grow at a rate, g_t, such that $A_t = (1+g_t)A_{t-1}$, where g_t is assumed to be deterministic. The return to capital and the wage rate are standard and defined by $r_t(k_t) = f'(k_t)$ and $W_t(k_t) = f(k_t) - k_t f'(k_t)$, and $k_{t-1} \equiv K_t/(A_{t-1}N_{t-1})$ defines the capital-labor ratio over growth rates.[7] Furthermore, I assume that over one generational period (app. 25 years) capital fully depreciates. The constraint on the economy's aggregate resources is,

$$q_t Y_t + Y_t - K_{t+1} = K_{t+1}^P + K_{t+1}^G R_{t+1} + N_t c_{1t} + \lambda_t N_{t-1} c_{2t} \tag{17}$$

[7] Since a smaller labor force leads to an increase in the capital-labor ratio, changes in factor returns are likely to occur, see Kotlikoff et al. (2001), Murphy and Welch (1992) and Welch (1979).

which features the return to the injected investments by the government which will simply become part of the economy's stock of capital. For the derivation of the model, I refer to the appendix (available upon request). However, it suffices to note that there will be one stable steady state equilibrium derived by interpreting the model in steady state given by the condition: $k_{t+1} = k_t$ yielding the decentralized capital stock, k^*.[8]

To extract the potential Pre-Salt oil some initial investments are assumed to take place. Such initial investment would allow for the further exploration of the Pre-Salt area, but there is a need for incorporating the investments into the model. Since the OLG framework of the model consists of 25-30 year periods, it is assumed that the investments take place during this generational period — but that they are front-loaded. It is hard to speculate on how much investment is actually necessary.

The necessary front-loaded investments may be just as uncertain as the future flow of oil revenue itself. And, the higher the needed tax increase is set to finance the initial investments, the more private saving will be reduced. As a result, the effect on the capital stock of the initial investment would be counteracted. Consequently, if we make some assumptions as to the size of the initial investment financed by taxes, we should then have a solid idea about the necessary scale of such taxation — which is not directly available or conjecturable.

One related way of incorporating the front-loaded investments would be to model the initial investment as a certain share of the expected flow of oil revenue — in that way uncertainties related to oil revenue is also reflected by the uncertainty related to the initial investment.[9] At the same time, in order to keep a complicated model tractable, it is assumed that the initial investments were financed from existing oil revenue, and that this financing was spread over the (generational) period where increased oil revenue is expected to occur.

In that way, the initial investment is ensured and it is financed by borrowing against future oil revenue. The model itself will then not be overcomplicated since the total increase in the capital stock due to higher oil revenues is merely "front-loaded" —s o instead of seeing the same increase in the capital stock from year to year (e.g. an increase in K by 2 percent per year for 25 years), then we will see a larger increase in the beginning and smaller increases after that — where the aggregate increase in K will be similar as before — just front-loaded instead of evenly spread over time. This is, at least, one feasible approch to making the extension with the initial investment as tractable as possible within a two-period OLG framework — and assumption adopted in our simulations.

2.5 Golden Rule Capital Stock

In order to compare the decentralized equilibrium with the dynamically efficient equilibrium, the level of the capital per efficient worker is derived. Consumption (which is the only variable in utility) is simply maximized relative to the economy's resources in (17) in efficiency units in steady state, given full depreciation of capital over a generational period.

[8] See appendix for derivations.
[9] This "initial investment ratio" could then be experimented with by saying that it could be 5, 10, or 15 percent of expected oil revenue, for example.

Combining the first derivate of consumption, $1=(1+q)f'(k)$, with income in efficiency units and in its steady state form from (16) yields the golden rule capital stock in (18)[10]. The decentralized optimum (k^*) can now be compared with the (dynamically) efficient capital stock per effective worker (k_{GR}):

$$k_{GR} = \left(\frac{\alpha(1+q)}{[(1+n)(1+g)]^{\alpha}} \right)^{\frac{1}{1-\alpha}} \tag{18}$$

In case Brazil's capital stock lies far away from its optimal level, then the efficient use of natural resource revenues would be to invest them and not transfer any part for consumption. Alternatively, if Brazil's capital stock is close to its optimal level, then just a smaller fraction of the oil revenue should be invested, and it would be more optimal to consumption the rest. In the latter case, the optimal share that should be consumed depends endogenously on the choice of distribution mechanism the government chooses – since they all affect private capital accumulation which, in turn, changes both the optimal decentralized capital stock and the optimal golden rule capital stock.

Table 2. Calibration of the Model

Parameter	*Value*	*Interpretation of steady state parameters*
α	0.1867	The capital share in output
τ	0.4450	The pension replacement rate
g	1.8626	The steady state growth rate of productivity
q	0.0700	The share of oil revenue in GDP (varies across scenarios)
λ	0.6088	The length of the retirement period
n	0.4726	The population growth rate
β	0.2785	The discount rate, yielding a saving rate of 20.91 percent for the aggregate economy
δ	1	The rate of capital depreciation
κ	1	The weight on workers in oil revenue transfers

Sources and notes: Time periods of the model are assumed to be 25 years. In order to calibrate for life expectancy, the length of the model's first period is normalized at unity, while the length of the second period equals 61 percent (estimated as the share of total life spent in retirement: average retirement age equals 57.83 (Queiroz and Figoli, 2010); average entry-age into the labor force is 13.3 (Leme & Málaga, 2001)]; life expectancy equals 69.3 (average life expectancy at birth over the period 1998–2088; UN Population Division, the 2008 Revision). The contribution rate to the social PAYG pension system is calibrated to 31 percent (11 percent from workers and 20 percent from employers (Queiroz and Figoli, 2010). The average replacement rate, weighted by the share of the population receiving pension benefits at various rates, for pensions is estimated to be 45 percent. The replacement rate to public servants is assumed to be 95 percent, since older public servants participated in a plan of virtually 100 percent replacement rate, while younger generations receive slightly less. The replacement rate for non-public-servants is estimated residually based on pension payment data for the two groups. The weighted average is constructed based on the share of the population is each group; the effective weighted average is found to equal 45 percent (data from DATAPREV, SUB, Plano Tabular da DIIE, and Ministerio da fazenda).

[10] The expression stated in dynamic terms: $k_{GRt} = \left(\alpha(1+q_t)/[(1+n_t)(1+g_t)]^{\alpha}\right)^{\frac{1}{1-\alpha}}$.

2.6 Solving the Model

In this section, the solution method is presented for, first, deriving the optimal share of oil revenue that should be invested (and consumed); secondly, the method to solve the problem about which allocation is equitable will then be presented. Throughout, the section will refer to the technical appendix for derivations.

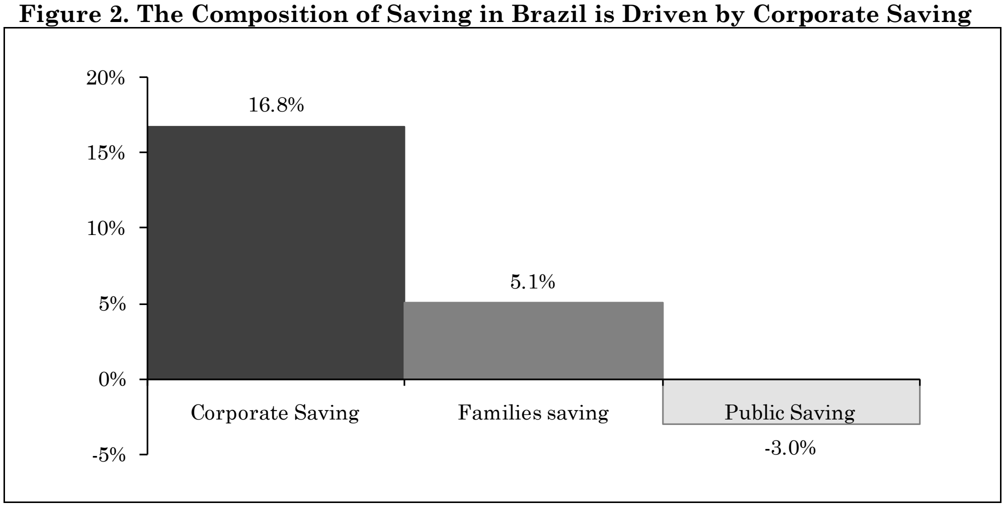
The share of oil revenue that should be invested (γ) in order for the economy to reach it's efficient level can simply be derived by equating, as in (21), the decentralized capital stock with the golden rule capital stock, since they both depend on γ. This is two equations with two unknowns to be solved for the optimal investment share, which therefore depends on all the economy's characteristics and can be derived as in (22),

$$k(\gamma) = k_{GR}(\gamma) \tag{21}$$

$$\gamma^* = \gamma^*(\mathbf{x}) \tag{22}$$

where $\mathbf{x} = [\alpha, n, g, \delta, \tau, \lambda, \beta, \gamma, q, \theta, \kappa]$. The model is calibrated with the values displayed in Table 1, which are believed to be realistic to fit Brazil. The following section of this paper will describe our findings. Private savings include both household and firms" saving, while public saving is negative in Brazil (Figure 2). This reveals that there is a major for corporate saving decisions and fluctuations in determining the saving rate in Brazil.

Figure 2. The Composition of Saving in Brazil is Driven by Corporate Saving



Source: IPEA 2006 (National Institute for Applied Economic Research).

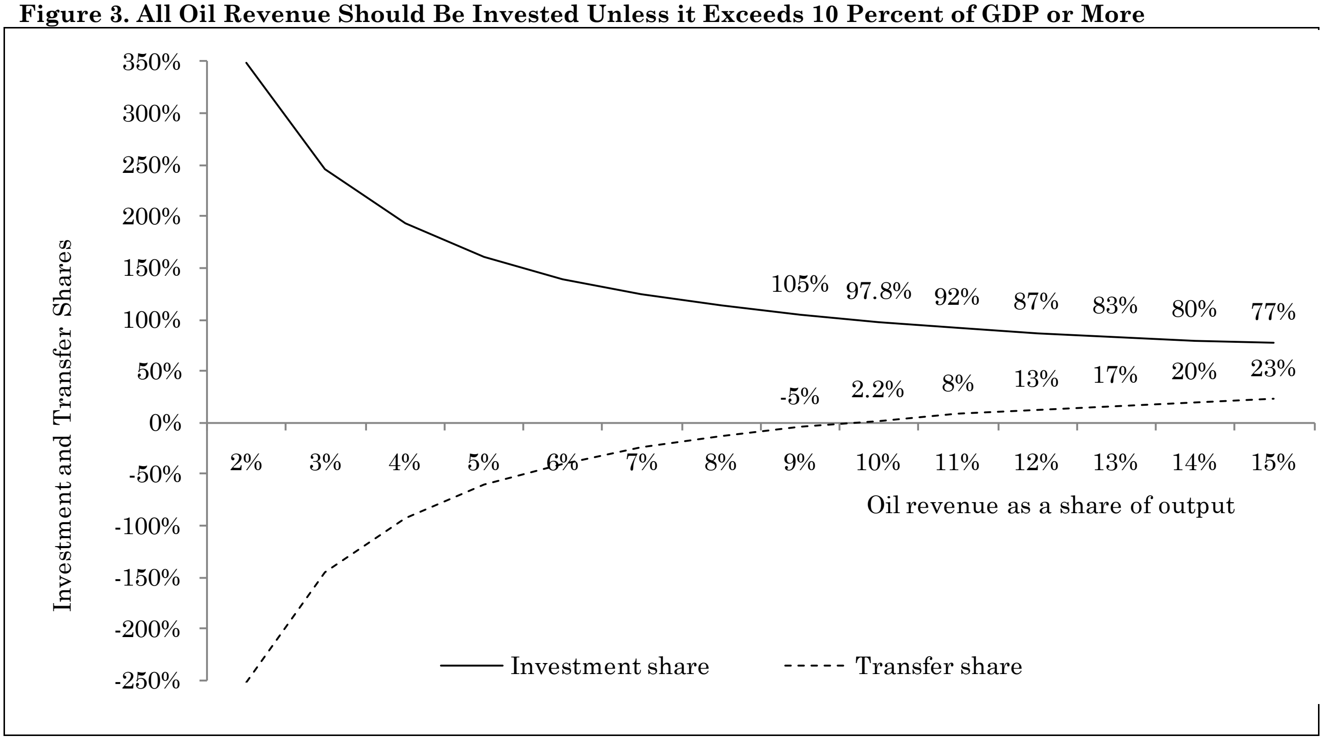
3 Macroeconomic Effects of Rising Oil Revenue in Brazil

When oil revenue increases there is scope for higher investment — and perhaps higher consumption if the increase in oil revenue is large enough. As a baseline, it assumed that the government is not investing the oil revenue but is, instead, using it for consumption by transferring it to the living generations. Workers will save a certain share of the transfer they receive but retirees will consume the full amount. As a result, when oil revenue increases and is subsequently transferred equally among people, private saving will increase.

However, there is a counteracting, and much stronger effect on private saving that tends to crowd out the capital stock; since current workers expect to receive an "oil transfer" from the government when they retire, there is less need to save for retirement. This mechanism reduces the incentive for workers to save and consequently crowds out the capital stock.

If the government decides, on the other hand, to invest a certain share of its oil revenue in physical capital — or human capital for that matter — there will be a direct injection of capital into the existing capital stock. This would further drive down private saving, but the capital stock would be maintained at high level that is conducive to growth. The question is how much of the available oil revenue that should be invested; if, for example, oil revenue as a share of GDP increases from 2 percent to 5 percent as a result of the Pre-Salt oil discoveries, how much of this revenue should be invested and how much could be consumed? This would depend on what is efficient from a macroeconomic perspective; which investment share would be most conducive to welfare and growth? The aim of this section is to analyze this question in depth using the macroeconomic model for Brazil developed in the previous section.

Figure 3. All Oil Revenue Should Be Invested Unless it Exceeds 10 Percent of GDP or More



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

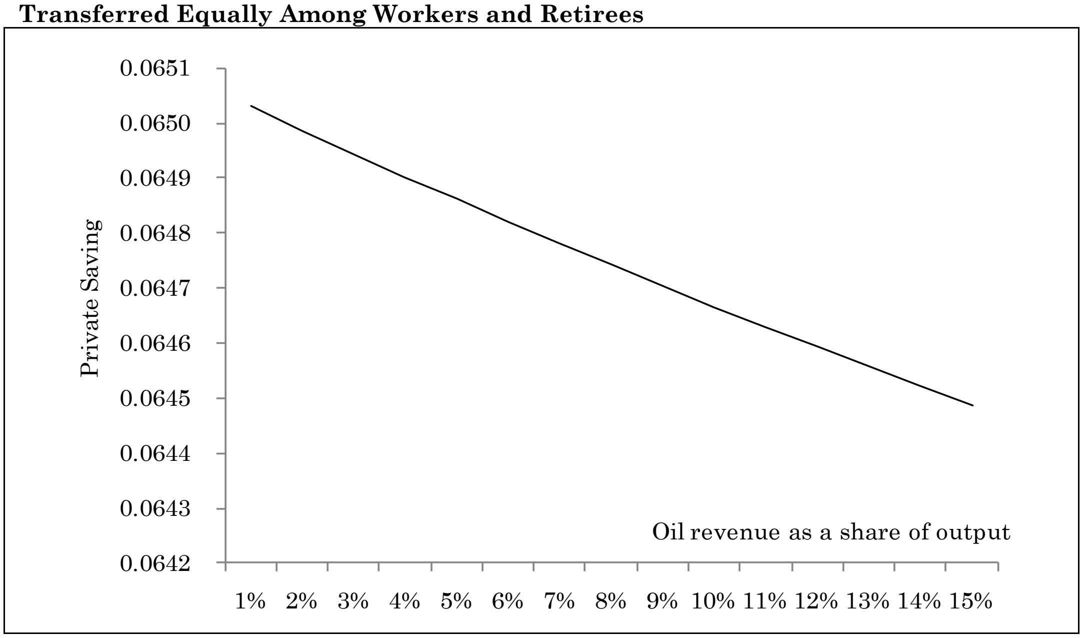
The derivation of the efficient investment share is carried out in the appendix (available upon request), but basically involves solving the model for the investment share under the condition that the capital stock must equal the golden rule capital stock. This leads to the condition (22) explained in section 2.6, $\gamma^* = \gamma^*(\mathbf{x})$, telling us which share of oil revenue should be invested and which share should be consumed, given that the distribution of consumption is in a completely equal proportion across generations: the same dollars per person in the population (no matter which generation you belong to).

3.1 Efficiency Implications of Higher Oil Revenue

A main finding of this paper is that if oil revenue as a share of GDP reaches, for example, 10 percent then 97.8 percent should be invested while 2.2 percent could be transferred for consumption whilst still maintaining an optimal allocation and achieving efficiency (Figure 3). The key issue is, though, that oil revenue as a share of GDP has to almost reach 10 percent before any revenue should be consumed. If oil revenue as a share of GDP increases to as much as 15 percent, for example, almost a quarter of the oil revenue could be consumed — so any percentage point increase in oil revenue as a share of GDP over 10 percent yields a larger and larger share that can be consumed.

Conversely, if oil revenue falls below 10 percent of GDP — even with the additional revenue that the Pre-Salt discoveries will bring — there is a need to invest all the revenue leaving nothing for consumption. This is simply because the investments from all the available oil revenue will still not be sufficient for Brazil to reach its optimal capital stock because Brazil is relatively far from that point. However, if oil revenue reached 10 percent or more of GDP there is scope for both an optimal (efficient) capital stock, increased consumption levels from the fraction of oil revenue that can be optimally consumed, as well as increased income growth (per capita) as the capital-labor ratio enhances the growth potential of the labor force.

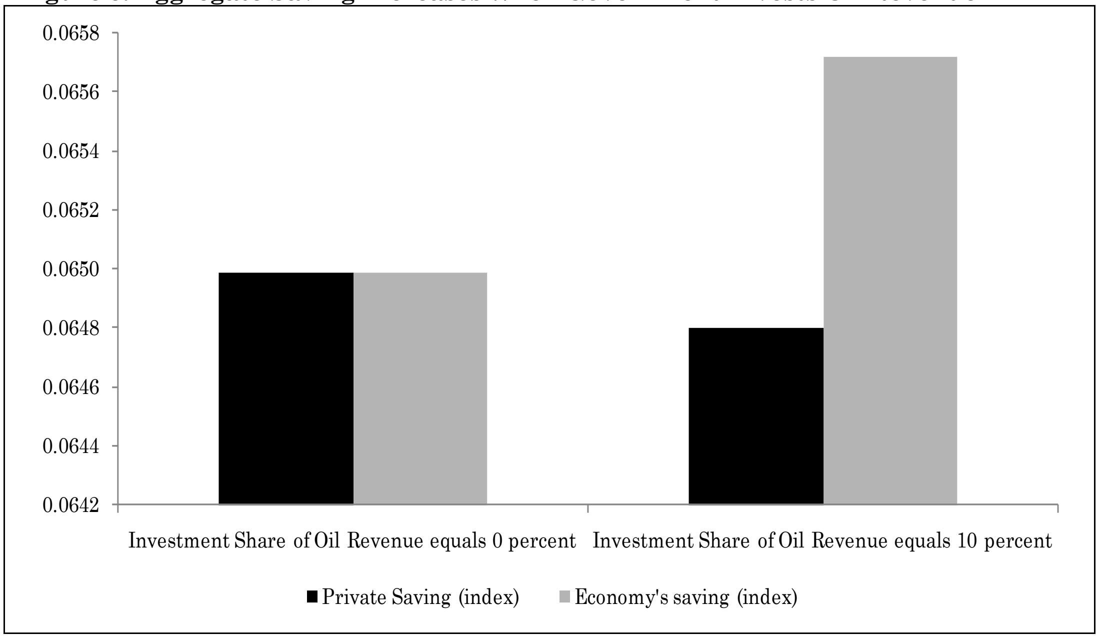
Figure 4. Oil Revenue Crowds Out Private Saving When Such Revenue is Transferred Equally Among Workers and Retirees



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

Going more into depth on this result, Figure 4 illustrates the falling private saving as oil revenue increases. The economic intuition is stated above, but this result depends crucially upon whether any share of the oil revenue is invested or not. If 100 percent of oil revenue is transferred for consumption, then the assumption on how it is distributed matters.

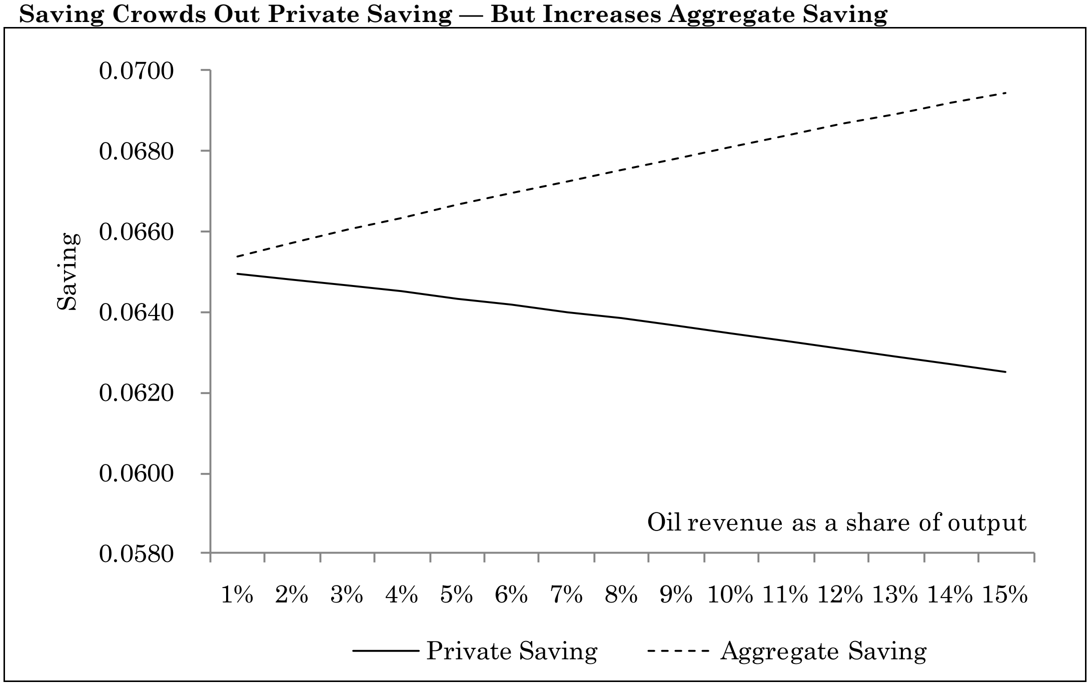
Figure 5. Aggregate Saving Increases When Government Invests Oil Revenue



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

In the baseline scenario it is assumed (but can be changed by varying kappa) that revenue is distributed equally across generations; i.e. equally many dollars per person for workers and retirees alike. Consequently, retirees experience a direct injection of cash into their disposable income since they do not save. But workers, on the other hand, save a fraction of their gross income which includes the transfers from oil revenue. As a result, when they can look forward to receiving a free transfer in old age, they feel no need to save as much today — as a result, saving falls.

Figure 6. When Public Saving is Always 10 Percent of Oil Revenue, Then Public Saving Crowds Out Private Saving — But Increases Aggregate Saving

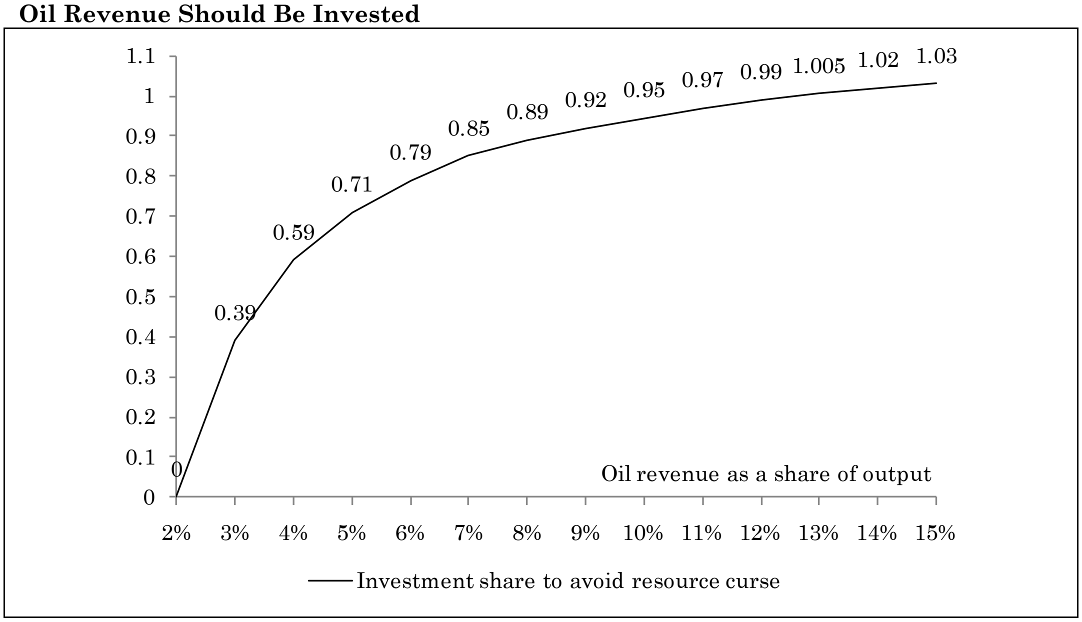


Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

When instead only 50 percent of oil revenue is transferred and the rest invested, for example, then extra disposable income of retirees is lower which reduced the incentive of workers to save less. At the same time, workers also receive a smaller transfer from which they save a relatively larger fraction. These dynamics lead to the conclusion that the higher the share of oil revenue that is invested, the less private saving is crowded out, and the larger total saving will be.

In Figure 5, two scenarios for the share of oil revenue share invested are illustrated. If by default, the government does not invest a single dollar of the oil revenue but rather transfer is all to workers and retirees, then private saving will be identical to the economy's aggregate saving because it is only workers who save — retirees and the government do not. However, if the government always invests 10 percent of its oil revenue then there will be less transfer to workers who then have less income to save from; as a result their saving falls slightly. On the other hand, aggregate saving in the economy now increases because it picks up the higher government saving.

Figure 7. To Avoid Crowding Out of the Capital Stock, Merely About 1 Percent of Oil Revenue Should Be Invested



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

This crowding out effect of private saving can also be illustrated by Figure 6 where a scenario of 10 percent investment of oil revenue is compared to a scenario where there is zero investment of oil revenue. It is seen that public investment of oil revenue outweighs the drop in private saving —yielding an overall increase in total saving and, thus, capital accumulation, where the discrepancy between the trajectories for aggregate and private saving is the increasing public saving.

Private saving will consequently be crowded out by the Pre-Salt oil revenue; both in the case where the revenue is fully (publicly) invested, because the increased public investment will tend to crowd out private investment, as well as in the case where the revenue is fully consumed, because if retirees receive any fraction of the revenue they are likely to save a very little share and workers will expect a similar "old-age transfer" in their old age which incites them to save less in their working years. The only mechanism to not achieve a crowding out of private saving is to transfer all revenue to workers; leaving them to intertemporally smooth consumption and saving.

While private saving will almost in any case be crowded out to some extent, this is not necessarily the case for aggregate saving (i.e. the aggregate capital stock). In fact, as oil revenue increases as a share of GDP, the degree of crowding out of both private and aggregate saving depends crucially on how much the government decides to invest of its oil revenue. If, for example, public saving out of oil revenue equals zero, then both aggregate and private saving will be crowded out — i.e. a resource curse will be the result. However, if the government merely saves about 1 percent of its oil revenue it can avoid the resource curse.

Figure 7 illustrates this point showing that as oil revenue as a share of GDP increases, more and more of that oil revenue should be invested to avoid a resource curse — this is, though, an increase that falls in the share of oil revenue in GDP. For very low levels of oil revenue as a share of GDP (e.g. 2, 3, or 4 percent) it is merely three-quarters of a percent of oil revenue that should be invested to avoid a resource curse, while for a larger increase in oil revenue due to the Pre-Salt discoveries (e.g. 10 to 15 percent) we find an optimal share of about 1 percent or slightly more.

The fact that merely about 1 percent of oil revenue should be invested to avoid a resource curse does not mean that such a low investment share would be efficient. The optimal investment share is illustrated in Figure 3 as a function of oil revenue to GDP, illustrating that 98 percent should be invested to achieve efficiency if oil revenue reaches 10 percent as a share of GDP. In comparison, if oil revenue is 10 percent GDP, then merely 0.95 percent should be invested to avoid a resource curse. This response is due to the reaction of private saving to changes in public saving and the non-saving of retirees (who also receive some share of oil revenue under the baseline).

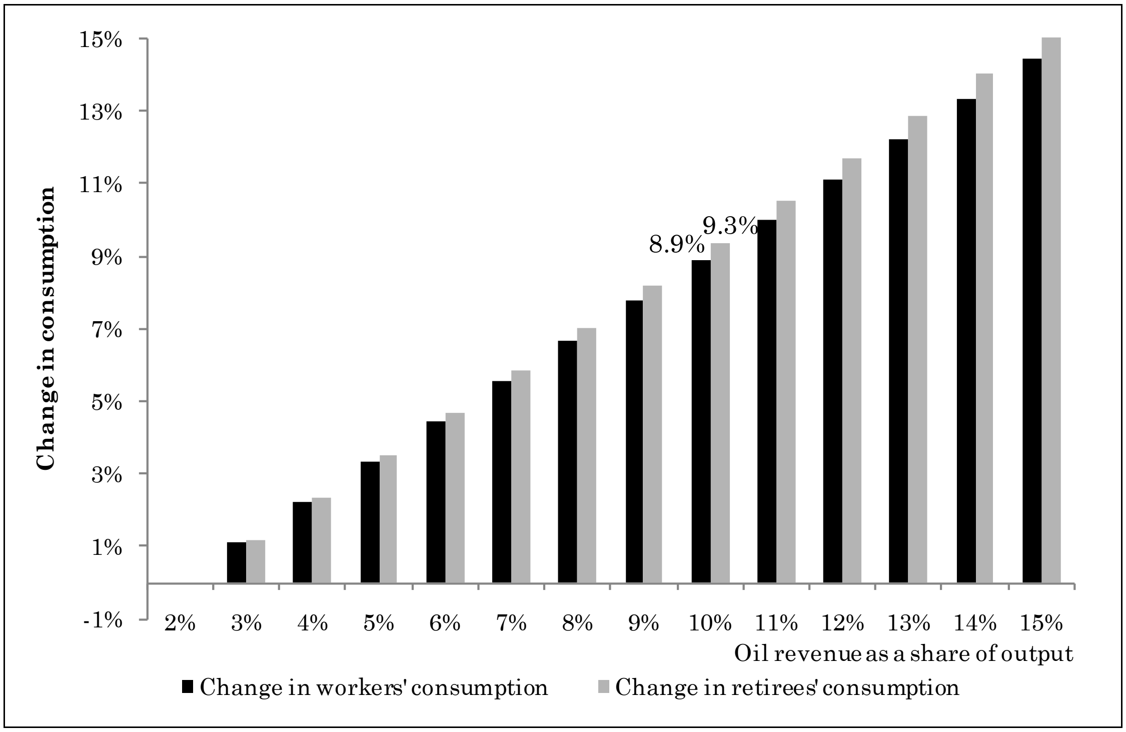
A crucial point is that Brazil is, at the same time, relatively far away from its efficient capital stock—as represented by the capital stock that optimizes consumption levels and, thus, welfare. The optimal capital stock is determined by deep characteristics of the Brazilian economy and, due to the relatively little capital per worker, large investments must be undertaken to drive Brazil's capital accumulation towards a dynamically efficient level. As referred to in relation to Figure 3, 100 percent of the Pre-Salt oil revenue must be invested unless the Pre-Salt oil revenue drives the aggregate Brazilian oil revenue above approx. 10 percent of GDP. This would be an increase of 8 percentage points; oil revenue of 2 percent of GDP to 10 percent of GDP.

Provided that Brazil will experience such a massive expansion of oil revenue, or perhaps even more, then there will be room for consumption of a rather small fraction (2 percent or slightly more) of the oil revenue. If this threshold of oil revenue constituting 10 percent of GDP or more is not reached a sensible rule-of-thumb would be to invest all the Pre-Salt oil revenue in either physical or human capital.

3.2 Equity Implications of Higher Oil Revenue

The distributional implications across generations when oil revenue is increasing can also be captured by the model. It is found that when oil revenue increases from 2 to 10 percent of GDP workers' consumption will increase by 8.9 percent while retirees' income will increase even more; by 9.3 percent (Figure 8). The higher the increase in oil revenue is, the more both generations will gain — and the overall consumption level will also increase at the average rate of the rate of increase in workers" and retirees" consumption (Figure 9).

Figure 8. Consumption Increases as a Result Of High Oil Revenue, but More So for Retirees Than Workers



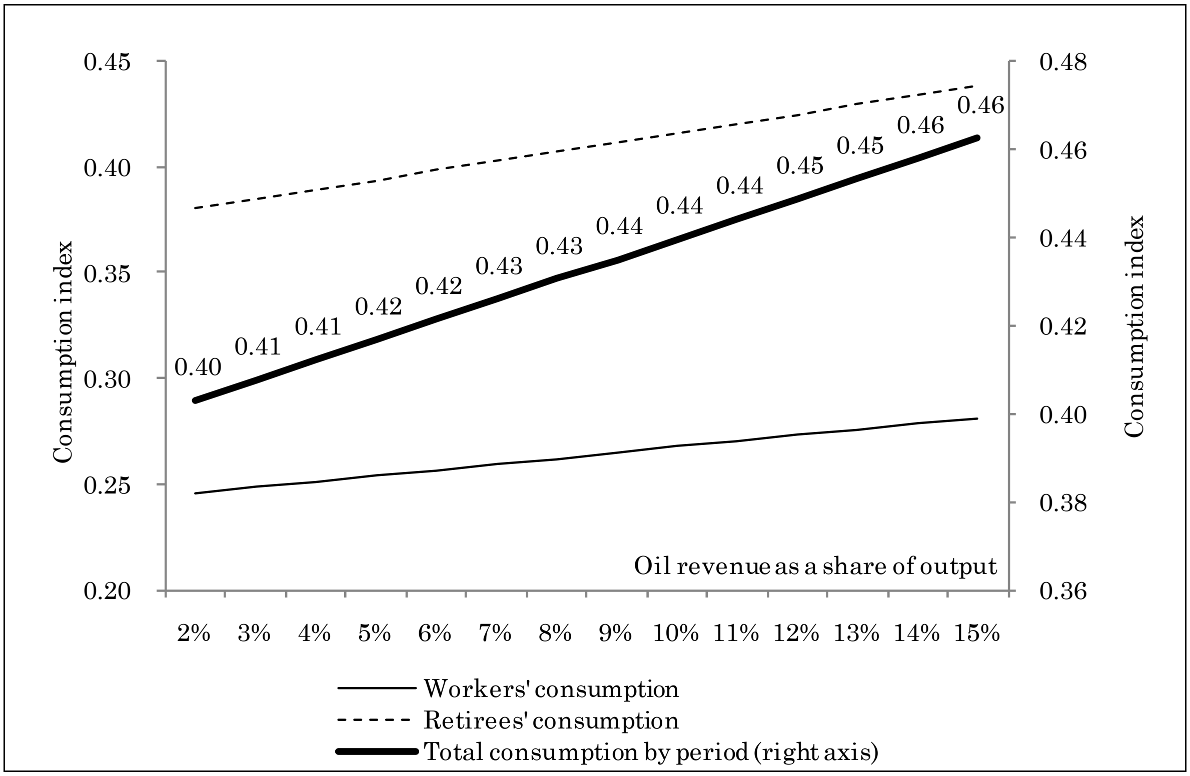
Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

The economic rationale behind a larger increase in consumption for retirees than workers is the following: As the share of oil revenue in output increases, private saving is being crowded out since workers realize that they will both receive a transfer from the government in their working age as well as in the old age. Workers therefore reduce saving and, since oil revenue is initially assumed not to be invested, the capital stock will be crowded out in line with the crowding out of private saving.

These dynamics lead to a lower capital-labor ratio which consequently reduces the premium on labor and increased the return to saving. As a result, workers receive a higher "oil transfer" from the government that boosts their consumption but there is a counteractive effect originating from a lower wage rate. The opposite is true for retirees; they also receive a transfer from the government but the return on their savings increases leaving them even better off. The end result is that both generations' consumption levels increase — but workers gain less than retirees (Figure 10).

This result depends on partly on the assumption that none of the oil revenue is invested. However, if some share is invested, then the crowding out of the capital stock as well as the generational transfers will be lower. This will entail that the effect on factor prices is smaller — but the direction of the effects will still be the same. The consequence is that workers will still gain from higher oil revenue but not to the same extent as retirees.

Figure 9. Aggregate Consumption Levels Increase as a Result of Higher Oil Revenue Which is Assumed Not To Be Invested



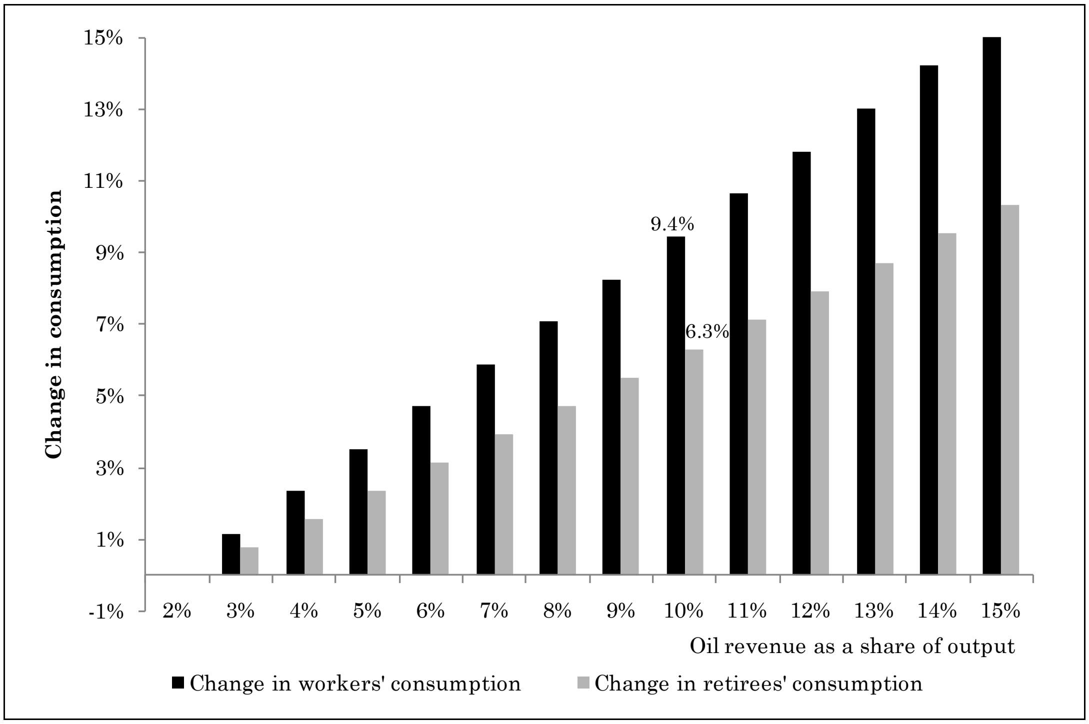
Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

The simulations above incorporate an assumption that public saving out of oil revenue is zero. As a result, when oil revenue is transferred for consumption on a fraction of that is saved and invested (i.e. the fraction that workers decide to save out of their additional gross income). This assumption can be compared to a scenario where the government saves for example, 10 percent of its total (including Pre-Salt) oil revenue. Assuming a 10 percent investment share, and, thus, a 90 percent consumption share, means that the capital stock will not be crowded out — since, as illustrated above in Figure 7, it only takes 1 percent investment share to offset the crowding out of aggregate saving.

When the 10 percent investment share is combined with the share of gross income that workers decide to save out of the, now 90 percent, consumption share enhances overall capital accumulation, then the capital labor ratio will increase and exert upward (downward) pressure on wages (interest rate). As a result, such a government policy will have distributional implications. Workers will gain markedly by such a policy while retirees will gain less in terms of consumption possibilities. Recall that retirees, despite lower returns to their saving, will still receive a large share of the 90 percent of oil revenue that is transferred — and this share will not have to be spent on saving as for workers.

The result, as illustrated in Figure 10, is that workers now experience the largest increase in consumption compared to retirees — which is simply due to an asymmetric impact on wages and interest rates of the investment policy that increases the capital-labor ratio through enhanced capital accumulation. Figure 11 shows, to further substantiate this distributional impact, that income per capita now increases (while it fell with a policy of zero-investment out of oil revenue).

Figure 10. With a 10 Percent Investment Share of Oil Revenues, Workers Will Gain More Than Retirees



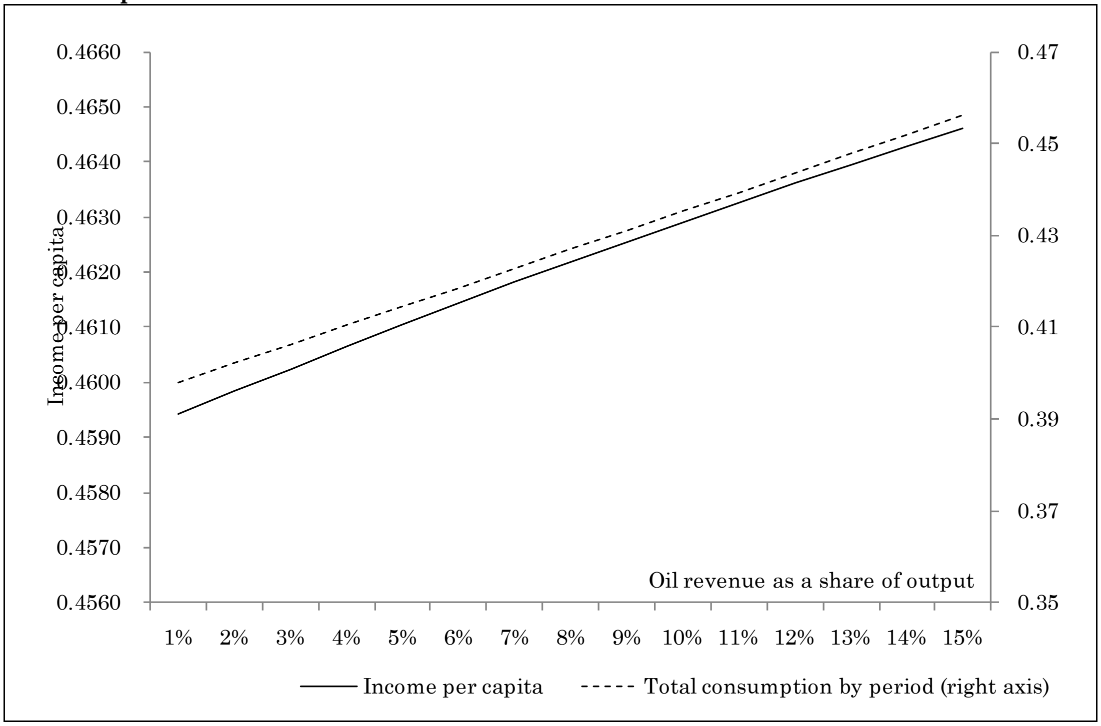
Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

The direct implications of a policy that is directed at investing a certain share of oil revenue will also be growth-enhancing. Even a small share of oil revenue could lead to sufficient capital accumulation to further promote the capital-labor ratio and, thus, income per capita. Our simulations reveal that slightly more than 1 percent of oil revenue as a share of GDP is necessary to ensure positive income growth. Consequently, if oil revenue increases to 10 percent of GDP as a result of the Pre-Salt discoveries, then a 9.01 percent increase in income per capita can be achieved if 98 percent of oil revenue is invested so the economy reaches its dynamically efficient level. Table 3 illustrates this point and reveals that the higher the increase in oil as a share of GDP the higher income growth can potentially be achieved — given that the efficient investment share is adopted.

Table 3 illustrates that, for oil revenue share of GDP lower than 10 percent the efficient investment share of 100 percent. The income growth that is potentially achievable is shown to be of significantly size. If all oil revenue currently obtained in Brazil is invested, GDP per capita will increase by 2.1 percent — and this is without any assumed increase in oil revenue originating from the Pre-Salt discoveries. Depending, then, upon the achievable extraction of oil and its associated (net) revenue, income per capita could increase from around 3 to 10 percent when the range of oil revenue to GDP constitutes 3 to 16 percent of GDP.

When comparing the results in Table 3 with the trajectory for the efficient investment share in Figure 3 it becomes clear that the Pre-Salt oil revenue will not be able to drive Brazil all the way towards its optimal capital stock. The reason is that if oil constitutes less than approx. 10 percent of GDP then it would take more than 100 percent of the oil revenue to reach the efficient capital stock. Figure 12 illustrates this point by comparing the investment share that is actually attainable — i.e. an investment share that is 100 percent at the most — with the efficient investment share.

Figure 11. As a Consequence of a Higher Investment Share of Oil Revenue, Consumption and Income Levels Will Increase



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

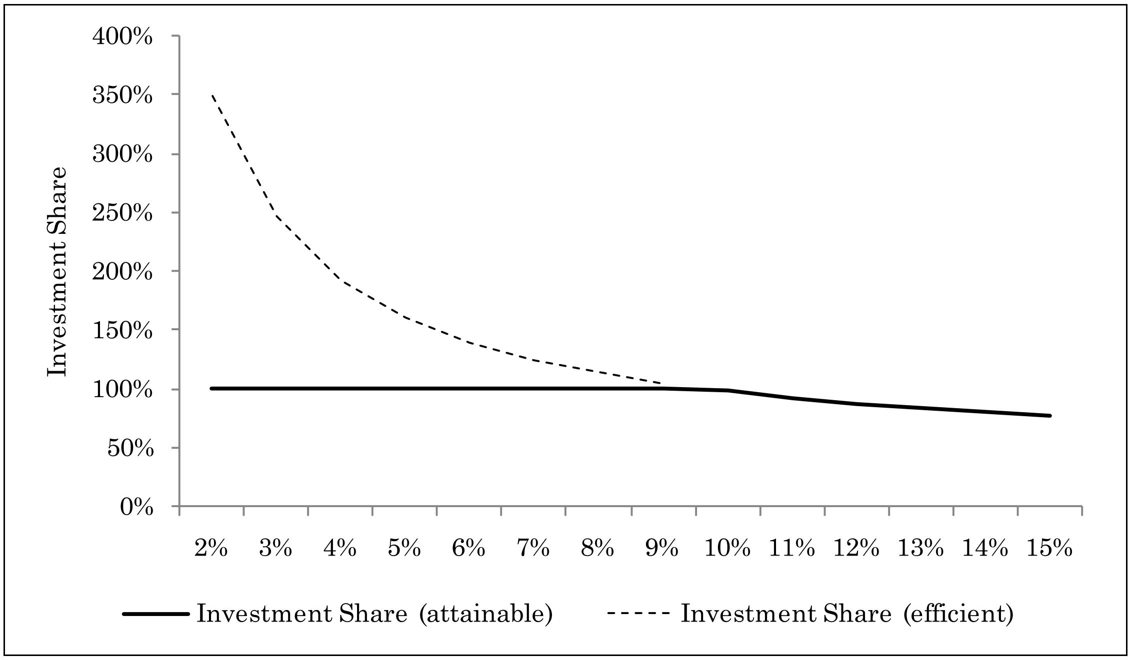
Figure 12 reveals that the Pre-Salt oil revenue will only be sufficient to drive Brazil all the way to its efficient capital stock from the point where the two trajectories intersect. This corresponds with the finding that all the oil revenue must be invested — and nothing consumed — if the oil revenue does not increase beyond approx. 10 percent of GDP. On the other hand, if oil revenue reached more than 10 percent of GDP then the capital labor ratio could reach its efficient level (Figure 12), there would be revenue left to be transferred for consumption (Figure 3), and growth in income per capita could be enhanced (Table 3).

Table 3. Growth Implications of (Pre-Salt) Revenue Investment Policies

Oil revenue/GDP	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
Investment Share	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	97.8%	92.1%	87.4%	83.5%	80.1%	77.3%
Growth (income per capita)	**2.1%**	**3.1%**	**4.0%**	**4.9%**	**5.8%**	**6.7%**	**7.6%**	**8.4%**	**9.0%**	**9.2%**	**9.5%**	**9.7%**	**10.0%**	**10.2%**

Source: Author's simulations based on a general equilibrium model with overlapping generations calibrated for Brazil.

Figure 12. Brazil Cannot Reach its Efficient Capital Stock Without an Increase in Oil Revenue To 10 Percent or More of GDP



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

3.3. Robustness Checks and Efficiency Implications of Population Aging

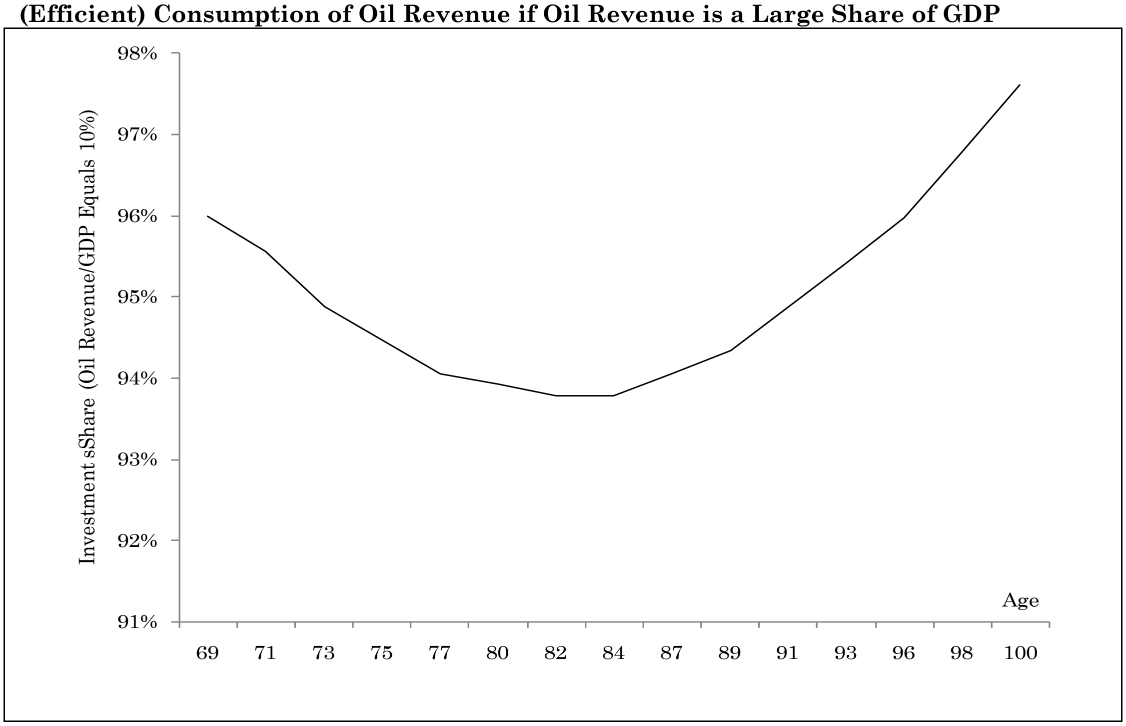
This section investigates some robustness issues related to the results above. In particular, the fact that the population in Brazil is aging rapidly (Jorgensen, 2011) means that age-structures change which is likely to affect both pension plans and saving behavior along the lines suggested by Jorgensen (2011).

First, if life expectancy increases, a defined benefits PAYG system in Brazil will leave retirees unaffected initially unless they retire later. This is because fewer workers will need to pay a flexible contribution rate that must cover a longer living retired population. This leaves less disposable income for workers to save from; thus, saving falls. At the same time, workers experience their parent living longer so their incentive to save changes towards saving more to finance the longer retirement period.

These dynamics are captured by the model and simulated in Figure 14, where the investment share of oil revenue is plotted against life expectancy. Average life expectancy in 1998-2008 was 69.3 years (UN Population Division), and in 2010 life expectancy was 73.5 years. These data are fed into the model, and the result is that an increase in life expectancy up to approximately 83 years will lead to a drop in the required investment share.

The example illustrated assumes that oil revenue has increase to is 10 percent of GDP due to the Pre-Salt oil discoveries, but lower shares of oil revenue to GDP will lead to a similar trajectory — only at higher levels of the investment share. This entails that increases in life expectancy will lead to a higher share of oil revenues that can be consumed. However, when life expectancy increases even further (beyond 83 years), then the investment share starts to increase. This is because workers save less and less and at some point the crowding out of the capital stock will become so strong that more investment from oil revenue is needed. The simulations also reveal that for oil revenue as a share of GDP reaching above approximately 6 percent there will be a potential increase in the share of oil revenue that can be consumed (since the sink of the trajectory will drop below 100 percent investment share. This will be the case until the population has aged substantially, and capital is crowded out sufficiently as to increase the necessary investment share.

Figure 13. An Increase in Life Expectancy from 73 to 83 Years Could Lead to Higher (Efficient) Consumption of Oil Revenue if Oil Revenue is a Large Share of GDP



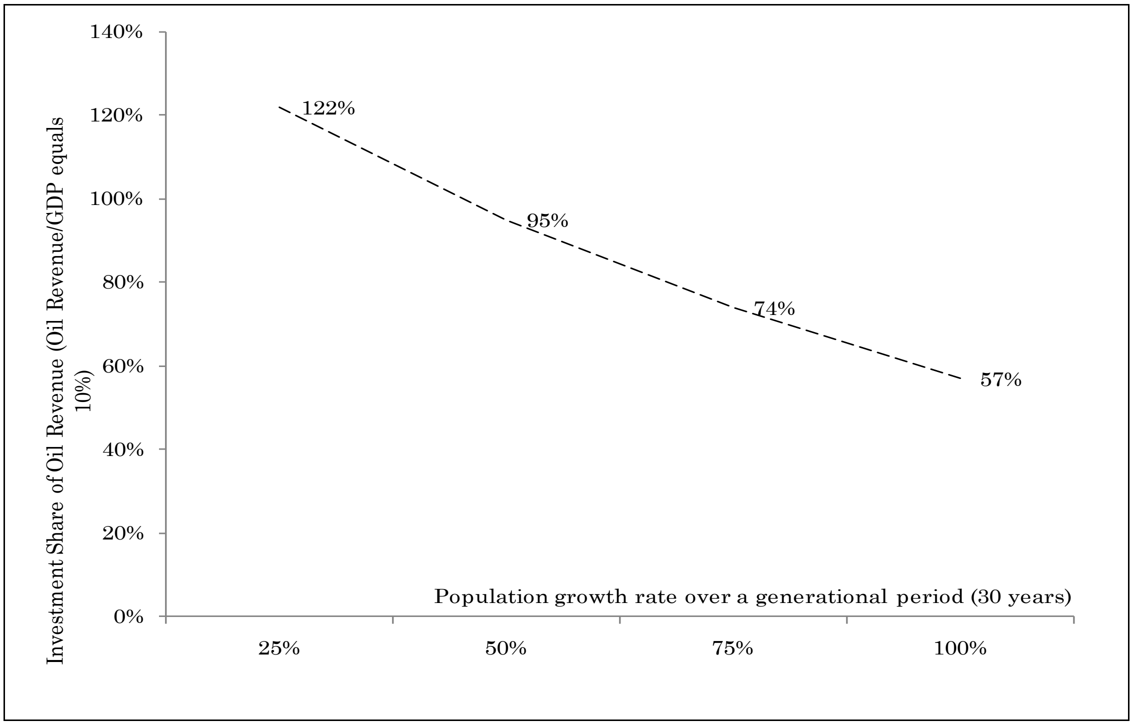
Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

Population aging is associated with two demographic phenomena; an increase in life expectancy (as studied above) and a drop in the fertility rate. The former part has been studied above while the latter can be simulated in the same manner. By simulating various population growth rates (which in the model are the same as fertility rates) the required reaction of the efficient investment share can be computed: With a population growth rate of 47 percent over a generational period, combined with oil revenue being 10 percent of GDP, we find that 97.8 percent of oil revenue must be invested. This is, obviously, in line our results from the baseline scenario analyzed above which assumes these two calibrations.

However, as the population growth rate falls, the efficient investment share increases (Figure 14). This is because there will be fewer workers to save and more relatively more retirees to dis-save and spend a relatively larger share of the transferred oil revenue on consumption.

Since the oil revenue transfers are assumed to be transferred equally among workers and retirees — one dollar per person — there will be a large fraction of the population in retirement, and these individuals save less, or not at all, and as such the economy's capital accumulation deteriorates. This must be made up for by increased investments of oil revenue; so the conclusion to the population aging phenomenon is that as the population ages a larger and larger share of oil revenue must be invested to make up for the lower saving caused by a smaller fraction of workers in the population.

Figure 14. A Decline in the Population Growth Rate, Caused By Falling Fertility Rates, Will Increase the Investment Share of Oil Revenue



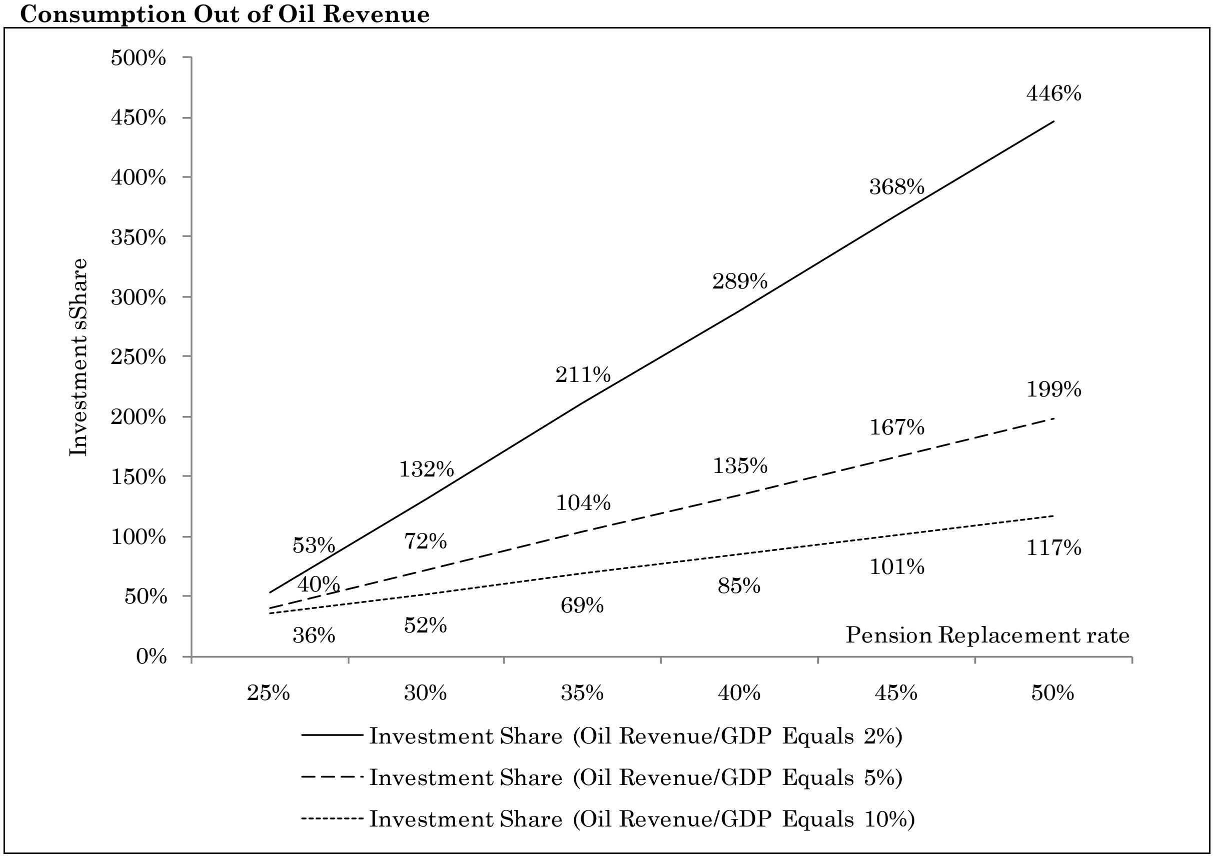
Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

Combining the two components in the aging process, life expectancy and fertility growth, yields a contradictory picture and it will be an empirical question to determine the combination of fertility and life expectancy rates that will drive the aging process in Brazil. What is clear, however, is that increased life expectancy will lead to less need for investment of oil revenue while the opposite is true for a drop in fertility rates. The net effect is ambiguous, but the increase in life expectancy is seen to have a very small, though negative, effect on the efficient investment share — while lower population growth is seen to have a much larger positive effect on the investment share. Our best judgment therefore suggests that population aging will require a larger share of oil revenue for investment.

The final robustness check is relative to the pension replacement rate. As long as that is kept high the capital stock will be crowded out to a high extent because workers do not need to save that amount they expect to receive in pension benefit when they retire. This basic mechanism leads to an increasing low investment share of oil revenue when the pension replacement rate falls. As a policy implications, therefore, lower pension replacement rates will lead to more capital accumulation and less need for oil revenue to be invested — leaving room for more consumption out of oil revenue. As Figure 15 illustrated, if the pension replacement rate is lowered, a lower efficient investment share is also obtained. Even if oil revenue is a high as 10 percent of GDP there will be potential for an efficient investment rate that is lower than 100 percent — leaving room for higher public consumption.

The robustness checks reveal that there is scope for policy to drive the economy towards its efficient capital stock, but that it will be challenged by population aging. However, these dynamics depend crucially on the projected increase in oil revenue; with low Pre-Salt revenues there will be less scope for consuming any part of the oil revenue without compromising efficiency. Population aging makes this problem even larger. However, if oil revenue approaches 10 percent or more of GDP, there will be ample opportunity to consume a part of the oil revenue.

Figure 15. Lower Pension Replacement Rates Will Leave Room for Higher Public Consumption Out of Oil Revenue



Source: Author's simulations based on a general equilibrium OLG model calibrated for Brazil.

4 Conclusion

The paper has investigated the economic issues related to the future Pre-Salt oil revenue in Brazil. The focus was on the implications for key macroeconomic variables when decisions on investment versus public consumption of the oil revenue must be taken. This was addressed in this paper theoretically, as well as empirically, for Brazil by focusing on (i) what is the *efficient allocation* of oil revenue between investment and consumption in Brazil; and (ii), since it may be efficient to consume a certain share of the oil revenue, what are the *distributional implications* across generations?

An overlapping generations model was developed and calibrated to match Brazil's economic characteristics. The model is novel in the sense that it features the choice between investing and consuming the aggregate oil revenue — combined with the actual presence of oil revenue and population dynamics in one unified framework. Existing literature, including Papyrakis and Gerlagh (2006), assumes that all oil revenue has been consumed by the government — which, therefore, naturally, leads to a resource curse since capital is crowded out. However, maybe by investing merely a relatively small fraction of oil revenue the government can escape the resource curse; maybe by investing the full amount of oil revenue can even promote growth and welfare; and, finally, maybe the effect on different generations could be positive at the same time if oil revenue to some extent is invested. These questions have not before been formally addressed in the economic literature but this paper derives empirical (comparative statics) results.

A natural resource blessing could be obtained if the government invests mere 1 percent or more of aggregate oil revenue. However, that would not ensure efficiency and optimal conditions to achieve income growth — an investment share of oil revenue of just 1 percent would merely ensure that capital accumulation and growth do not deteriorate so a curse is avoided. In order to drive the economy towards its optimal state — with capital accumulation at its dynamically efficient level — most of the oil revenue must be invested. The reason is that the capital stock per worker in Brazil is relatively far from its efficient level.

In fact, if the Pre-Salt oil revenue does not drive aggregate oil revenue in Brazil above 9.7 percent of GDP, then all of the oil revenue should go to investment in order to ensure efficiency — and to maximize the potential for income growth and welfare. This would leave nothing for public consumption. However, if the Pre-Salt oil revenue brings the aggregate oil revenue in Brazil up to, or above, 10 percent of GDP, there will be scope for consuming a certain share of it. In fact, if oil revenue increases to 10 (12) percent of GDP, then 2 (13) percent of oil revenue can be used for public consumption while still maintaining efficiency. The higher oil revenue is, the larger the increase in the income growth rate — provided that the efficient share of oil revenue is invested. For example, if oil revenue as a share of GDP was 5 (10) percent, then the additional achievable income growth would be 4.9 (9.0) percent.

In terms of the distributional implications across generations, the increased oil revenue, and the subsequent investments, could drive the capital stock towards its efficient level — and reach it if oil revenue reaches 9.7 percent (almost 10 percent) of GDP. The effect on the return to factors of production of rising investments from oil revenue depends on the size and openness of Brazil's economy. So, wage and interest rate changes could affect the consumption and welfare of the population. It is found that if no oil revenue is invested, but rather fully used for public consumption distributed equally across generations, then retirees would tend to gain more than workers; but both generations gain from such a transfer policy. On the other hand, if some of the oil revenue is invested, then workers would gain more than retirees. As a result, there are social implications of the public policy adopted to allocate oil revenue — but the transfer policy could be adjusted to ensure equity in its distribution.

There is ample opportunity to contribute further to this literature; by, for example, experimenting with the design of the transfer system, as well as with which types of capital investment — physical or human – could give the highest return in the future. But, in any case, a good policy rule on what to do with the oil revenue in Brazil is to invest it all unless oil revenue increases to as much as 10 percent of GDP. Well targeted investments would lead to sustained growth — especially if the social profiles of such investments are balanced to further reduce inequality through human capital enhancement.

In summary, unless oil revenue reaches 10 percent or more of GDP, it should all be invested. The more oil revenue increases beyond this threshold, the more can be used for public consumption — while maintaining efficiency and enhanced income growth. The distributional implications are positive for all generations, but the equity element can be addressed through careful design of transfer policies.

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