Savings and Investment Decisions in a Poor Oil Economy: Beyond the Textbook Case

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Abstract

The current commodity boom is a major opportunity for poor countries exporting exhaustible resources such as oil. In the past oil booms were often mismanaged leaving the country with lower long run income. Many countries are now well aware that booms require intricate savings and investment strategies and some are use legislation to lock-in such strategies. However, the textbook characterization of optimal savings and investment is not appropriate for poor oil economies. Such countries have imperfect access to international capital markets and traded construction services and they run a risk that a future populist regime will run down the assets saved for future downturns. We investigate the effects of these characteristics on optimal savings and investment and use a simulation model to illustrate their importance.

1. Introduction

The current global commodity boom is a major opportunity for many low-income countries to accelerate their development. In the case of exhaustible resources (which we will refer to as oil) the opportunity arises not only from the fact that existing exporters are getting unusually high revenues: in addition the high prices have induced the exploitation of small fields in politically fragile environments, an example being the discovery in 2007 of modest oil deposits in northern Uganda. Both the possibility that the high price may be temporary and the short life of new fields suggest that for additional consumption to be sustainable a substantial part of the revenues will need to be saved and invested productively.

Unfortunately, the record of turning resource revenues into sustained development is not encouraging. For example, Collier and Goderis (2007) simulate the consequences of the current booms based on a co-integration analysis over the period 1963-2003. While the predicted short run effects on growth rates are positive, in the long run they find a 'resource curse'. Predicting the path of constant price GDP for an economy with commodity exports of 35% of GDP, they find that if the 2000-2005 increase in commodity prices is sustained it will eventually reduce GDP by around 25%. There is now a considerable analytic literature on the political economy of the resource curse (Lane and Tornell (1996), Tornell and Lane (1999), Baland and Francois (2000), Torvik (2002), Acemoglu *et al.* (2004), Wick and Bulte (2006), Mehlum *et al.* (2006), and Robinson *et al.* (2006)). Central to this literature are the savings and investment choices made by the government. In an attempt to improve on past performance, several governments have recently tried to lock in to asset accumulation strategies through legislation. Kuwait and Norway pioneered long term savings rules through 'future generation' funds which are now widely imitated by much poorer societies such as Timor-Leste. Chile and Nigeria have pioneered medium-term rules for smoothing public expenditure during fluctuations in the price of the export commodity. However, the theory implicit in these rules is the familiar textbook characterisation of optimal savings from the extraction of a non-renewable resource. While this framework may be adequate for economies such as Norway and Kuwait, some of its core assumptions and omissions make it seriously deficient for the countries most in need of savings rules. In this paper we show how important and distinctive characteristics of low-income commodity exporters modify the rules for optimal asset accumulation.

Since extraction depletes an asset, in order for consumption to be sustainable some offsetting asset accumulation is necessary. In the textbook case of an open economy facing perfect world capital markets there is a complete divorce between the savings decision and the domestic investment decision. The return on domestic investment is presumed already to have been driven down to the world interest rate so that incremental savings should be held abroad as financial assets. Further, since with optimal global extraction strategies the price of the commodity will increase at the world interest rate, the sustainable increase in consumption enabled by the resource is independent of the rate of extraction. Indeed, whether the government chooses to retain ownership of the extraction rights and receive a flow of revenue from their extraction, or sells the rights is of no consequence for consumption and savings. The resource depletion strategies which most closely correspond to this depiction are those of the governments of Norway and Kuwait.

While this simple model of optimal asset responses to resource extraction captures an important insight, it is inadequate as a guide to the policies appropriate for a typical low-income commodity exporter. We change four features of the textbook model to make it applicable in this context.

First, we assume that the economy is rationed in world credit markets. An implication is that the country will be capital-scarce. This creates a presumption that assets should be accumulated within the economy rather than internationally. Second, we assume that a proportion of domestic investment is in structures which are produced by the construction sector. This sector has only limited capacity to expand and so becomes a bottleneck to domestic investment. These two assumptions create a tension between the potentially high returns from using savings for domestic investment and the waste generated if high spending on investment is dissipated by high construction costs. Third, we assume that the society has only weak political institutions. In particular, the government has only a limited ability to bind its successors. A future populist government may be able to use any accumulated liquid assets for a consumption binge. Hence, the present, prudent government must incorporate the risk of such a government (similar to a "rotten descendant") into its saving and investment strategy. In conjunction, these three complications reconnect the savings decision with the domestic investment decision.[1] This leads to our final feature, the incorporation of the decision problem arising from fluctuations in commodity prices. In the textbook model described above, although price fluctuations alter commodity revenues, they do not affect the savings and investment rule: all revenues are saved abroad. However, in the more complex and realistic case that we develop in this paper, price fluctuations alter saving and investment decisions.

In Section 2 we discuss the four extensions of the textbook model and sketch how they are likely to affect saving and investment decisions. In Section 3 we formalize the discussion setting out a model which incorporates these distinctive complications. We illustrate the possible quantitative impact of these complications through a simulation model. Section 4 concludes.

2. Asset decisions: four complications

[1] The first two problems (imperfect capital markets and the danger of construction booms) have been analyzed extensively in the trade shocks literature (e.g. Bevan *et al.*, 1987, 1989 and Collier and Gunning, 1999, chapter 1 and 2005). That literature has not dealt with the issues related to the possibility of a future populist government. The contribution of the present paper is to analyze the implications of the conjunction of these three issues.

Our discussion of optimal savings and investment rates applies to all non-renewable commodities in which the government holds extraction rights. For convenience, we will refer to them as ‘oil’ while recognizing that the analysis is more general.

The Benchmark

Because oil is a depleting resource there is some expectation that over the long run it will gradually get more expensive. With optimal depletion rates the long term the world price should rise by the world rate of interest. This “Hotelling Rule” implies that even the oil in the ground is an asset that is yielding an income and this can finance consumption on a sustainable basis. Since sustainable consumption is given by the rate of appreciation of the asset in the ground and revenue is given by the extraction rate, the optimal savings rule is simply to save a proportion of revenue equal to the world rate of interest divided by the extraction rate. Since this is the savings rate needed to offset depletion, the formula can be thought of as *the long run depletion rule*. Note that savings to offset depletion only becomes pertinent if the depletion rate exceeds the assumed rate of increase in future world oil prices.

Capital scarcity

In the benchmark case the savings decision can be completely separated from domestic investment. The latter occurs up to the point at which returns equal the world interest rate, a position which is assumed already to have occurred, and all savings beyond this point are therefore held in foreign financial assets. Further, there is assumed to be no significant divergence between private and social returns.

In practice, the typical low-income oil exporter is short of capital. This is partly because the country is credit-rationed so that the private return exceeds the world interest rate. In turn, credit rationing is typically due to a combination of a high risk of default on sovereign borrowing, and a high risk of default on commercial borrowing due to badly functioning legal processes, poorly developed domestic financial markets, and a volatile economy. In addition to the private return on investment being above the world interest rate, the social return is likely to be substantially above the private return. This is because property rights, in the sense of the right to expropriate the return on investment, are insecure, reflecting weaknesses in institutions such as the courts. Hence, the social rate of return on investment is likely to be considerably above the world interest rate and it is this comparison which is the pertinent criterion for the government in determining its choice of assets. In this respect the typical resource-rich low-income country is radically different from Norway and Kuwait in both of which there is little reason to expect the social return on domestic investment to exceed the world interest rate.

The high social rate of return implies that the government should invest savings domestically rather than accumulate foreign financial assets or simply leave the oil in the ground, and this can be thought of as *the long-run asset composition rule*.

Construction bottlenecks

Although saving should be directed to domestic investment, if too much extra investment is attempted in a short period then the rate of return will be driven down. One reason for this is that during periods of boom the cost of those capital goods that can only be produced domestically gets driven up. To a reasonable approximation the distinction between tradable and non-tradable capital goods corresponds to that between equipment and structures. Usually, these two types of capital good are complements in the production process: trucks need roads, and machines need factories. Because structures cannot readily be substituted by equipment, as the demand for investment goods increases this generates a construction boom, during which construction costs are unusually high. Construction booms are often particularly acute in the small, low-income oil-producing countries currently in the throws of commodity booms: prior to these booms they usually had a prolonged period of stagnation during which their construction sectors shrank. During this period the skills and organizations and capital specific to the sector withered away. In addition to these limitations of supply, public investment is disproportionately in structures: governments spend on roads and the private sector on trucks.[2]

In addition to these problems arising from the non-tradability of investment in structures, typically the predominant capital goods which the government wishes to accumulate, a public investment boom in a small, low-income country is likely to encounter other important costs due to limited managerial capacity in the public sector. Investment is intensive in planning and these skills are in very short supply. Hence, public capital spending cannot be expanded rapidly without sacrificing efficiency.

As a result of these two effects the high social returns on domestic investment collide with temporarily high unit costs. It may therefore be optimal to defer some of the investment expenditure until the construction boom has abated and managerial capacity has been augmented. By deferring these domestic investments public investment gets better value for money. Thus, at times when the overall savings from oil revenue are atypically high, a greater percentage of them should be temporarily saved abroad until construction costs have eased. In effect, the expansion of the construction sector needs to be planned so that it is reasonably orderly, rather than boom-bust. The government of Botswana, which managed its resource revenues very effectively, ran a plan-within-a-plan specifically for the construction sector, ensuring that demand and supply were broadly matched. Public investment projects were deferred if there were signs of congestion, and the emerging bottlenecks in the construction sector such as skill shortages were identified by consulting the industry and tackled.

The counterpart of a decision to defer investment is to save in foreign financial assets. Since the role of these savings is to smooth the expansion of the construction sector these savings need to be in liquid foreign financial assets. The acquisition and depletion of these financial savings abroad so as to enable a gradual expansion of the construction

[2] This introduces a set of policy issues related to the possibility that the two types of capital will be accumulated in inappropriate proportions. We discuss these issues in Collier and Gunning (2005).

sector and government planning capabilities can be thought of as *the short run construction price smoothing rule*.

Future Prices

The future price of oil is expected by Hotelling's rule on average to rise at the world interest rate, which is below the return on capital within the economy. However, the world oil price is also extremely volatile. At any one time it is therefore likely to be either well above or well below the level implied by its long run path. In the model of Section 3 we simplify these expected price changes to a single future expected price which can nevertheless deviate from the long term trend implied by the Hotelling rule. The savings decision has to be influenced by a judgment as to the current deviation in the price from the long run path. Income generated by a price judged to be above the long run path needs to be saved. This can be thought of as *the medium run oil price smoothing rule*. These savings are intended to finance subsequent consumption during periods when the oil price is below its long run path. There is thus a strong case for holding these assets in liquid form, which implies the acquisition of financial assets abroad.

The smoothing of the unit cost of non-tradable capital goods is directly pertinent to the efficiency of investment. However, the government might reasonably be concerned about Dutch disease more broadly, most notably if a temporary real appreciation destroys organizational capital in the export sector. An important consequence of holding these temporary savings abroad and then bring them back at times of low prices is that this will dampen the volatility of the real exchange rate. Dramatic contrasting examples of the consequences of different savings strategies for the real exchange rate are Chile and Zambia during 2005, a period when the world price of their common commodity export, copper, was exceptionally high. The government of Chile followed a savings rule such that the incremental revenue from high prices was saved, whereas the government of Zambia continued to run a fiscal deficit. During 2005 the real exchange rate mildly *de*preciated in Chile despite the boom, whereas in Zambia it *ap*preciated by around 80%, causing intense problems for non-copper exports.

Thus, the strategy has both a fiscal aspect and a foreign exchange market aspect – when times are good the government runs a fiscal surplus and the central bank accumulates foreign exchange reserves. The reduction in exchange rate volatility is directly beneficial to the private sector. Hence, not only does it enable the government to smooth its own expenditures, with a payoff in terms of a higher quality of government spending, it also makes the environment for private activity less risky. The smoothing of government spending and the smoothing of the exchange rate are two sides of the same coin. It is not possible for the central bank to smooth the exchange rate unless the government is also smoothing its spending. Conversely, if the government tries to smooth its spending but the central bank fails to smooth the exchange rate the result will be to inflict volatility onto firms and households.

The oil price smoothing rule can only be introduced when the prevailing world price is above its expected path. This enables savings to build up which can then subsequently finance a period of dis-saving. If the rule were introduced at a time when the world price was judged to be below the world price there would be an initial period of borrowing, and such behaviour would be indistinguishable from straightforward fiscal irresponsibility. For credibility, a fiscal rule has to start with the politically more challenging decision of saving.

Although both the *construction price smoothing rule* and the *oil price smoothing rule* involve temporarily saving abroad in financial assets, the uses to which these savings are then put when they are run down are distinct. The savings accumulated under the *construction price smoothing rule* are used to finance domestic investment involving construction when conditions in the construction sector are calmer. The savings accumulated under the *oil price smoothing rule* are used to finance both investment and consumption to prevent them from being reduced when the oil price is below trend.

The time-consistency problem

Above we have suggested that although a Norwegian style strategy of accumulating foreign financial assets in a 'future generations' fund is not generally appropriate for low-income countries, there are two powerful arguments why in the throws of a commodity boom a government should accumulate such assets abroad. We now show that even this strategy must be qualified.

The incentive to adhere to good policy rules on inter-temporal public spending is dependent upon what policy makers today expect to be the behaviour of their successors. In particular, if policy makers today believe that at some time in the relatively near future a successor is likely to cash in on their prudence to finance their own imprudent spending, then there is little point in making the savings effort in the first place. Thus, for example, in a country with a history of fiscal imprudence, even a reforming finance minister may reasonably decide that it is better to spend a windfall now rather than save it for a less careful successor. This is a form of time-inconsistency. The risk of a future populist government inhibits the current government from saving. Thus, no future government can benefit from its freedom to run down savings because there are none to run down. Future governments would be better off if they were able to commit themselves not to run down liquid assets because then the current prudent government would save, enabling future income to be sustainably higher.

Evidently, future governments cannot provide such a commitment, but the current government has some scope to bind successor governments. The technology for binding future governments is to embed the policy rules in the law as with the Fiscal Responsibility Acts in Chile (2006) and Nigeria (2007). However, in many low-income countries laws have a record of being overturned or ignored by successor governments. In Chad the law enacted to govern the management of oil revenues at the onset of the discovery survived less than two years once the revenues arrived. The limited credibility of legal restraints is a corollary of a more general weakness of institutions. A law provides a degree of protection to the prudent government but not full protection.

The degree of confidence that the prudent government has in adherence to prudence by future governments should influence its asset allocation as between foreign savings and domestic investment. Foreign savings are intrinsically liquid whereas domestic investment, being fixed, can only be liquidated more gradually through economizing on maintenance, and the sale of the few public assets which are marketable. Hence, the less confident is the government in the behaviour of future governments the less it should save abroad. As the government switches instead into domestic investment, the return on investment will decline and this will have repercussions for the savings rate.

3. Managing Commodity Booms: a Formalization

In this section we formalize these ideas in a 3-period model. There are three assets: oil, bonds and infrastructure. The capital market is modeled as imperfect in the sense that the country can accumulate bonds but it cannot borrow abroad. Oil can be produced in each period and for a given initial stock of oil in the ground the model determines the optimal depletion path. Oil extraction is characterized by increasing marginal cost. Depending on extraction costs and given world oil prices it may or may not be optimal to exhaust the initial stock completely.

Investment in bonds and infrastructure occurs only in periods 1 and 2. In the first period investment decisions are taken under uncertainty as to future capture of assets. This uncertainty is resolved before the final investment decisions are taken in period 2. The two non-oil assets differ in two respects. First, while bonds are subject to capture infrastructure is not. This is the salient element of our model. It implies that investment decisions are distorted: the possibility of capture acts a tax on bonds. There is a given probability that capture occurs. In this case any investment in bonds is lost entirely and there will be no further investment since it is certain that capture will occur again. Secondly, investment in infrastructure requires non-tradables (such as labour input) and therefore faces increasing marginal costs. This introduces a construction boom issue: concentrating infrastructure investment in a single period is costly. In particular, while it is attractive to postpone infrastructure investment until uncertainty as to capture of bonds is resolved, this has the disadvantage that if investment is concentrated in time it is more costly.

The government maximizes expected discounted utility over the three year period: $u(c_1)+\beta E[u(c_2)+\beta u(c_3)]$ where $u(c_t)$ is instantaneous utility as a (strictly concave) function of consumption in period t and β is the discount factor ($\beta<1$). The cost of extracting a quantity of oil e is e^{α} where $\alpha>1$ (increasing marginal cost). We denote as $\bar{e}$ the production level which maximizes short-run profits $\pi e-e^{\alpha}$ where π is the price of oil. Hence $\bar{e}$ solves $\pi=\alpha e^{\alpha-1}$: oil is extracted until marginal extraction costs equal the given oil price. Whether this short-run profit maximizing production level is optimal in the 3-period model remains to be seen.

Using the principle of optimality we consider the decision problems in period 3, 2 and 1 in that order. In the final period the problem is:

$$\max_{e_3 \geq 0} u(c_3) = u[(e_3\pi_3 - e_3^{\alpha}) + (1+r_b)b_3 + (1+r_i)i_3]$$
$$\text{subject to } \; e_3 \leq S - e_1 - e_2$$

where r_b and r_i are the given rates of return on bonds and infrastructure, b and i are the (predetermined) stocks of these assets, S is the initial stock of oil and e_1 and e_2 are the amounts of oil already extracted. Since this is the final period there is no investment and the only decision concerns the level of oil production e_3. All resources available (the value of oil production minus extraction costs and the value of the two assets, inclusive of the returns r_b and r_i) are consumed. Clearly, optimal oil production is equal to $\bar{e}_3$ if this is feasible ($\bar{e}_3 \leq S - e_1 - e_2$) and otherwise any remaining oil is extracted. Therefore:

$$e_3^* = \min(\bar{e}_3, S - e_1 - e_2).$$

Using this solution the period-2 problem is:

$$\begin{aligned}
&\max_{e_2 \geq 0, b_3 \geq b_2, i_3 \geq i_2} W = u(c_2) + \beta u(c_3) \\
&= u[(e_2\pi_2 - e_2^{\alpha}) - I(b_2 > 0)(b_3 - (1+r_b)b_2) - (i_3 - i_2)^{\gamma} + r_i i_2] \\
&+ \beta u[(e_3\pi_3 - e_3^{\alpha}) + (1+r_b)b_3 + (1+r_i)i_3] \\
&\text{subject to } e_3 = \min(\bar{e}_3, S - e_1 - e_2) \text{ and } e_2 \leq S - e_1
\end{aligned}$$

where $\gamma > 1$ introduces a construction boom effect (increasing marginal cost of investment in infrastructure) and the asset levels b_2 and i_2 are predetermined. *I(x)* is an indicator function: *I(x) = 1* if *x* is true and otherwise *I(x) = 0*. Hence the term $I(b_2 > 0)(b_3 - (1+r_b)b_2)$ indicates that if capture has taken place ($b_2 = 0$) it will occur again. Therefore $b_3 = 0$ in that case: there will be investment in bonds only if there has been no capture.

If bonds have *not* been captured ($b_2 > 0$) then the first order condition for b_3 is:

$$u'(c_2) = \beta(1+r_b)u'(c_3).$$

This is a standard Euler equation: the marginal return (in terms of discounted utility) to investment is equal to its opportunity cost (in terms of the utility of foregone consumption). Note that the equation implies that consumption will increase if and only if the interest rate exceeds the discount rate so that $(1+r_b)\beta > 1$.[3]

[3] If the condition is satisfied $u'(c_3) < u'(c2)$ hence $c_3 > c_2$: consumption increases.

For i_3 the first order condition is:

$$u'(c_2)\gamma(i_3 - i_2)^{\gamma-1} = \beta(1 + r_i)u'(c_3).$$

The left hand side measures the marginal cost (in terms of utility) of investing an amount $(i_3 - i_2)$ in infrastructure, *i.e.* the cost of increasing the stock of infrastructure from i_2 to i_3; the right hand side measures the corresponding marginal utility in the next period. (Note that in the absence of capture the last two equations imply $\delta(i_3 - i_2)^{\delta-1} = (1 + r_i)/(1 + r_b)$ so that infrastructure investment in the second period depends only on the parameters r_b, r_i and δ. This indicates that the return on bonds is the opportunity cost of investment in infrastructure.)

The first order condition for e_2 depends on whether or not oil will be exhausted in the final period. If it is (*i.e.* if $e_3 = S - e_1 - e_2 < \bar{e}_3$) then the first order condition for oil is:

$$u'(c_2)(\pi_2 - \alpha e_2^{\alpha-1}) = \beta u'(c_3)(\pi_3 - \alpha e_3^{\alpha-1}).$$

Since $e_3 < \bar{e}_3$ the RHS of this condition is positive. Therefore the LHS is positive as well and $e_2 < \bar{e}_2$. Note that the first order condition amounts to the Hotelling Rule. In particular the extraction path depends on changes in (discounted) oil prices. An increase in, say, the price π_3 will induce intertemporal substitution: less will be extracted today, more tomorrow. Note also that if oil is not exhausted in the final period ($e_3 = \bar{e}_3$) then the first order condition reduces to $\pi_2 = \alpha e_2^{\alpha-1}$ and hence $e_2 = \bar{e}_2$. Short run profit maximization is optimal in this case since the level of oil production in the final period is fixed. Changes in the level of production in period 2 therefore have no intertemporal effects. In particular, producing less than $\bar{e}_2$ makes no sense since the extra oil left in the ground will not be used in period 3: it would be too costly to extract. Hence there are two regimes: either $e < \bar{e}$ in both periods or $e = \bar{e}$ in both periods. The first regime is characterized by exhaustion of the oil stock, the second one by short run profit maximization.

Now consider the period 1 problem. Recall that decisions in the first period are taken under uncertainty. Bonds will be captured with probability *p*. Denoting investment in bonds as $\overline{b_2}$ the stock of bonds in period 2 is equal to that level ($b_2 = \overline{b_2}$) with probability *(1-p)* and is otherwise 0: if capture occurs it is total. Denote the optimal value of the period 2 maximand as $W(S - e_1, b_2, i_2)$. Then the problem can be written as:

$$\max_{e_1,\overline{b_2},i_2 \geq 0} u(c_1) + \beta E[u(c_2) + \beta u(c_3)]$$
$$= u[(e_1\pi_1 - e_1^{\alpha}) - \overline{b_2} - i_2^{\gamma}] + \beta[pW(S - e_1, 0, i_2) + (1 - p)W(S - e_1, \overline{b_2}, i_2)]$$

subject to $e_1 \le S$.

It is convenient to denote optimal values in the two cases (capture or not) by subscripts, *c* and *n* respectively. Then the first order condition for i_2 is:

$$u'(c_1)\gamma i_2^{\gamma-1} = \beta[pu'(c_{2c})(r_i - \gamma(i_{3c} - i_2)^{\gamma-1}) + (1-p)u'(c_{2n})(r_i - \gamma(i_{3n} - i_2)^{\gamma-1})].$$

This shows that the possibility of capture affects the decision to invest in infrastructure in two ways. First, capture reduces the resources available for consumption in period 2: $c_{2c} < c_{2n}$ and this provides an incentive to increase infrastructure investment i_2. Secondly, as noted earlier, while the possibility of capture makes postponement of investment in infrastructure attractive, this option value cannot be fully exploited because postponement makes subsequent investment more costly. This is the construction boom issue.

For b_2 the first order condition can (using the envelope condition) be written as:

$$u'(c_1) = \beta(1-p)(1+r_b)u'(c_{2n}).$$

This is an Euler equation modified for capture: the expected return on bonds is $(1-p)(1+r_b)$ rather than $1+r_b$. Clearly, the more likely capture the less will be saved in liquid form, as bonds.

Finally, using the first order condition for oil it is easily shown that the earlier two regime result extends to all three period. In other words, either there is sufficient oil to make short run profit maximization feasible (and then $e_t = \bar{e}_t$ for all *t*) or extraction today has an opportunity cost in terms of future extraction and then all oil will be exhausted and $e_t < \bar{e}_t$ for all *t*.

We use this model in simulation experiments to investigate the effects of changes in parameter values.[4] The results are shown in Table 1.

We vary two parameters: the probability of capture, *p*, and the oil price in the final period, π_3. In the base case there is investment in both assets in period 1. In period 2 there is, obviously, investment in bonds only in the no-capture case. This is partly at the expense of infrastructure investment which in this case is lower than if capture occurs.

[4] We assume log utility: $u(c) = \ln c$ and hence $u'(c) = 1/c$. In the base case the parameter values are: $\alpha = 2$, $\beta = 1/1.06$, $\gamma = 1.3$, $r_b = 0.5$, $r_i = 0.15$, the oil price π is constant at 10, and $p = 0.3$. For these values the oil production level which maximizes short-run profits is 5 in each period. In case A ("high oil reserves") these production levels are feasible since $S = 20$. In case B ("low oil reserves") $S = 12$, the profit maximizing production level is therefore not feasible and it is optimal to exhaust the reserves completely.

A lower probability of capture (we reduce p from 0.30 to 0.28 hence by only 2 percentage points) has marked effects. It reduces infrastructure investment in both periods (in period 2 in both the capture and no-capture cases). Investment in bonds increases in both periods and in the case of period 1 dramatically so. Hence, at least in this numerical example, investment in assets which may be captured is very sensitive to the probability of capture.

An increase in the oil price π_3 (by 1%: from 10 to 10.1) reduces investment, of all types and in all periods. This is an intuitive result. The price increase raises income in the final period and therefore amounts to an increase in wealth. It therefore substitutes for investment which raises period 3 income at the expense of consumption in the earlier periods. An important corollary is that if oil prices are expected to increase then the problem of capture is less serious: there is less incentive to invest and therefore less to be feared from capture. Conversely, if oil price prospects deteriorate (from the point of view of the producer) then the capture problem becomes more serious since the country ought to save more to substitute for the lost oil wealth.

The Table shows the results separately for the two regimes, i.e. for a country with high oil reserves and for a country with low oil reserves (so that depleting the stock completely is optimal). Qualitatively the results are quite similar. The key difference is that in Case B (low oil reserves) optimal savings are higher. Again, this can be seen as substitution of non-oil assets for oil wealth. An implication, of course, is that countries with limited reserves stand more to lose from capture.

Table 1: The Effects of Changes in Capture Probabilities

and Oil Prices on Investment Decisions

	Case A: High oil reserves			**Case B: Low oil reserves**		
Parameters	Base case	lower p	higher π_3	base case	lower p	higher π_3
p	0.3	0.28	0.3	0.3	0.28	0.3
S	20	20	20	12	12	12
π_3	10	10	10.1	10	10	10.1
Investment levels in period 1						
bonds	0.323	0.739	0.226	0.427	0.855	0.338

infrastructure	0.423	0.388	0.418	0.430	0.392	0.425
Investment levels in period 2 (after capture occurred)						
bonds	0	0	0	0	0	0
infrastructure	0.940	0.901	0.912	0.976	0.930	0.946
Investment levels in period 2 (no capture)						
bonds	2.803	3.103	2.547	2.988	3.296	2.743
infrastructure	0.703	0.662	0.698	0.711	0.666	0.706

4. Conclusion

In a response to the mishandling of the commodity booms of the 1970s several low-income commodity exporters have recently enacted legislation to guide savings and investment decisions out of commodity revenue. While in general terms such rules are surely appropriate, the specific choice of saving and investment rates in these environments is far more complex that the relatively simple decision problem facing a high-income commodity exporter such as Norway, whose economy is fully integrated into global markets for both finance and construction services.

In this paper we have developed a simple model which incorporates some of the major distinctive characteristics of the low-income developing countries that are now recipients of the boom. We have shown that these characteristics both complicate and change the saving and investment decisions appropriate for these countries relative to the benchmark case in which the two decisions are divorced. Most importantly, if the government of an oil producing country knows it may be succeeded by a more populist regime then it is optimal to invest more in infrastructure (even though this exacerbates construction boom effects). This issue is particularly important for countries with relatively low oil reserves. We have used simulation experiments with a simple model to illustrate the effect of changes in oil prices and in the probability of a future populist regime on optimal savings rates and investment choices.

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