WP/12/200

IMF Working Paper

Resource Windfalls, Optimal Public Investment and Redistribution: The Role of Total Factor Productivity and Administrative Capacity

Rabah Arezki, Arnaud Dupuy and Alan Gelb

INTERNATIONAL MONETARY FUND

 WP/12/200

IMF Working Paper

Institute for Capacity Development

Resource Windfalls, Optimal Public Investment and Redistribution: The Role of Total Factor Productivity and Administrative Capacity

Prepared by Rabah Arezki, Arnaud Dupuy and Alan Gelb[1]

Authorized for distribution by Marc Quintyn

August 2012

Abstract

This paper studies the optimal public investment decisions in countries experiencing a resource windfall. To do so, we use an augmented version of the Permanent Income framework with public investment faced with adjustment costs capturing the associated administrative capacity as well as government direct transfers. A key assumption is that those adjustment costs rise with the size of the resource windfall. The main results from the analytical model are threefold. First, a larger resource windfall commands a lower level of public capital but a higher level of redistribution through transfers. Second, weaker administrative capacity lowers the increase in optimal public capital following a resource windfall. Third, higher total factor productivity in the non-resource sector reduces the degree of des-investment in public capital commanded by weaker administrative capacity. We further extend our basic model to allow for "investing in investing" — that is public investment in administrative capacity— by endogenizing the adjustment cost in public investment. Results from the numerical simulations suggest, among other things, that a higher initial stock of public administrative "know how" leads to a higher level of optimal public investment following a resource windfall. Implications for policy are discussed.

JEL Classification Numbers: E60, F34, H21.

Keywords: Resource Windfall, Public Investment, Total Factor Productivity, Administrative Capacity.

Author's E-Mail Address: rarezki@imf.org; agelb@cgdev.org; a.dupuy@maastrichtuniversity.nl

---

[1] International Monetary Fund (Arezki), Reims Management School and Sciences Po Paris (Dupuy) and Center for Global Development (Gelb). The authors gratefully acknowledge the financial support of the Economic Research Forum (ERF) and thank Paul Collier, Rick van der Ploeg, Tony Venables, participants in the ERF conference on Understanding and Avoiding the Oil Curse in the Arab World, January 15–16, 2012, Kuwait, and numerous IMF and World Bank colleagues for very helpful comments and suggestions. All remaining errors are ours.

Contents

I. INTRODUCTION

Countries dependent on natural resources face important challenges. In the short run, revenues derived from the exploitation of natural resources because of their lumpy, volatile, and uncertain nature complicate the conduct of macroeconomic policy (see Frankel, 2012). In the long run, the biggest challenge for resource rich countries is to rebalance their wealth away from exhaustible natural capital, as relying solely on revenues derived from the exploitation of the latter may not be a viable option.[2] To ensure economic sustainability, the non-resource sector needs to eventually generate enough wealth after the stock of natural capital would be exhausted.[3] To illustrate the extent of needed rebalancing, Figure 1 shows that the share of natural capital in developing countries in Africa and the Middle East amount to over thirty percent of overall wealth as opposed to below five percent for the most advanced economies such as the United States and other European economies. This paper aims at fostering the understanding of optimal public investment decisions in countries experiencing a resource windfall.

To do so, we use an augmented version of the Permanent Income framework with public investment faced with adjustment costs capturing the associated administrative capacity as well as government direct transfers. A key assumption is that those adjustment costs rise with the size of the resource windfall. The main results from the analytical model are threefold. First, a larger resource windfall commands a lower level of public capital but a higher level of redistribution through transfers. Second, weaker administrative capacity lowers the increase in optimal public capital following a resource windfall. Third, higher total factor productivity in the non-resource sector reduces the degree of des-investment in public capital commanded by weaker administrative capacity. We further extend our basic model to allow for "investing in investing" —that is public investment in administrative capacity— by endogenizing the adjustment cost in public investment. Results from the numerical simulations suggest, among other things, that a higher initial stock of public administrative "know how" leads to a higher level of optimal public investment following a resource windfall.

To operate what is a delicate rebalancing act, governments in resource rich countries need to be able to identify, implement and monitor key investment projects so as to provide the

---

[2] The focus of the present paper is on resource windfalls stemming from revenues derived from the exploitation of non-renewable resources such as hydrocarbons and minerals. We thereafter refer to natural resources as resources of the non-renewable type. It should be noted however that the issues raised in this paper are also relevant to countries dependent on the exploitation of renewable resources such as agricultural products, fisheries and forestry. Indeed, the overexploitation of a stock of a priori renewable resources may in turn become exhaustible.

[3] Also, we focus here on a typical developing economy faced with resource windfalls which are economically large but not large enough to sustain a "rentier state". By rentier state, we mean a state relying solely on the financial returns earned on its financial capital resulting from the transformation of its initial stock of natural capital. We are less concerned here with non populous economies which do not, in principle, face apparent binding budget constraints. In practice, the latter economies also should worry about the nature and the quality of their investments.

public goods necessary for the non-resource private sector to develop.[4] Warner (2012) shows however that it is not necessarily optimal to address every externality and it is not optimal to always select expenditures with the highest social returns. Governments thus need to carefully design their strategy in the provision of public goods so as to avoid wasting limited resources. Administrative capacity in conducting such public investments in resource rich countries is generally weak. Figure 2 shows that the quality of public investment, as measured by Kyobe et al. (2011) public investment management index, is on average markedly lower in resource rich countries compared to non-resource rich ones. Gelb (1988) provides case studies where he rigorously documents that governments in resource rich countries have embarked in large investment projects following commodity price booms. He argues that those investment projects were plagued by inefficiencies and also contributed to resource misallocation. In addition, those disproportionally large investment projects get depreciated quickly or even become obsolete as governments are unable to cover the associated high maintenance costs due to lack of continued financing. As results, resource rich countries often fall into debt overhang following commodity price booms. Arezki and Brückner (2010 a, b) provide systematic evidence that commodity price booms lead to increased government spending, external debt, default risk and sovereign bond spreads in resource rich countries with weak institutions. To avoid those pitfalls, resource rich countries need to take into account their ability to conduct public investment in determining their optimal level of spending following a resource windfall.

While skills shortfall and a limited stock of know-how in public administrations contribute to explain weak administrative capacity in many developing countries, rent seeking is certainly a major part of the explanation for the latter especially in resource rich countries. Indeed, resource revenues transit directly through government coffers and thus offer more scope for discretion and capture by public officials. Arezki and Bruckner (2011) provide systematic empirical evidence that an increase in oil rents causes a significant increase in corruption using a panel of 30 oil-exporting countries during the period 1992–2005. Rent seeking is thus more prevalent in resource rich countries and is thus is likely to render public expenditure ineffective. Arezki and Nabli (2012) argue that the so-called old industrial policies in resource rich Middle East and North Africa countries have not yielded economic diversification because those policies have been captured by entrenched elites and because managerial skills are weak in public administrations in those countries. In deciding over their optimal level of spending following a resource windfall, resource rich countries thus need to take into account the level of corruption which is likely to affect the effectiveness of their expenditure.

Beyond the quality of public administration in resource rich countries, the determination of the optimal level of expenditure in resource rich countries should take into account the quality of the economic environment in which firms operate. Indeed, rule of law and existing regulations affect firms' investment decision. Indeed, weak rule of law increases the risk of expropriation and diverts both foreign and domestic investment (Alfaro et al., 2008). Incentive incompatible regulations may also trigger rent seeking which may in turn deter

[4] Governments in resource rich countries are often involved in the natural resource sector either through taxation, the sale of licenses to foreign companies, or more directly through government owned companies. As such, they are the recipient of parts the rents derived from the exploitation of natural resources.

private sector development. Figure 3 provides evidence that Sub-Saharan Africa and Middle East and North Africa, the locus of many resource rich countries, are faced with a poor level of investor protection as measured by the World Bank (2011). Using panel data for over a hundred countries, Arezki et al. (2011) provide evidence that the quality of economic institutions played a crucial role in allowing government expenditure to boost non-resource sector growth in commodity exporting countries over the period 1970 to 2007.

To avoid wasting limited resources, some authors have argued that it would be appropriate to redistribute a part or the entirety of resource windfalls to the population through direct transfers rather than for governments in resource rich countries to embark in large investment programs. Sala-i-Martin and Subramanian (2003) and Birdsall and Subramanian (2004) have made the case for such direct redistribution to citizen to fight the "resource curse" in the case of Nigeria and Iraq. The Center for Global Development has since then launched an Oil-to-Cash initiative to explore the potential for citizen dividends to help deliver visible benefits, create public demand for accountability, and strengthen the social contract (see Moss, 2011). US state of Alaska and the Canadian province of Alberta have such large scale system of redistribution through direct transfers already in place. For instance, the dividend received by each Alaskan resident amounted about $1,300 in 2009 (see Ross, 2012). In this paper, we explore theoretically the optimal choice between public capital investment and direct redistribution in a context of countries with varying levels of state capacity and economic institutions experiencing resource windfalls.

Recent research building on North (1990) has considered the role of institutions in shaping economic outcomes. For instance, Keefer and Knack (1995), Quinn and Wooley (2001), and Acemoglu, Johnson, and Robinson (2001) have found some relationships between some measures of political institutions and macroeconomic outcomes. In a context of a development accounting exercise, Hall and Jones (1999) provide cross-sectional evidence that the quality of institutional arrangements (aiming at limiting the expropriation risk investors face) have a statistically significant and economically large impact on cross-country total factor productivity (TFP) differences. The level of TFP is thus a good measure of the quality of the economic institutions faced by private firms. In the case of resource rich countries, we are specifically interested in the level of TFP in the non-resource sector that is the economic conditions faced by firms operating in the non-resource sector. Figure 4 shows a measure of the level of non-resource sector TFP for various regions.[5] Africa where resource discoveries are plenty is the region with the lowest level of non-resource sector TFP.
Our paper relates to a strand of literature which has recently attempted to separate the effect of different institutions on economic development. Indeed, while there is evidence of a causal relationship between good institutions and economic development, we know little about which specific institution is fundamental in this process. What makes measurement difficult is that existing measures of institutions are quite highly correlated. Among the recent attempts to "unbundle" institutions is Acemoglu and Johnson's (2005), who examine the effects of broad property rights institutions and narrow contracting institutions. They find that only the latter are important in determining economic outcomes. In the present paper, we

[5] In computing Figure 4, we have attempted to reduce the noise created by resource extraction when computed standard measure of TFP.

distinguish public sector's administrative capacity from economic institutions for the purpose of determining the optimal level of public investment in the countries experiencing resource windfalls. As shown in Figure 5 the correlation between non-resource sector TFP and the public investment index discussed earlier is positive but rather low that is a little over five percent. In addition the variance associated with the cross-correlation is quite large. This indicates that those two institutional features have different informational content. It is thus crucial to understand how these two institutional features play a role so as to derive specific country recommendations.

The remainder of the paper is organized as follows. Section 2 discusses briefly the existing theoretical frameworks used in the literature on optimal public spending. Section 3 discusses the set up of our basic model. Section 4 presents an extension of the model. Section 5 discusses policy implications.

II. Existing Theoretical Frameworks

The Permanent Income (PI) framework is commonly used to help inform policy makers identify the appropriate level of spending given a transitory increase in resource revenues (see Ossowski and Barnett, 2002). Specifically, the PI framework derives the level of (non-interest) spending that maximizes the lifetime utility of an infinite horizon agent in an economy endowed with an exhaustible stock of natural resources. Formally the optimization program is as follows:

$$\underset{\{G\}_{t=1}^{\infty}}{Max}\sum_{t=1}^{\infty}\beta^{t-1}U(G_t)$$

$$st B_t = RB_{t-1} + G_t - T_t - Z_t \qquad (1)$$

$$\lim_{s\to\infty} B_{t+s} = 0 \qquad (2)$$

Where *G* is (non interest) government spending, *B* is the level of indebtedness, *T* is non-resource revenue, *Z* is resource revenue, *N* is the number of years the stock of natural resource reserve will last, β is the discount factor, *r* is the interest rate, *R* is defined as: $R=1+r$. We further assume $\beta R=1$. Equation (1) is simply the resource constraints, and equation (2) is the standard transversal condition.

The solution derived from the maximization is straightforward and rewrites as follows:

$$\overline{G} = T + \frac{r}{R}\sum_{j=0}^{N-1} R^{-i} Z - rB_{t_0}$$

Where $\overline{G}$ is the optimal level of government spending. The middle term is the flow of interest revenues that would be earned on the present discounted value of the future resource revenue streams derived from the exploitation of natural resources. The solution suggests that government would be consuming out the annuity derived from the permanent income on total wealth derived from recurrent income sources and the exploitation of exhaustible resources. Hausmann, Powell, and Rigobon (1993) describe the solution derived from the PI framework as: "The government behaves as if it sold all of its oil immediately, thus effectively transforming the flow of oil revenue into a stock of financial assets." To illustrate this further Figure 6 provides a graphic exposition of the evolution of the accumulation of financial assets over time under a specific parameterization. It shows that the government accumulates assets up to the point where it reaches its target level. Consumption in this specific case is flat.

The above framework suffers from a number of important caveats. Many authors have thus attempted to enrich the traditional PI framework introducing a number of realistic assumptions. Most noticeably, Collier, Venables, van der Ploeg and Spence (2011) and Venables and van der Ploeg (2011) augment the PI framework with three main features. First the authors assume that individuals face borrowing constraints. Second the economy faces interest premiums on foreign debt (decreasing with the level of foreign debt). Third the economy faces capital scarcity that is that the marginal product of capital in the home country is higher than the marginal product of capital in the rest of world.

Results derived from the authors' numerical simulations yield three main lessons. First, a government attempting to smooth individuals' consumption and facing borrowing constraints should use windfalls to increase individuals' consumption through increased dividends financed through borrowing first and then financed through interests derived from savings from resource windfalls. Second, heavily indebted countries facing premiums in their foreign borrowing should consider using their resource windfalls to repay their foreign debt as opposed to accumulating assets with typically lower earning returns. Third, low income countries facing capital scarcity should favor public investment including infrastructure over investment in foreign financial assets yielding lower returns to help encourage domestic investment.

While those recent developments have surely expanded the frontier of knowledge on optimal spending decisions in developing countries, they miss important imperfections in the level of administrative capacity and economic institutions faced by many of those countries.[6] We now turn to introducing our simple theoretical framework specifically integrating those important features.

III. A Simple Model of Public Investment

A. Model Set-up

We consider a small open economy that can borrow or lend unlimited amounts at world interest rate r^*. The government has access to international capital markets and let F be the level of sovereign debt. The economy is composed of two sectors namely the resource sector and the non-resource sector. At time $t = 0$, the government anticipates a windfall N_t

---

[6] Berg et al. (2011) and Van der Ploeg (2012) explore how absorptive capacity constraints shape the macroeconomic effects of natural resource oil windfalls in developing countries, including those associated with public investment. They, however, do not investigate specifically at the interaction between administrative capacity and economic institutions. Also, the theoretical framework presented in our paper is tractable enough to allow us to derive closed form solutions.

between period $t = t_0$ and $t = t_N$ originating from the natural resource sector.[7] Non-resource domestic income is given by $Y = AH(K, S)$ where A is the total factor productivity of the non-resource sector capturing economic conditions faced by the latter. K is the stock of private capital and S the stock of public capital.[8] We do not impose a particular functional form for the function H but derive our results assuming that this function is homogenous of degree one, which means that we can re-write

$$Y = AH\left(\frac{K}{S}, 1\right)S = Ah\left(\frac{K}{S}\right)S.$$

This assumption is general enough to allow for different values of the elasticity of substitution between private and public capital stock, i.e. it nests the well-known Constant Elasticity of Substitution (CES) production function, a special case of which is the Cobb-Douglas form.

Public capital is owned by the government and depreciates at rate δ_S and private capital depreciates at rate δ_K and is rented from foreign owners who face a world interest rate r^*. The government can invest in public capital but faces adjustment costs $g(I_t) \geq 0$.[9] If the government plans to increase the stock of public capital by I_t units, the government needs to spend $I_t + g(I_t)$. A key assumption is that those adjustment costs rise with the value of the resource windfall that is the net present value of the windfall, $V = \sum_{t=0}^{T}(1 + r^*)^{-t}N_t$.[10] For notational simplicity, we do keep this relation implicit in the functional form of $g(I_t)$. The rationale behind this assumption is that revenue windfalls such as revenues derived from the exploitation of natural resources lead to more rent seeking, as those resource revenues transit directly through government coffers and thus offer more scope for discretion and capture by public officials. Resource booms have been followed by large public investment programs which can be important vehicle for corruption. As a result, corruption is likely to rise with the size of resource windfalls. Arezki and Bruckner (2011) provide empirical evidence that an increase in oil rents causes a significant increase in corruption using a panel of 30 oil-exporting countries during the period 1992–2005. The adjustment cost associated with public investment is aimed at capturing the cost of corruption resulting from government officials' demand for special payments and the extent of illegal payments throughout government tiers (see Political Risk Services, 2009).[11]

---

[7] In this paper, we assume no uncertainty regarding the resource revenue and leave this for future work.

[8] We assume regularity of the production function H, i.e. $H_X > 0, H_{XX} < 0 \; for \; X = K, S$.

[9] Note that the results presented in this section hold for any functional form $g(I)$satisfying $g() \geq 0$.

[10] It is important to note that the specification chosen is general enough to accommodate various situations but we focus here on the case where those adjustment costs depend on the net present value of the resource windfall. In section 4, we consider the case where adjustment costs depend on the stock of public administrative know-how.

[11] We abstract here from modeling specifically the potential welfare loss resulting from misallocation of resources and the costs associated with secrecy.

Households have no access to foreign markets but the government can distribute transfers. Current consumption C_t is given by $C_t = W_t + G_t$ where W_t is the current wage and G_t is the transfer.

Profit maximizing firms will set the marginal productivity of private capital equal to its marginal cost which yields:

$$Ah_K\left(\frac{K}{S}\right) = r^* + \delta_K.$$

Under the regularity conditions imposed on the production function this equation yields an implicit function of the stock of private capital on the current stock of public capital $K_t = K(S_t, A_t)$. Given our regularity conditions, the inverse function h_K^{-1} exists such that we obtain: $K = h_K^{-1}\left(\frac{r^*+\delta_K}{A}\right)S$. The optimal stock of private capital is linear in S.

Since wages are by definition given as $W_t = Y_t - (r^* + \delta_K)K_t$, we have that current wages are given by an implicit function of the current stock of public capital say:

$$W_t = W(S_t, A_t) = \left(Ah\left(h_K^{-1}\left(\frac{r^*+\delta_K}{A}\right)\right) - (r^* + \delta_K)h_K^{-1}\left(\frac{r^*+\delta_K}{A}\right)\right)S.$$

We note here that:

$$W_S = Ah\left(h_K^{-1}\left(\frac{r^*+\delta_K}{A}\right)\right) - (r^* + \delta_K)h_K^{-1}\left(\frac{r^*+\delta_K}{A}\right) = \frac{Y-(r^*+\delta_K)K}{S} > 0,$$

is constant. We therefore have that $W_S(S, A) = W_S(A)$.

Furthermore, differentiating with respect to A yields the cross-partial:

$$W_{SA} = h\left(h_K^{-1}\left(\frac{r^*+\delta_K}{A}\right)\right) > 0.$$

Wages are increasing with the stock of public capital and even more so when non-resource sector TFP is higher.

The government's problem is to choose investment in public capital I_t and transfers G_t so as to maximize the utility of its citizens:

$$Max_{\{I_t,G_t\}} \sum_{t=0}^{\infty} \beta^t U(C_t)$$

while facing the following constraints:

$$F_{t+1} = (1 + r^*)F_t + G_t + I_t + g(I_t) - N_t$$

$S_{t+1} = (1 - \delta_S)S_t + I_t$

$C_t = W(S_t, A_t) + G_t$

$\lim_{t \to \infty} F_t = 0$

$F_0 = F.$

The associated Bellman equation reads as follows:

$$V(F_t, S_t) = Max_{\{I_t, G_t\}}\{U(C_t) + \beta V(F_{t+1}, S_{t+1})\}$$

Combining the first order conditions and envelop conditions to this problem yields the following Euler equations:

$U_{C_t} = \beta(1 + r^*)U_{C_{t+1}}$ (1)

$g_I(I_t) = \frac{r^* + \delta_S - W_{S_t}}{1 - \delta_S} + \frac{1 + r^*}{1 - \delta_S} g_I(I_{t-1})$ (2)

Equation (1) indicates that it is optimal to smooth consumption over time, i.e. $C_t = C_{t+1} = C$ if $\beta(1 + r^*) = 1$. This optimal level of consumption is obtained from the boundary condition imposed on the sovereign debt. Equation (2) gives the dynamic optimal path of investment in public capital.[12] This is a first order difference equation linking investments at *t* to investments at *t-1*. The steady state is as follows:

$g_I(I^*) = \frac{W_S(A)}{r^* + \delta_S} - 1$ (3)

Note that as long as the world interest rate is smaller than the (net of depreciation) marginal benefit (costs) of the stock of public capital, i.e. $r^* < W_{S_t} - \delta_S$, there exist a solution for I^*.

Equation (3) indicates that countries with a higher TFP will have a higher steady state investment in public capital as long as g_{II}>0.[13] Also, consider two economies, say k and l,

---

[12] One should note that this difference equation represents an upward sloping line with slope $\frac{1+r^*}{1-\delta_S} \geq 1$, in the $\big(g_I(I_{t-1}), g_I(I_t)\big)$ plan. This means that the dynamic process does not converge towards the steady state, i.e. if $g_I(I_{t-1}) < g_I(I^*)$ then $g_I(I_t) < g_I(I_{t-1})$ and vice versa. Stated otherwise, we have $g_I(I_t) = c + bg_I(I_{t-1})$ and replacing successively $g_I(I_{t-1})$ by its expression using this equation we obtain: $g_I(I_t) = c\frac{1-b^t}{1-b} + b^t g_I(I_0)$. Clearly, the steady state is given by $c\frac{1}{1-b}$. As *t* becomes large, we would converge to the steady state if and only if *b* is lower than 1. In our case, $= \frac{1+r^*}{1-\delta_S} \geq 1$.

[13] Let $I^*(A)$ be the implicit solution of equation (3). Plugging this expression and differentiating (3) with respect to *A* yields: $g_{II} I_A^* = \frac{W_{SA}}{r^* + \delta_S} > 0$. For $g_{II} \geq 0$, this implies that $I_A^* > 0$.

with $g_I^l(\quad) > g_I^k(\quad)$ such that economy l faces higher marginal adjustment costs, but otherwise similar. Clearly, the public capital investment in steady state will be lower in economy l than in economy k since the right hand side of (3) is the same for both economies and $g_{II} > 0$. This means that the larger the marginal investment costs (i.e., possibly because of a higher windfall), the lower the steady state investment in public capital.

It follows that the steady state stock of public capital, i.e. $S^* = \frac{I^*}{\delta_S}$, and therefore of private capital, is larger in economies with higher levels of TFP, or with smaller adjustment costs, ceteris paribus.

For illustration purposes, we use numerical simulations of the model when H takes a Cobb-Douglas functional form $K^\gamma S^{1-\gamma}$ where $0 < \gamma < 1$. Appendix 1 also provides the details of the parametrization. Figure 7 describes the evolution of the level of debt under a temporary resource windfall for our benchmark calibration. The government first accumulates debt anticipating the resource windfalls and then accumulates assets. The level of wages appears relatively flat. The latter result is not surprising since the objective of the maximization program is to smooth consumption that is the wage plus the government transfer. In the following, we discuss the results of numerical simulations under various parameter values for the adjustment cost and the TFP.[14]

B. Discussion of Results

Figure 8 corresponds to an experiment where we let two economies start from a similar steady state except for the respective size of their resource windfall at time, t_0. Recall that the adjustment cost depends positively on the present value of the windfall. This experiment allows us to compare the differences between economies in the evolution towards steady state of spending in public capital.[15] A larger resource windfall commands a lower level of public capital. This can be explained by the fact that a larger windfall imposes higher adjustment costs in turn raising the cost of investing in public capital. The latter renders spending the windfall through public investment suboptimal relative to redistribution through direct government transfers. Indeed, Figures 9 and 10 show that while the level of wage is lower, the level of consumption is higher in the economy with a larger windfall compared to the economy with lower one.

We now turn to our discussion of our various scenarios involving different levels of administrative capacity and TFP. Three important results emerge from the graphical illustrations. First, a higher level of TFP reduces the optimal level of public capital as private capital is crowded in, everything else being equal. Indeed, when the level of TFP is high,

[14] Note that for our benchmark calibration, we choose: $I_0 = I^*, S_0 = 0.75 \times S^*, F_0 = 5, N = 10, \delta_S = 0{,}05, \delta_K = 0{,}05, r^* = 0{,}08, A = 0{,}29, \gamma = 0{,}56 \; and \; \bar{\alpha} = 0{,}1 + 0.005 \times V$. We increase A by 0.075 for "high TFP" scenarios and the constant in $\bar{\alpha}$ by 0.7 for "high adjustment costs" scenarios.

[15] Note that in this experiment, we use the same parametrization as in the benchmark case.

government let private entrepreneurs rent capital leading to a higher level of private capital and lower level of public capital, as shown in Figures 11 and 12. Given our choice of functional form and parametrization, wages are lower. To compensate for the potential loss in consumption resulting from lower wages the government increases transfers. Overall wages are lower when TFP is higher as a larger share of output goes to the (private) rental of capital and a lower share to wages. This situation is addressed through relatively higher transfers in the case of higher TFP resulting in higher wage levels when the level of TFP is high, as shown in Figure 13.

Second, weaker administrative capacity lowers the level of optimal public capital. Indeed, adjustment costs are higher, the optimal public investment is reduced and less private capital is rented, as shown in Figures 11 and 12. Wages are thus lower and consumption is lower as shown in Figures 13. The intuition is simply that governments willing to smooth individuals' consumption internalize the prohibitive level of adjustment costs and thus relinquish on the option to invest a large amount of public capital. Three, better general economic conditions reduce the degree of des-investment in public capital triggered by weaker administrative capacity. Figure 11 shows indeed that the gap in optimal public investment between economies with high and low adjustment costs is lower when the level of TFP is higher. This is because better economic conditions allow to compensate for the weak administrative capacity in turn narrowing the gap in optimal public investment between countries with different levels of administrative capacity. The results above suggest that individually economic environment and administrative capacity have a differentiated impact on optimal public investment and also that their interaction play an important role.

IV. An Extension of The Model with Endogenous Investment in Administrative Capacity

So far, we have assumed that adjustment costs are exogenously determined. In the following, we describe a simple way to make them endogenous. Let T_t be the stock of "know how" in administering public investment projects. Assume that this stock can be increased through investments J_t as follows:

$$T_{t+1} = T_t + J_t \ .$$

Let adjustment costs in public capital investment be given by the function $g(I_t, T_t)$ with $g_I > 0$ and $g_T < 0$ such that past investments aimed at building administrative capacity (captured in the current stock of T_t) decrease adjustment costs.[16]

The government now chooses both investment in administrative capacity and investment in public capital and faces the additional accumulation constraint. The government's problem is

[16] We use $g(I_t, T_t) = \frac{1}{2}\bar{\alpha}(T_t)(I_t - \tilde{I})^2$ as the specific functional form in the numerical examples presented in this section.

now to choose transfers G_t, investment in public capital I_t and investment in administrative capacity J_t so as to maximize the utility of citizens:

$$Max_{\{I_t,J_t,G_t\}} \sum_{t=0}^{\infty} \beta^t U(C_t)$$

While facing the following constraints:
$F_{t+1} = (1 + r^*)F_t + G_t + I_t + g(I_t, T_t) + J_t - N_t$
$S_{t+1} = (1 - \delta_S)S_t + I_t$
$T_{t+1} = T_t + J_t$
$\lim_{t\to\infty} F_t = 0$
$F_0 = F.$

This yields a third Euler condition compared to the initial optimization program that is as follows:

$-g_{T_t} = r^*$ (4)

Under regularity conditions imposed on the function g, this third Euler condition allows us to write investment in public capital at time *t* as an implicit function, say $q(T_t)$, of the stock of know-how in the public administration at time *t* as:

$I_t = q(T_t)$ (5)

A simple comparative static exercise allows to show that public investment will increase with the stock of know-how if and only if $-\frac{g_{TT}}{g_{TI}} > 0$.[17] It seems reasonable to assume that $g_{TT} > 0$, $g_{IT} < 0$ and $g_{II} > 0$. In which case, $-\frac{g_{TT}}{g_{TI}} > 0$ and the steady state investment in public capital investment increases with the stock of know-how in the public administration. This result expand interestingly on the ones obtained using the basic model, as they suggest that countries faced with resource windfalls should adjust their optimal level of investment in public capital to their existing stock of know how in the public administration.

Moreover, replacing I_t by $q(T_t)$ as derived from the third Euler condition, we can re-write the second Euler equation to arrive at:

---

[17] $\frac{\partial I_t}{\partial T_t} = q_T(T_t) = -\frac{g_{TT}}{g_{TI}}$ provided $g_{TI} \neq 0$.

$\Delta(T_t) = \frac{r^*+\delta_S-W_{S_t}}{1-\delta_S} + \frac{1+r^*}{1-\delta_S}\Delta(T_{t-1})$ (6)

where $\Delta(T_t) = g_I(q(T_t), T_t)q(T_t)$ and with $\Delta_T(T_t) = \left(g_{IT} - g_{II}\frac{g_{TT}}{g_{TI}}\right)q - g_I\frac{g_{TT}}{g_{TI}}$.

Note that the sign of $\Delta_T(T_t)$ clearly depends in a non-trivial fashion on the shape (the curvature of function $g(.)$ in T and I and the degree substitution between T and I in function $g(.)$) of the adjustment cost function. However, we note that a sufficient, though not necessary, condition for $\Delta_T(T_t) > 0$ is $g_{IT} - g_{II}\frac{g_{TT}}{g_{TI}} > 0$ since $q > 0$ and $-g_I\frac{g_{TT}}{g_{TI}} > 0$ when $g_{TT} > 0$, $g_{IT} < 0$ and $g_{II} > 0$.

This sufficient condition rewrites as $g_{IT}^2 < g_{II}g_{TT}$.

The steady state of the stock of know-how is as follows:

$\Delta(T^*) = \frac{W_S(A)}{r^*+\delta_S} - 1$ (7)

This equation yields an implicit function of the steady state stock of know-how $T^*(A)$. Plugging this into (7) and differentiating with respect to *A* yields:

$$\Delta_T T_A^* = \frac{W_{SA}}{r^* + \delta_S} > 0$$

The steady state stock of know-how should increase with the quality of economic institutions, if and only if $\Delta_T > 0$. Without further assumption on the shape of adjustment costs, it is however impossible to ascertain that the sign of this derivative is positive. However, if $g_{TT} > 0$, $g_{IT} < 0$ and $g_{II} > 0$ and $g_{IT}^2 < g_{II}g_{TT}$ then $\Delta_T > 0$ and $T_A^* > 0$, this derivative is positive. Under those assumptions, it is therefore optimal to invest in building the stock of know-how in public administrations in a context of higher level of TFP.

V. Policy implications

The paper has studied the optimal public investment decisions in countries experiencing a resource windfall. Our results suggest that it is not necessarily the case that governments in resource rich countries should increase in the context of temporary resource windfalls. Indeed, spending is public capital investment is not the only option especially in a context of weak state capacity. We found that a larger resource windfall commands a lower level of public capital but a higher level of redistribution through direct transfers under the realistic assumption that adjustment costs rise with the size of the resource windfall. We also found that weaker administrative capacity lowers the increase in optimal public capital following a resource windfall. Higher total factor productivity in the non-resource sector reduces the degree of des-investment in public capital commanded by weaker administrative capacity. That said administrative capacity may be relatively more malleable than non-resource sector total factor productivity. In the medium run, investment in relaxing those constraints should be considered. We thus extended our basic model to allow for “investing in investing” —that is public investment in administrative capacity. We found that a higher initial stock of public administrative “know how” leads to a higher level of optimal public investment following a resource windfall.

Practically, investment in administrative capacity in resource rich countries could take place through increasing transparency in the handling of resource windfalls and better identifying and implementing projects. There exist important international initiatives aimed at enhancing transparency in the management of natural resources revenues as well as at enhancing the effectiveness with which those revenues are spent. For instance the Extractive Industries Transparency Initiative (EITI) constitutes a set of global standard for transparency in the oil, gas and mining extractive industries. The Natural Resource Charter which builds on EITI represents a more comprehensive set of principles for governments and societies on how to best harness the opportunities created by extractive resources for development. Those initiatives could serve as anchors for enhancing transparency and accountability in resource rich countries and in turn reducing misappropriation and overruns costs in public investment programs.

Some lessons can also be learned from Chile’s three decades of experience in subjecting all public projects to disciplined and transparent cost-benefit analysis (see Ley, 2006). The National System of Investments (SNI) was established at the Ministry of Planning (MoP), currently administered jointly with the Ministry of Finance (MoF). All public-investment projects are appraised by MoP on the basis of cost-benefit analyses carried out with a clearly specified methodology—including a shadow social price system and a social rate of discount.[18] Regarding the issue of project implementation the World Bank has long advocated for the establishment of Project Implementation Units (PIU), stand alone entities composed mainly of a project director, a procurement,a financial and monitoring and evaluation specialists to assist in the implementation of World Bank-financed projects.. The record with PIUs is however mixed at best mainly due tothe lack of continuity and accumulation of know- how in administrative capacity. The fact is that PIUs are set up (and financed) for the duration of one specific project and disappear once the project is closed.. The World Bank has been recommending that those PIUs be integrated to the line ministry so as to allow employees of those units to share their knowledge throughout the relevant ministries. While those experiences are useful and telling, there is a need for both more empirical work in documenting systematically cross- and within country differences in state capacity and also more academic work on the political economy of building state capacity.

[18] The SNI currently comprises an online databank with over 300,000 entries—i.e., policy ‘initiatives.’

References

Acemoglu, Daron, Simon Johnson, and James Robinson, 2001, "The Colonial Origins of Comparative Development: An Empirical Investigation," *American Economic Review,* Vol. XCI, pp. 1369–1401.

Acemoglu Daron and Simon Johnson, 2005, "Unbundling Institutions," *Journal of Political Economy*, University of Chicago Press, October, Vol. 113(5), pages 949–995.

Alfaro, Laura, Sebnem Kalemli-Ozcan, and Vadym Volosovych, 2008, "Why doesn't capital flow from rich to poor countries? An empirical investigation," *Review of Economics and Statistics,* Vol. 90(2), pp. 347–68.

Arezki Rabah, Kirk Hamilton and Kazim Kazimov, 2011, "Resource Windfalls, Macroeconomic Stability and Economic Growth," IMF Working Paper 11/142 (Washington, International Monetary Fund).

Arezki, Rabah and Markus Brueckner, "Oil rents, corruption, and state stability: Evidence from panel data regressions." *European Economic Review* (forthcoming).

______, 2011a, "International Commodity Price Shocks, Democracy and External Debt", the *Economic Journal* (forthcoming).

______, 2011b, "Resource Windfalls and Emerging Market Sovereign Bond Spreads: The Role of Political Institutions," *World Bank Economic Review*.

Barnett, Steven and Rolando Ossowski, 2002, "Operational Aspects of Fiscal Policy in Oil-Producing Countries," IMF Working Paper 02/177, (Washington, International Monetary Fund).

Berg, A., R.Portillo, S. Yang and L.F. Zanna, 2011, "Public Investment in Resource Abundant Low-Income Countries," IMF Manuscript (Washington, International Monetary Fund).

Birdsall, Nancy, and Arvind Subramanian, 2004, "Saving Iraq from Its Oil," Foreign Affairs, July–August, Vol. 83(4), pp. 77–89.

Hall, Robert E., and Charles I. Jones, 1999, "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *Quarterly Journal of Economics,* Vol. 114, pp. 83–116.

Hausmann, Ricardo, Andrew Powell, and Roberto Rigobon, 1993, "An Optimal Spending Rule Facing Oil Income Uncertainty (Venezuela)," in Engel, Eduardo and Meller, Patricio, eds. External shocks and stabilization mechanisms, Inter-American Development Bank, distributed by Johns Hopkins University Press, Washington, DC, pp. 113–71.

Heston Alan, Robert Summers and Bettina Aten, 2006, Penn World Table Version 6.2, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, September.

Keefer, Philip, and Stephen Knack, 1995, "Institutions and Economic Performance: Cross-Country Tests Using Alternative Measures," *Economics and Politics,* Vol. VII, pp. 207–27.

Kyobe Annette & Jim Brumby & Chris Papageorgiou & Zac Mills & Era Dabla-Norris, 2011, "Investing in Public Investment: An Index of Public Investment Efficiency," IMF Working Papers 11/37 (Washington, International Monetary Fund).

Van der Ploeg , R. 2007, "Challenges and Opportunities for Resource Rich Economies," OXCARRE WP 2008-05.

Van der Ploeg R. and T. Venables, 2009, "Harnessing Windfall Revenue: Optimal Policies for Resource-Rich Developing Economies," Cesifo WP 2571.

Collier P., R. van der Ploeg, M. Spence and T. Venables, 2009, "Managing Revenues in Developing Countries," OXCARRE WP 2009-15.

Frankel J., 2012, "The Natural Resource Curse: A Survey of Diagnoses and Some Prescriptions," Forthcoming in *Commodity Price Volatility and Inclusive Growth in Low-Income Countries* (Arezki, Quintyn, Pattillo and Zhu, eds) International Monetary Fund.

Gelb, Alan and associates, 1988, "Oil windfalls: Blessing or curse?" *Oxford University Press*, for the World Bank, New York.

Gelb A., 2011, "Economic Diversification in Resource Rich Countries," published in Beyond The Curse: Policies to Harness the Power of Natural Resources.

Ley E., 2006, "Appraisal of Public Investment: Chile," Knowledge Brief for Bank Staff, The World Bank, Washington.

Moss, T., 2011, "Oil to Cash: Fighting the Resource Curse through Cash Transfers", Working Paper, 237, January, Center for Global Development, Washington.

North, Douglass C., 1990, *Institutions, Institutional Change, and Economic Performance* (Cambridge: Cambridge University Press).

Political Risk Services, 2009, *International Country Risk Guide.*

Quinn, Dennis P., and John T. Woolley, 2001, "Democracy and National Economic Performance: The Preference for Stability," *American Journal of Political Science,* Vol. XLV, pp. 634–57.

Ross, Michael L., 2012, “The Political Economy of Petroleum Wealth in Low-Income Countries: Some Policy Alternatives” in *Commodity Prices and Inclusive Growth in Low-Income Countries*, ed. by Rabah Arezki, Catherine Pattillo, Marc Quintyn, and Min Zhu, International Monetary Fund.

Van der Ploeg, Frederick, 2011, “Natural resources: curse or blessing?” *Journal of Economic Literature*, Vol. 49(2), pp. 366–420.

Van der Ploeg, R., 2011, “Oil windfalls and investing to invest in Central Africa,” for B. Aikitoby and S. Coorey (eds.), *Oil in Central Africa - Policies for Inclusive Growth*, IMF (Washington, International Monetary Fund), to be published.

Warner, Andrew, “A Framework for Efficient Government Investment”, International Monetary Fund, mimeo.

World Bank, 2006, “Where is the Wealth of Nations?,” The World Bank Group, Washington.

______, 2011a, Doing Business Database, The World Bank Group, Washington.

______, 2011b, World Development Indicators, the World Bank Group, Washington.

Appendix 1: Parametric Specification

Let $U(C) = \frac{C^{1-1/\sigma}}{1-1/\sigma}$ with $\sigma < 1$ such that $U_C = C^{-1/\sigma}$ and let $g(I) = \frac{\bar{\alpha}}{2}(I - \tilde{I})^2$ where $\bar{\alpha} \geq 0$. Let the production function be of a Cobb-Douglas form with constant returns to scale, i.e. let $\mathrm{H}(K, S) = K^\gamma S^{1-\gamma}$ where $0 < \gamma < 1$.

We have:

$K(S, A) = aA^{\frac{1}{1-\gamma}}S$, where $a = \left(\frac{\gamma}{r^* + \delta_K}\right)^{\frac{1}{1-\gamma}}$

$C = W(S, A) = a^\gamma A^{\frac{1}{1-\gamma}}(1 - \gamma)S$

$W_S = a^\gamma A^{\frac{1}{1-\gamma}}(1 - \gamma) = \bar{W}_S$

$g_I = \bar{\alpha}(I - \tilde{I})$.

The Euler equation now reads as:

$$\bar{\alpha} I_t = \frac{r^* + \delta_S - W_{S_t}}{1 - \delta_S} + \frac{1 + r^*}{1 - \delta_S}\bar{\alpha} I_{t-1} - \bar{\alpha}\frac{\delta_S + r^*}{1 - \delta_S}\tilde{I}$$

When $\bar{\alpha} > 0$, we obtain:

$$I_t = \frac{1}{\bar{\alpha}}\frac{r^* + \delta_S - W_{S_t}}{1 - \delta_S} + \frac{1 + r^*}{1 - \delta_S} I_{t-1} - \frac{\delta_S + r^*}{1 - \delta_S}\tilde{I}$$

We further write $\bar{\alpha} = \alpha + \delta V$ with $\alpha > 0$ and $\delta \geq 0$ to take into account the potential link between the windfall size and adjustment costs.

Appendix 2: Parametric Specification of the Extended Model

Let $g(I, T) = \bar{\alpha}(T)\frac{(I - \tilde{I})^2}{2}$ where $\bar{\alpha}(T_t)$ is modeled as follows:

$\bar{\alpha}(T_t) = \frac{1}{n}(1 + e^{T_t})^{-n}$, with $n > 0$. As T_t tends to ∞, the adjustment costs tend to 0. The parameter n governs the speed with which this convergence process occurs. The larger n the faster it converges to 0.

Given this specification, the third Euler condition can be rearranged to obtain: $I_t = (2r^*)^{1/2}(1 + e^{T_t})^{\frac{n+1}{2}} + \tilde{I}$, which yields: $\frac{\partial I_t}{\partial T_t} = \frac{n+1}{2}(2r^*)^{1/2}(1 + e^{T_t})^{\frac{n-1}{2}} > 0$.

The second Euler condition yields:

$\Delta(T_t) = \frac{(2r^*)^{1/2}}{n}(1 + e^{T_t})^{\frac{1-n}{2}}$ for all t.

We therefore obtain:

$$\frac{\partial\Delta(T_t)}{\partial T_t} = \frac{1-n}{2}\frac{(2r^*)^{1/2}}{n}(1+e^{T_t})^{-\frac{1+n}{2}}$$

Since $\Delta(T_t)$ increases over time as indicated by the second Euler condition when $r^* + \delta_S - W_{S_t} > 0$, this means that when $n > 1$ the stock of know-how decreases over time and so does investment in public capital. However, when $0 < n < 1$, the stock of know-how increases over time and so does investment in public capital.

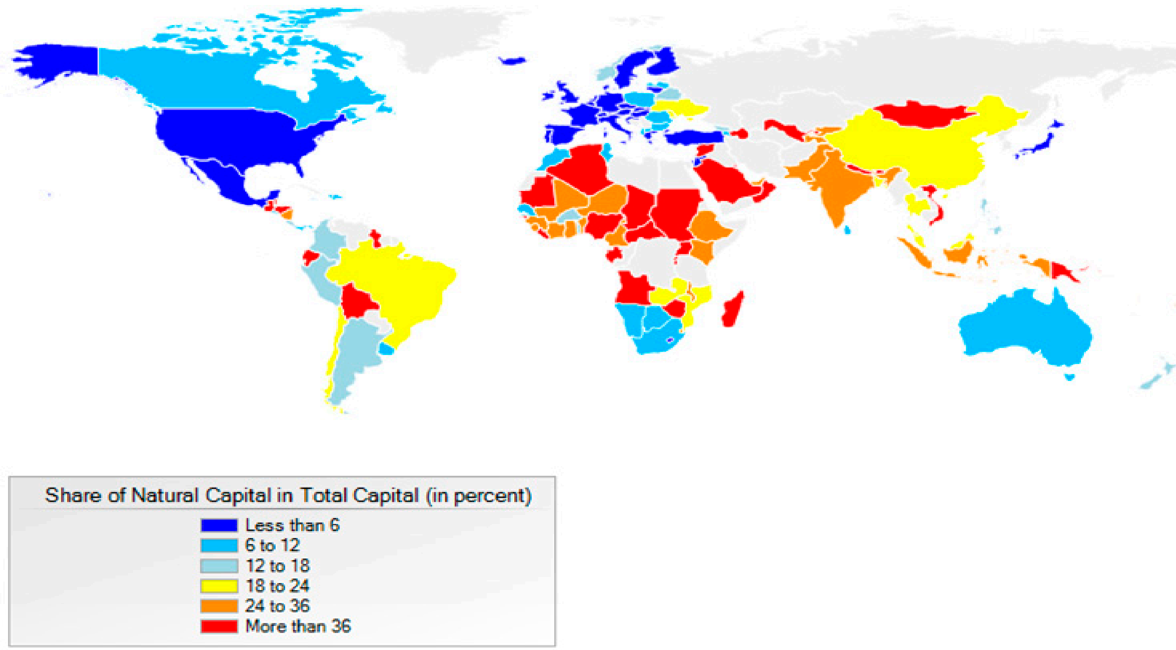
It follows that: $\Delta_t = \sum_{s=0}^{t-1}\left(\frac{1+r^*}{1-\delta_S}\right)^s \frac{r^*+\delta_S - W_{S_{t-s}}}{1-\delta_S} + \frac{1+r^*}{1-\delta_S}\Delta_0$.

The comparative statics now read as:

$\frac{\partial\Delta(T_t)}{\partial A} = -\sum_{s=0}^{t-1}\left(\frac{1+r^*}{1-\delta_S}\right)^s \frac{1}{1-\delta_S}\frac{\partial W_{S_{t-s}}}{\partial A} < 0$ since $\frac{\partial W_{S_{t-s}}}{\partial A} > 0$ for all $t-1 \geq s \geq 0$.

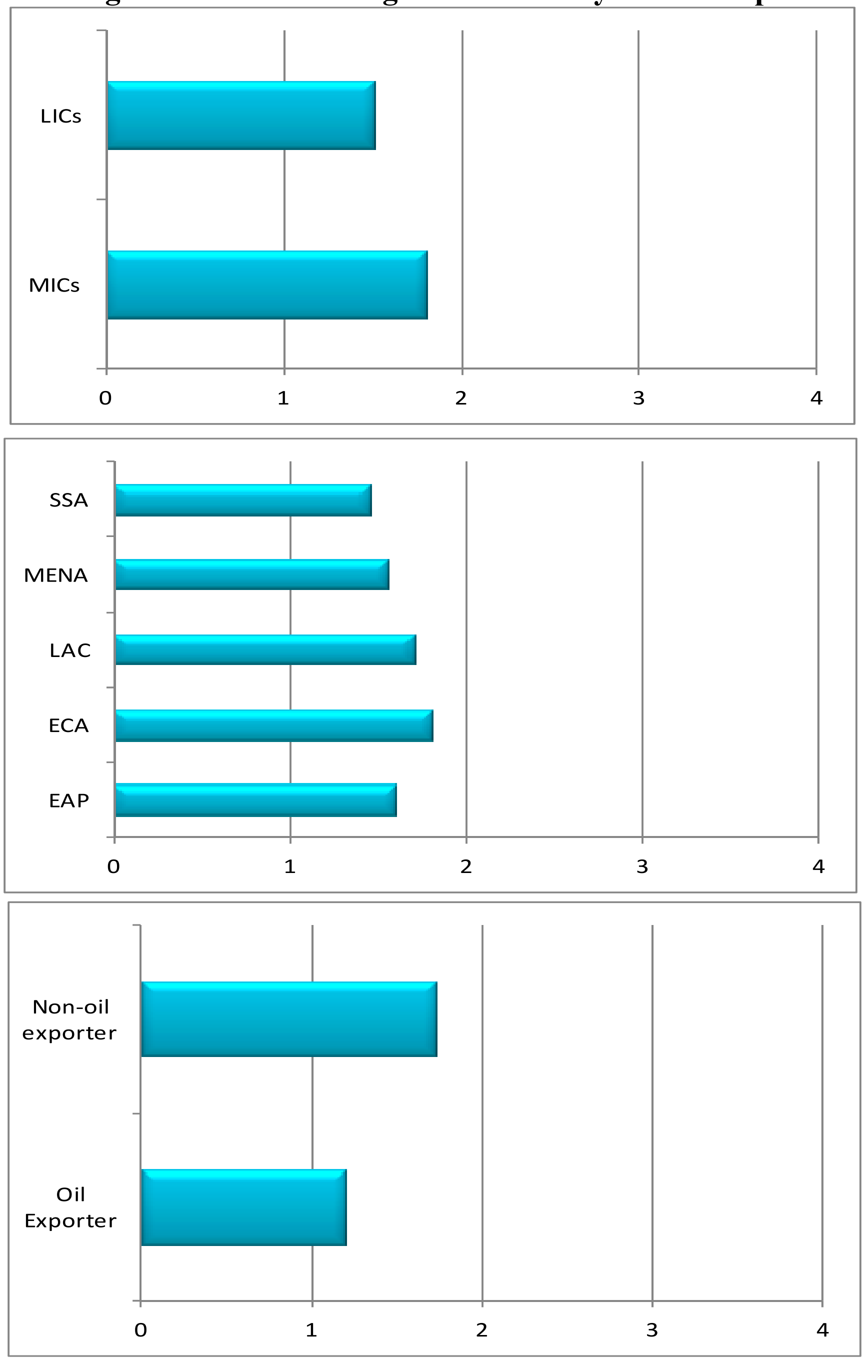
$\frac{\partial\Delta(T_t)}{\partial\Delta(T_0)} = \frac{1+r^*}{1-\delta_S} > 0.$

Figure 1. Share of Natural Capital around the World



Source: World Bank (2008).
Note: The share of natural capital is defined as the ratio of natural capital over total wealth. Natural capital is sum of Crop, Pasture Land, Timber, Non Timber Forest, Protected Areas, Oil, Natural Gas, Coal, and Minerals. Total wealth is sum of net foreign assets, produced capital, natural capital and intangible capital. Total wealth is calculated as the present value of future consumption that is sustainable, discounted at a rate of time preference of 1.5 percent, over 25 years. Intangible capital is obtained as the residual of total wealth minus net foreign assets, natural capital, and produced capital.

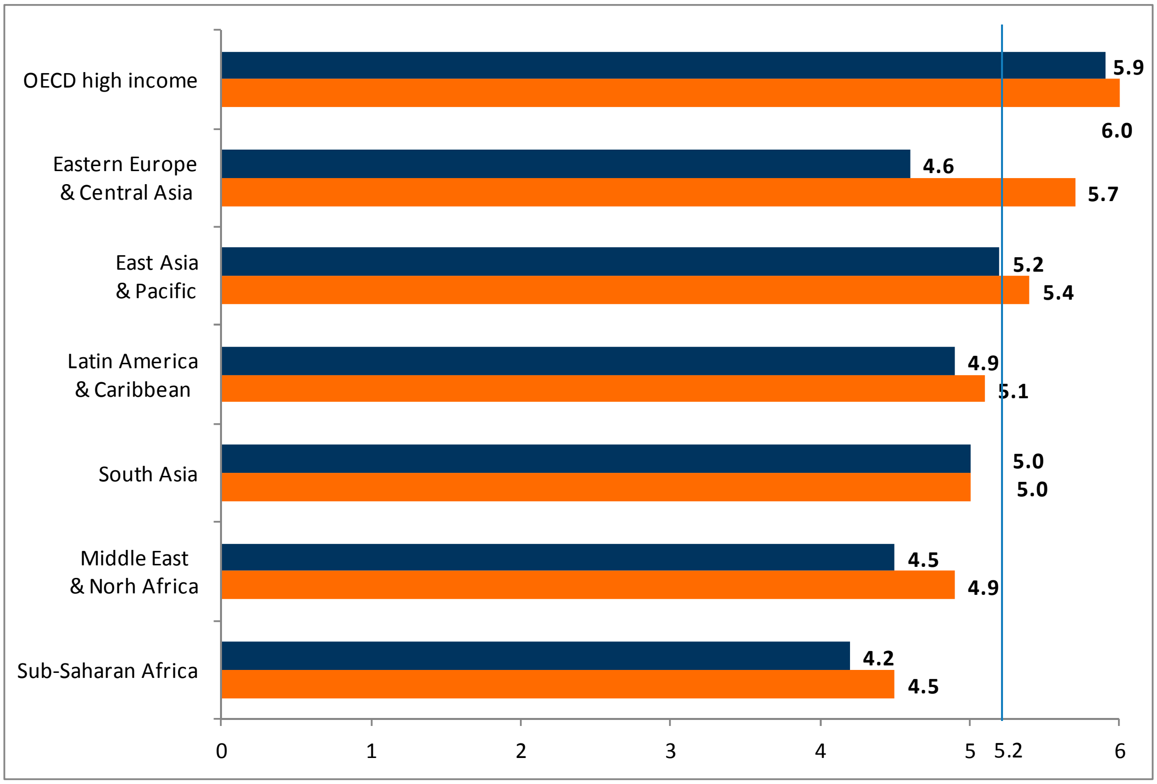
Figure 2. Public Management Index by Sub-Groups



Source: Kyobe, Brumby, Papageorgiou, Mills and Dabla-Norris (2011).

Note: The Public Investment Management Index (PIMI) overall index is derived as a simple average of the four sub-indices namely: (i) Strategic Guidance and Project Appraisal; (ii) Project Selection; (iii) Project Implementation; and (iv) Project Evaluation and Audit. The PIMI overall index aims to systematize available information regarding the functioning of identified stages of the public investment cycle. LICs: low-income countries; MICs: middle-income countries; SSA: Sub-Saharan Africa; MENA: Middle East and North Africa; LAC: Latin America and the Caribbean; ECA: Europe and Central Asia; EAP: East Asia and Pacific.

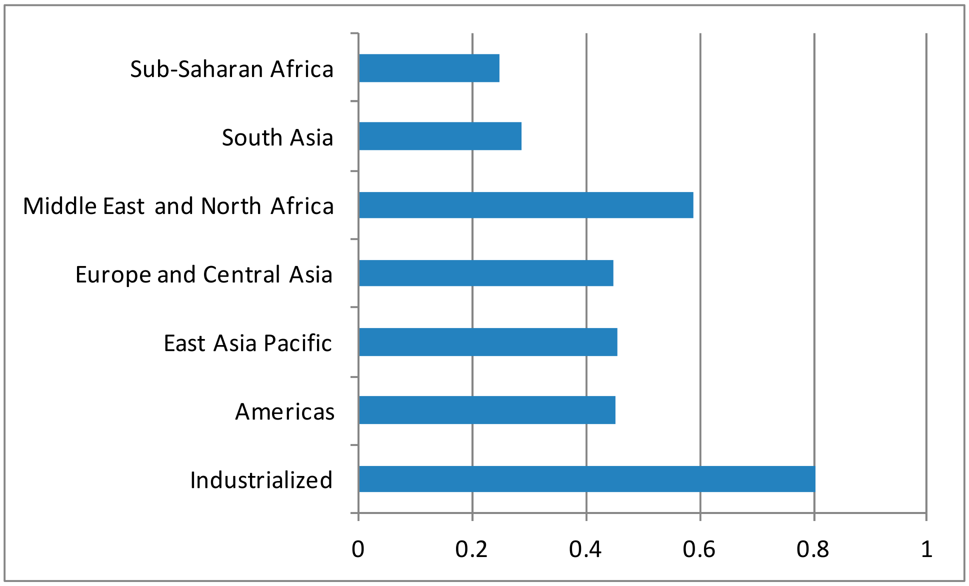
Figure 3. Investor Protection Index



Source: *Doing Business* database (DB).

Note: The data sample for DB 2006 (2005) includes 174 economies. The sample for DB2012 (2011) also includes The Bahamas, Barhain, Brunei Darussalam, Cyprus, Kosovo, Liberia, Luxembourg, Montenegro and Qatar, for a total of 183 economies. DB2006 data are adjusted for any data revisions and changes in methodology and regional classifications of economies.

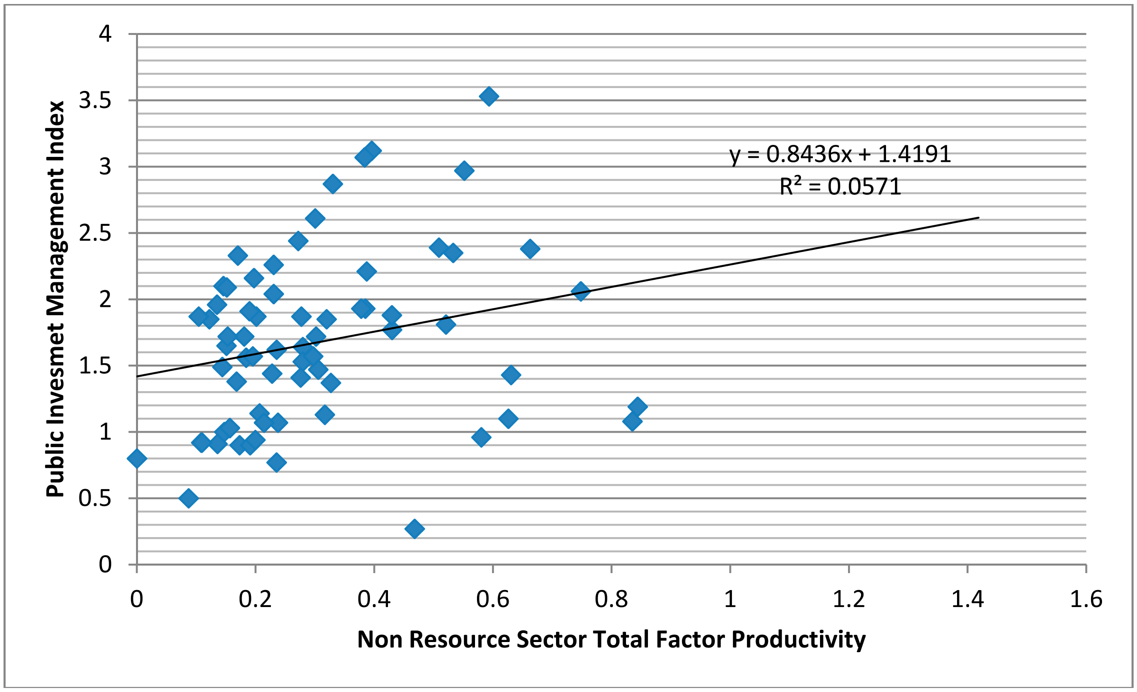
Figure 4. Non-Resource Sector Total Factor Productivity



Sources: Heston, Summers and Aten (2006), World Bank (2011b) and authors' own calculations.

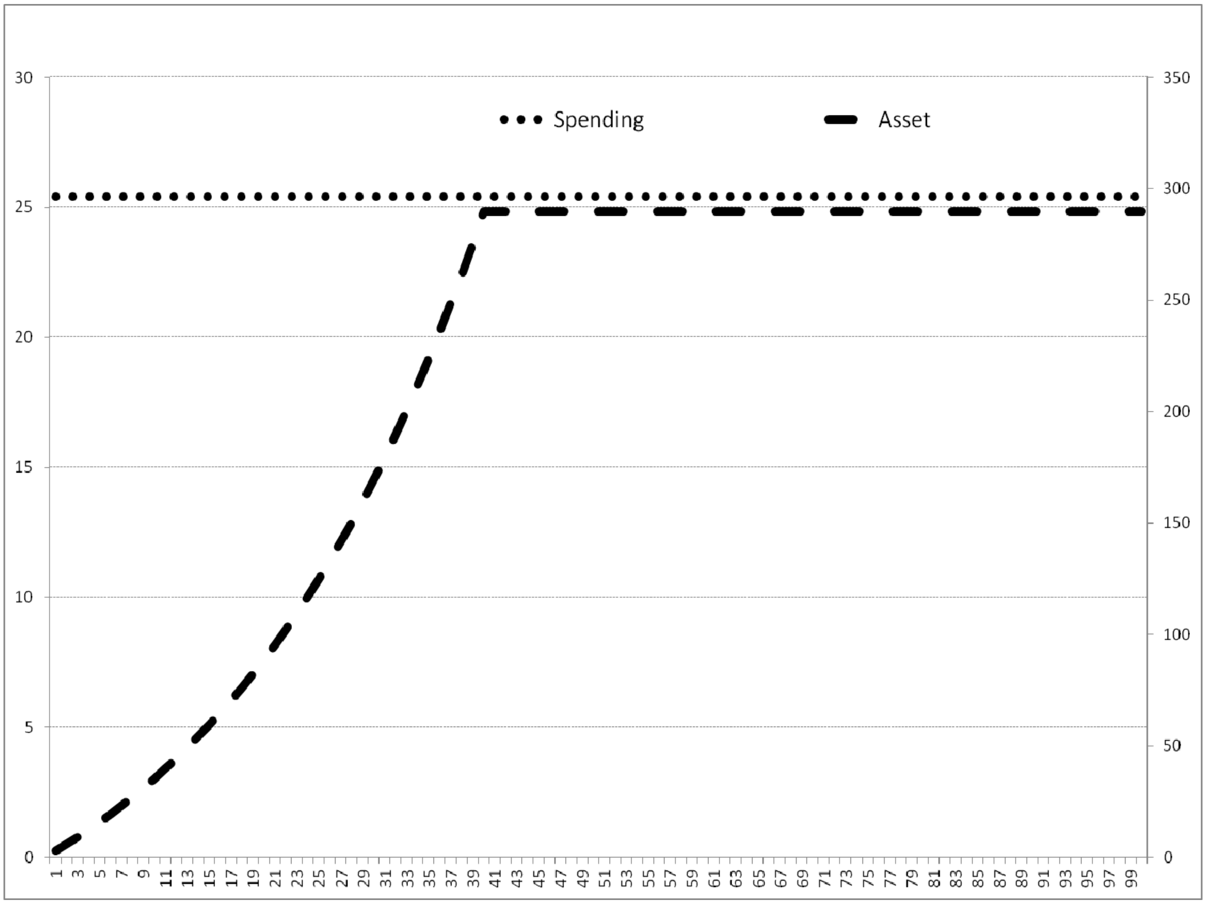
Note: Non-resource GDP is approximated by subtracting the real values of natural resources rents (obtained from World Bank, 2011b) from total GDP per worker in 2000 PPP adjusted USD (obtained from Heston, Summers and Aten, 2006). For each type of resource and each country, unit resource rents are thereby derived by taking the difference between world prices (to reflect the social opportunity cost of resource extraction) and the average unit extraction or harvest costs (including a "normal" return on capital). Unit rents are then multiplied by the physical quantity extracted or harvested to arrive at total rent. The energy resources include oil, natural gas and coal, while metals and minerals include bauxite, copper, gold, iron ore, lead, nickel, phosphate, silver, tin, and zinc. To back out non resource sector TFP by dividing non resource output by the stock of reproducible capital (derived from perpetual inventory method) at the power the factor share. The factor share is set at 0.34 as is standard in the literature. Capital investment is obtained from Heston, Summers and Aten (2006).

Figure 5. Public Investment Management Index and Non-resource Sector Total Factor Productivity



Sources: Kyobe, Brumby, Papageorgiou, Mills and Dabla-Norris (2011), Heston, Summers and Aten (2006), World Bank (2011b) and authors' own calculations.

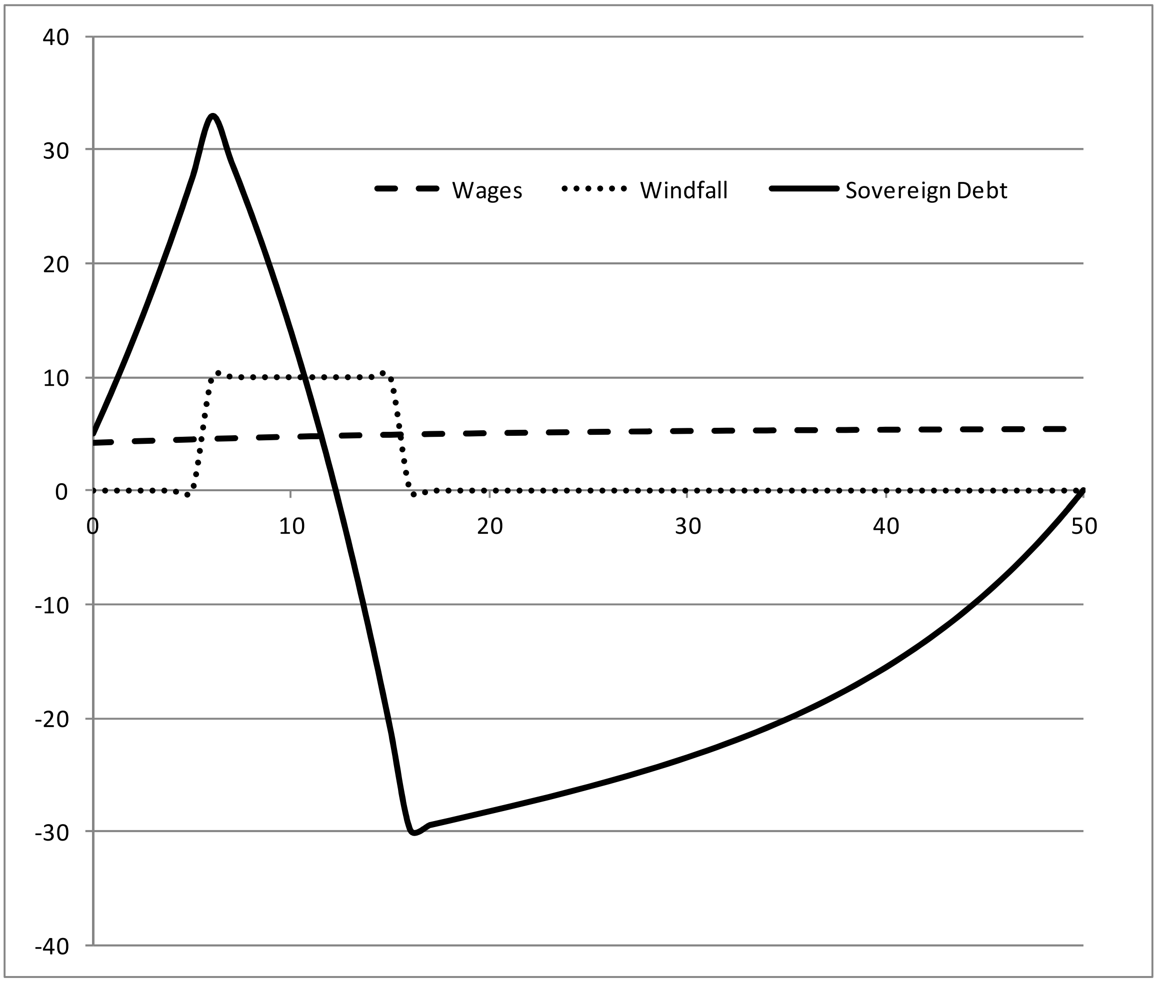
Figure 6. Resource Windfall, Consumption and Foreign Debt under the Permanent Income Framework



Source: Authors' own calculations.

Note: The parametrization used is as follows: initial debt Bo=40; non-oil GDP Y=100, non-oil revenue T=τY=15; oil revenue Z=15 for 40 years; discount factor β=0.96 implying an interest rate r=0.04. Spending describes the optimal level of public spending in the most basic permanent income framework and Asset describes the evolution of financial asset accumulated under this optimal path.

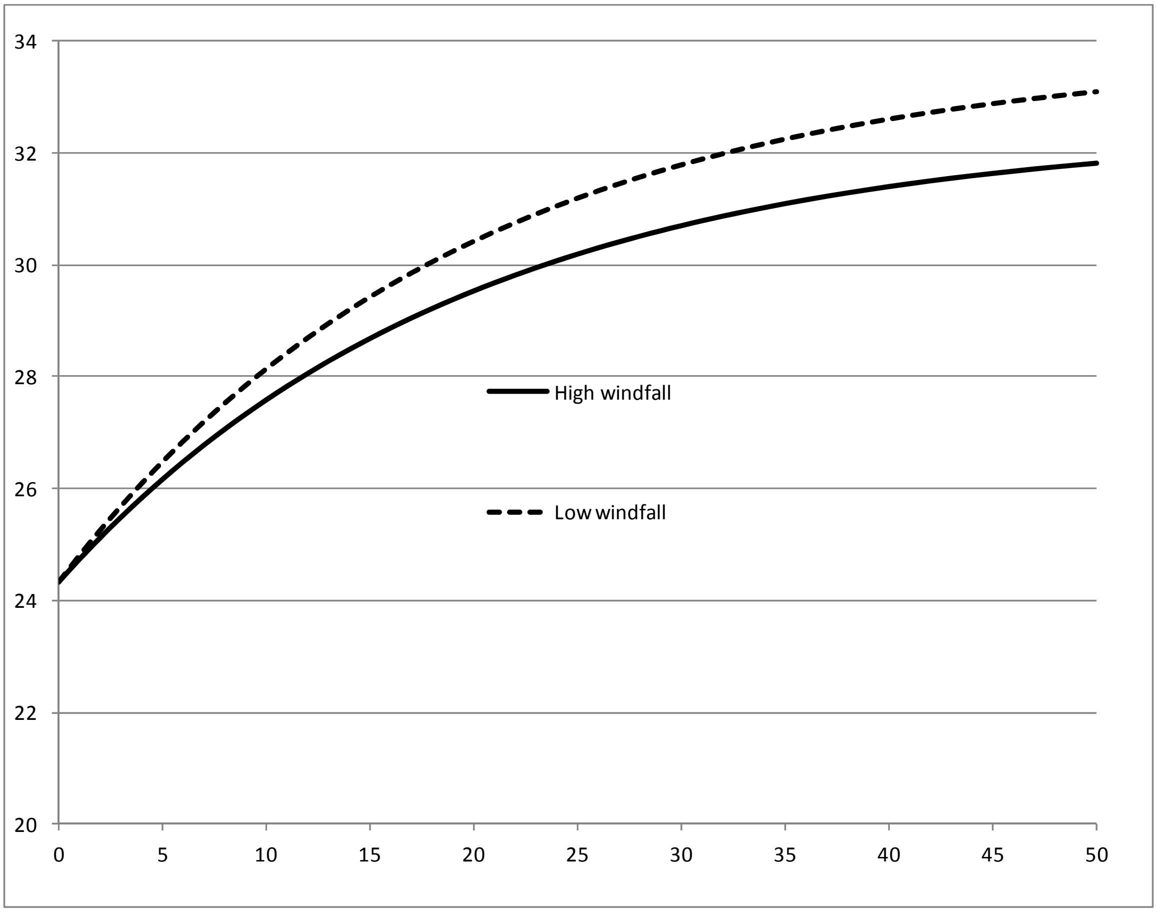
Figure 7. Evolution of Wages, Resource Windfalls and Sovereign Debt



Source: Authors' own calculations.

Note: Our parametrization is such that: $I_0 = I^*, S_0 = 0.75 \times S^*, F_0 = 5, N = 10, \delta_S = 0{,}05, \delta_K = 0{,}05, r^* = 0{,}08, A = 0{,}29, \gamma = 0{,}56$ and $\bar{\alpha} = 0{,}1 + 0.005 \times V$. I_0: investment in public capital at t=0; I^*: steady state investment in public capital; S_0: initial stock of public capital at t=0; S^* : steady state stock of public capital; F_0 : level of sovereign debt at t=0; N: number of periods during which the resource windfall is non zero; δ_S : public capital depreciation rate; δ_K : private capital depreciation rate; r^* : world interest rate; A: total factor productivity ; γ: private capital income share; $\bar{\alpha}$: adjustment cost parameter ; V : net present value of the resource windfall.

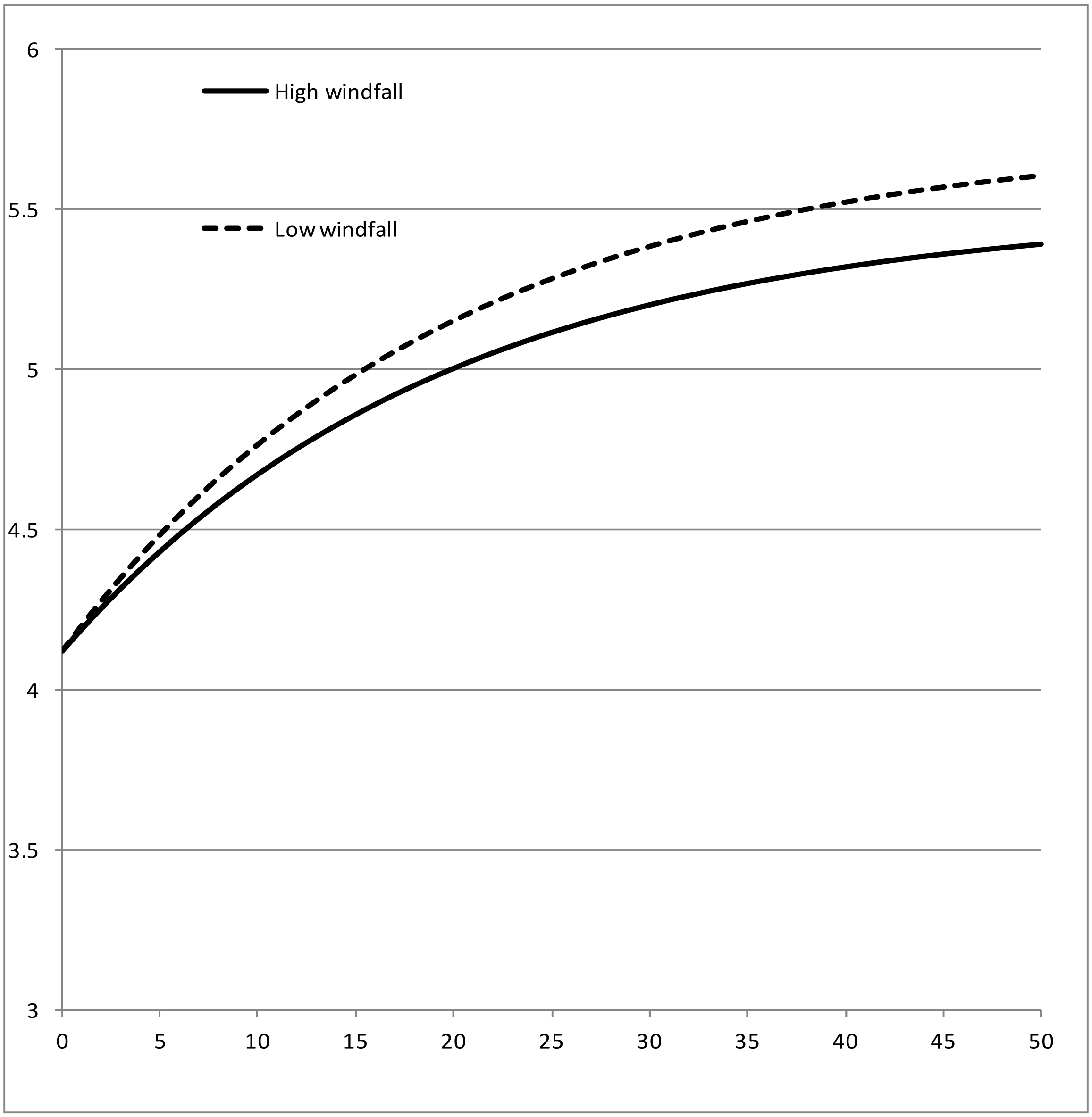
Figure 8. Evolution of the Stock of Public Capital under Different Scenarios



Source: Authors' own calculations.

Note: This figure corresponds to an experiment where we let two economies start from a similar steady state except for the respective size of their resource windfall at time, t_0. Recall that the adjustment cost depends positively on the present value of the windfall. This experiment allows us to compare the differences between economies in the evolution towards steady state of spending in public capital. We use our benchmark case parametrization to conduct the experiment.

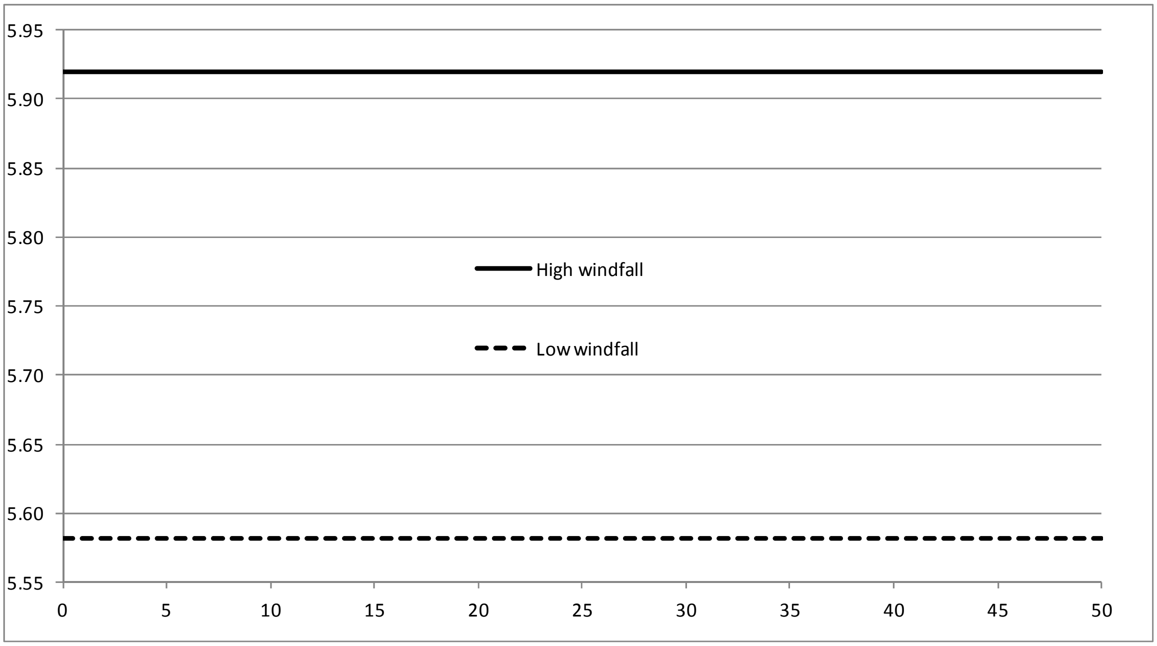
Figure 9. Evolution of Wages under Different Scenarios



Source: Authors' own calculations.

Note: This figure corresponds to an experiment where we let two economies start from a similar steady state except for the respective size of their resource windfall at time, t_0. Recall that the adjustment cost depends positively on the present value of the windfall. This experiment allows us to compare the differences between economies in the evolution towards steady state of spending in public capital. We use our benchmark case parametrization to conduct the experiment.

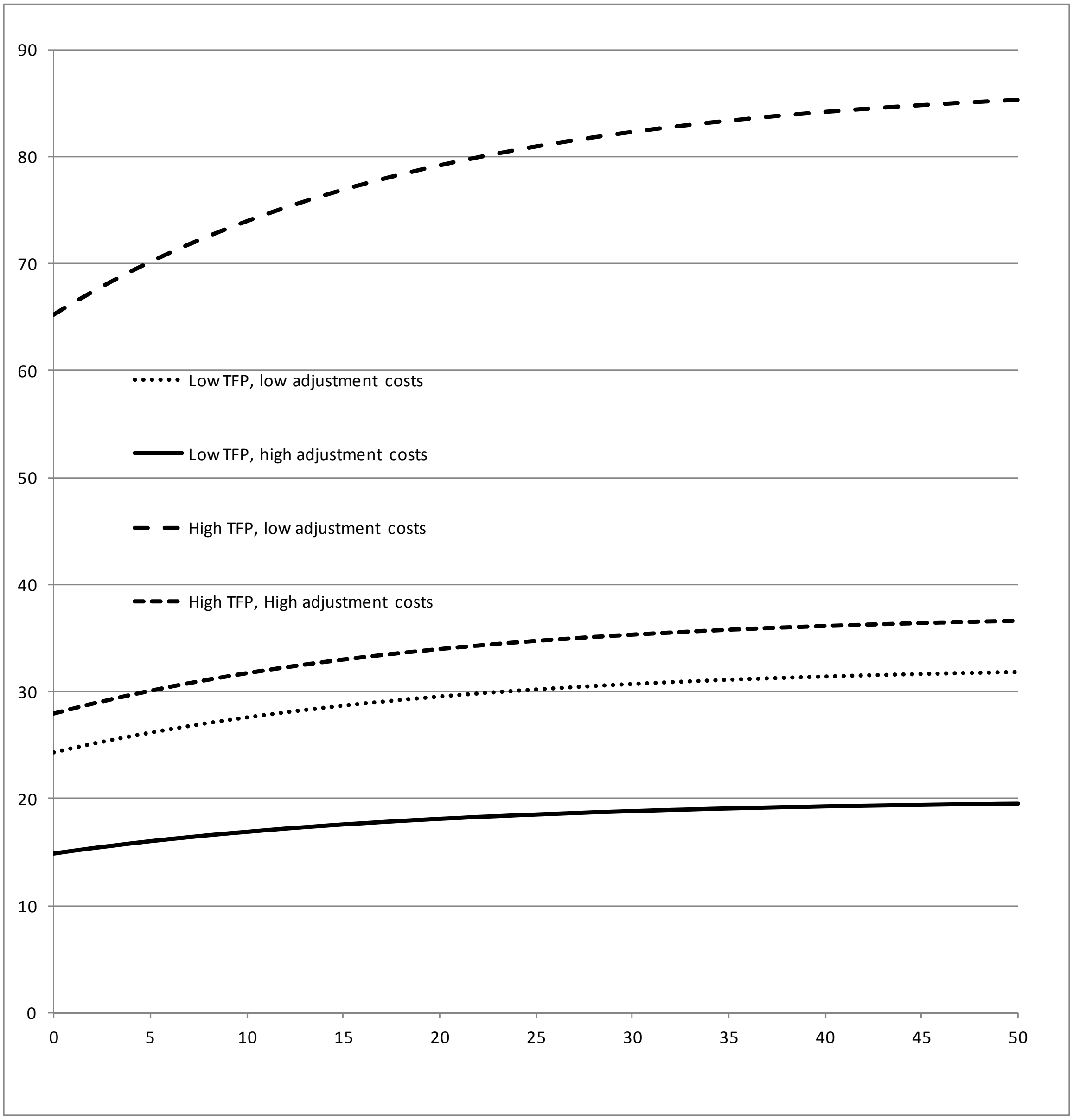
Figure 10. Evolution of Private Consumption under Different Scenarios



Source: Source: Authors' own calculations.

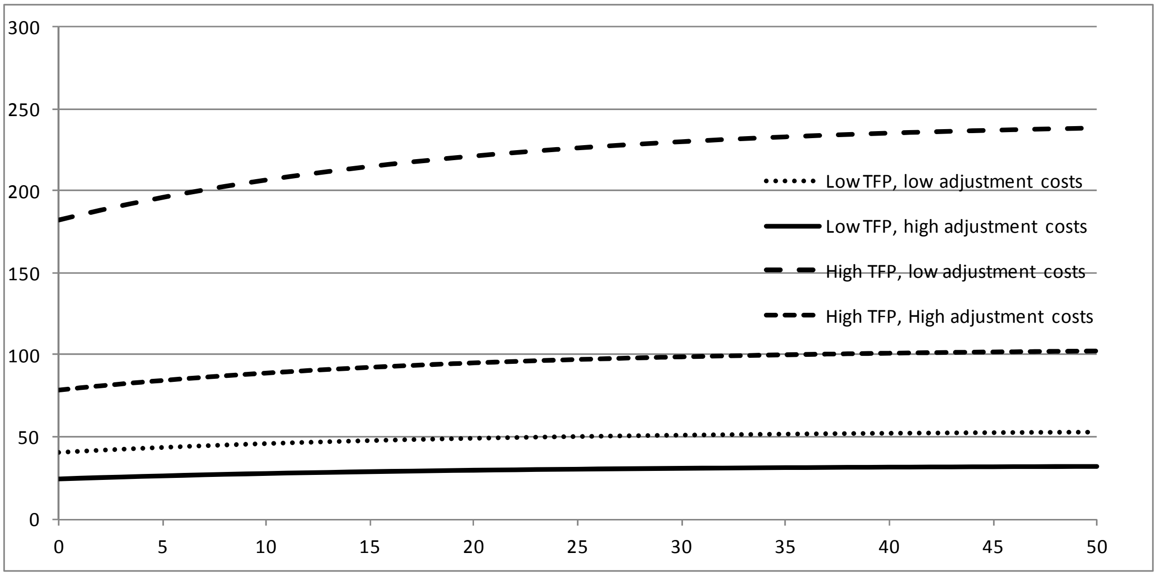
Note: This figure corresponds to an experiment where we let two economies start from a similar steady state except for the respective size of their resource windfall at time, t_0. Recall that the adjustment cost depends positively on the present value of the windfall. This experiment allows us to compare the differences between economies in the evolution towards steady state of spending in public capital. We use our benchmark case parametrization to conduct the experiment.

Figure 11. Evolution of the Stock of Public Capital under Different Scenarios



Source: Authors' own calculations.
Note: Our benchmark parametrization is such that: $I_0 = I^*, S_0 = 0.75 \times S^*, F_0 = 5, N = 10, \delta_S = 0{,}05, \delta_K = 0{,}05, r^* = 0{,}08, A = 0{,}29, \gamma = 0{,}56$ and $\bar{\alpha} = 0{,}1 + 0.005 \times V$. I_0: investment in public capital at *t=0*; I^*: steady state investment in public capital; S_0: initial stock of public capital at *t=0*; S^* : steady state stock of public capital; F_0 : level of sovereign debt at *t=0*; N: number of periods during which the resource windfall is non zero; δ_S : public capital depreciation rate; δ_K : private capital depreciation rate; r^* : world interest rate; A: total factor productivity ; γ: private capital income share; $\bar{\alpha}$: adjustment cost parameter ; V : net present value of the resource windfall. The benchmark parametrization corresponds to a "low TFP" and "low adjustment costs" scenario. We increase A by 0.075 for "high TFP" scenarios and the constant in $\bar{\alpha}$ by 0.7 for "high adjustment costs" scenarios.

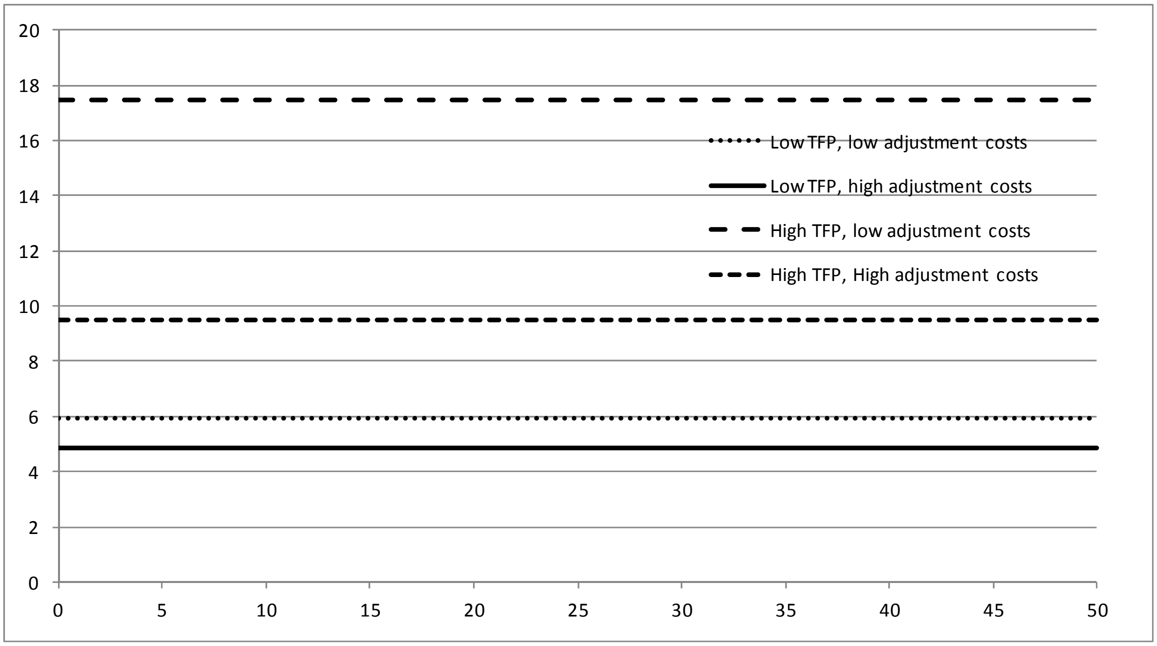
Figure 12. Evolution of the Stock of Private Capital under Different Scenarios



Source: Authors' own calculations.

Note: Our benchmark parametrization is such that: $I_0 = I^*, S_0 = 0.75 \times S^*, F_0 = 5, N = 10, \delta_S = 0{,}05, \delta_K = 0{,}05, r^* = 0{,}08, A = 0{,}29, \gamma = 0{,}56$ *and* $\bar{\alpha} = 0{,}1 + 0.005 \times V$. I_0: investment in public capital at *t=0*; I^*: steady state investment in public capital; S_0: initial stock of public capital at *t=0*; S^* : steady state stock of public capital; F_0 : level of sovereign debt at *t=0*; N: number of periods during which the resource windfall is non zero; δ_S : public capital depreciation rate; δ_K : private capital depreciation rate; r^* : world interest rate; A: total factor productivity ; γ: private capital income share; $\bar{\alpha}$: adjustment cost parameter ; V : net present value of the resource windfall. The benchmark parametrization corresponds to a "low TFP" and "low adjustment costs" scenario. We increase A by 0.075 for "high TFP" scenarios and the constant in $\bar{\alpha}$ by 0.7 for "high adjustment costs" scenarios.

Figure 13. Private Consumption under Different Scenarios



Source: Authors' own calculations.

Note: Our benchmark parametrization is such that: $I_0 = I^*, S_0 = 0.75 \times S^*, F_0 = 5, N = 10, \delta_S = 0{,}05, \delta_K = 0{,}05, r^* = 0{,}08, A = 0{,}29, \gamma = 0{,}56$ and $\bar{\alpha} = 0{,}1 + 0.005 \times V$. I_0: investment in public capital at *t=0*; I^*: steady state investment in public capital; S_0: initial stock of public capital at *t=0*; S^* : steady state stock of public capital; F_0 : level of sovereign debt at *t=0*; N: number of periods during which the resource windfall is non zero; δ_S : public capital depreciation rate; δ_K : private capital depreciation rate; r^* : world interest rate; A: total factor productivity ; γ: private capital income share; $\bar{\alpha}$: adjustment cost parameter ; V : net present value of the resource windfall. The benchmark parametrization corresponds to a "low TFP" and "low adjustment costs" scenario. We increase A by 0.075 for "high TFP" scenarios and the constant in $\bar{\alpha}$ by 0.7 for "high adjustment costs" scenarios.