Managing the Exploitation of Natural Assets: lessons for low income countries

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Abstract

This paper provides an analytic review of the upstream aspects of the exploitation of natural resources: the assignment of ownership rights, taxation, the discovery process, extraction, renewability, and clean-up. It sets these issues within the principal-agent framework. It proposes that the present common system whereby governments sell extraction rights prior to discovery through signature bonuses is likely to be socially costly, since the sale of rights occurs at a stage where irreducible risks generate a severe discount. It also proposes that the present common system whereby governments sell extraction rights by means of negotiated deals might disadvantage governments relative to more transparent and competitive systems such as auctions. While the paper is primarily analytic, it also briefly reviews African experience, suggesting that both high commodity prices and the low value of discovered assets per hectare imply major opportunities.

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1. Introduction

This paper discusses the analytic issues of how natural assets are exploited. We focus on the upstream stages of exploitation: natural assets must first be discovered, then extracted, and then renewed where appropriate, or the legacy of extraction cleaned up. Our companion paper considers the downstream issues of how revenues might be used (Collier and Venables, 2008).

The exploitation of natural assets matters for Africa. Even if the valuation of Africa's natural assets is restricted to those already discovered, they are an important component of the region's overall wealth. However, it is likely that most of Africa's natural assets are yet to be discovered. A reasonable approximation is that over a sufficiently large area they are proportionate to the endowment of land. Africans have around 50 percent more land per person than the global average. Conversely, they have radically less physical and human capital per person. Hence, the true African asset portfolio is likely to be very heavily skewed towards natural assets: their exploitation matters for the region. It is likely that most of these natural assets are as yet undiscovered. Exploration is a costly and risky investment and so known reserves are determined by the economic environment rather than simply being a geological given. As we discuss, the average square kilometre of the African landmass has beneath it only around $25,000 of known sub-soil assets, whereas the corresponding figure for the landmass of the OECD is $125,000. Since the sub-soil assets of the OECD have been heavily exploited for a far longer period than those of Africa, it is likely that the true average value of Africa's sub-soil assets exceeds that of the OECD. The contrast in known assets therefore points to the potential for discovery and hence to the importance of investment in prospecting.

Section 2, the core of the paper, is analytic. Countries face complex choices, as they should seek to maximise the benefits of natural resources for their citizens, while at the same time maintaining the incentives for firms to make large, complex and long-lived investment decisions. All these choices, by government and by firms, are undertaken in an environment with a high degree of uncertainty, asymmetries in information, and intense pressures for the benefits to be captured by narrow groups in society. We flag the

key points we make as 'core analysis'. In Section 3 we briefly review some salient aspects of the actual African experience.

2. Principles

For most economic activities the role of government is peripheral; however, for the exploitation of natural assets government is centre stage. Being natural, the ownership rights to these assets must be assigned socially: for practical purposes government has custodial rights on behalf of citizens who are collectively the owners. Government must manage the natural assets in its custody in such as way as to maximize their value to citizens and this poses a range of analytic problems.

Table 1 lays out the various steps in the exploitation of natural resources and relates them to the standard framework of the principal-agent problem. The three material processes are discovery, extraction and clean-up. In most circumstances in each case the actor will be a private firm, although not necessarily the same one for all three. Outcomes are subject to a high degree of uncertainty – 'nature' decides geology and determines costs and the ultimate price of the resource. The payoff to actions depends also upon how ownership rights are assigned and the tax regime. Usually, both of these will be set by the government. In setting them the government faces both an information problem and a credibility problem.

The information problem arises because natural assets must be discovered before they can be exploited. Quite generally, the production of knowledge is a complex social problem: intrinsically knowledge is a public good and so will be radically undersupplied unless either private rights are socially constructed or the activity is public funded. For example, scientific discoveries are encouraged both by the patent system and by public funding of research.

The credibility problem is likely to be important because the process of resource extraction is intrinsically sequenced. In table 1 decisions are given by the order in which they are likely to be taken, but some can be reversed, and others not. If actors lack robust commitment technologies that bind some key actions that are otherwise reversible then decisions concerning the irreversible actions are liable to be affected.

Table 1: Natural Assets as a Principal Agent Problem

Actor	Decision points	Options	Issues
Government	Ownership rights	Lawless societies	Equity, lack of incentives, conflict.
		Finders-Keepers	Equity (ex ante/ex post), Rent dissipation, 'Gold rushes'.
		Landowner	Equity
		Region/ Nation	Equity – jurisdiction size
Government	Fiscal system	Royalty Production share Profits tax	Rent extraction. Incentives, risk sharing, Asymmetric information
Government	Allocation of exploration rights	State: NOC	Capacity to undertake exploration
		Private: allocation of licences. Auction.	Asymmetric information Rent extraction. Transparency
Firm	Exploration effort	High /low	Uncertainty Valuing information
Nature	Uncertain geology		
Government	Allocation of production licences	State: NOC	Competition Technology transfer
		Private: combine with exploration licenses.	Compounding risk
		Private: separate from exploration licences: Allocation/ auction	Asymmetric information Rent extraction. Transparency
Firm	Extraction effort	High/ low	Returns to extraction
Nature	Uncertain costs Uncertain price		
Firm / government	Depletion path	Fast/ slow	Risk aversion, time preference. Absorptive capacity.
Government	Renegotiation/ expropriation		Time consistency and hold-up
Firm	Clean up		Time consistency
Firm, Government	Expected revenue flows		

A further complication is that resource extraction is a high-value process that is usually located far from major urban centres. This makes the physical security of the process far more difficult than either that of high-value urban activities or low-value rural activities. The government may be open to challenge for the physical control of the extraction process from private organized violence in the form of rebellion or criminality. The first step in the process of exploiting natural assets is the assignment of ownership rights. These preliminaries are the subject of Section 2.1. The two key economic processes are discovery and extraction and they are covered in section 2.2. Although natural assets obviously need to be discovered before they can be extracted, Africa in 2008 is evidently not virgin territory: many assets have already been discovered and are being extracted. Hence, for expositional purposes we take the sequence in reverse, and in each case our discussion concerns the design of incentive systems that are socially efficient. Finally, in Section 2.3, we consider the special issues that arise from the exploitation of those natural assets that are renewable.

2.1 Preliminaries: Assigning Ownership

Most assets are the consequence of investment. As such, their ownership follows naturally from the process of their creation: the investor owns the asset and is free to sell the ownership right to others. Natural assets are distinctive in that they are not the consequence of investment: while resources may have to be devoted to their discovery and extraction, there is an economic surplus or rent over and above these costs. Ownership of such assets cannot therefore follow from the process of their creation: ownership rights of natural assets are intrinsically 'unnatural'. The process by which ownership rights over natural assets are acquired has potent economic implications both for the distribution of income and for efficiency. The more narrowly are the rights held the less equal will the society be. Further, the social construction of rights over natural assets is itself a value-conferring activity and so economic actors can gain from influencing its outcome, opening scope for rent-seeking behaviour. Finally, any outcome which separates ownership from control has the potential for inefficiency in production.

A second aspect of natural assets is that they are usually difficult to observe. Minerals lie hidden under the ground until discovered, and soil quality can only be ascertained by scientific tests. Those natural assets over which property rights have not been assigned and which are readily observable are living dangerously: people will try to plunder them. This is why game becomes so scarce: once the American West started to be settled even at very low densities, the once immense herds of buffalo were rapidly hunted to the verge of extinction. Being difficult to observe, natural assets must therefore be discovered. This creates a problem in the economics of information: the value is not apparent in advance of the discovery. In this respect the economics of natural assets is analogous to that of invention.

Natural Assets without Social Enforcement

In the standard economics textbook output is generated by labour and capital: government remains offstage because it is unnecessary for the analysis of production. However, government is central to the economics of the exploitation of natural assets and to see this consider what happens if government is absent or weak. Our first scenario is anarchy: there is no authority able to construct and enforce property rights over natural assets. This is an 'ideal type' rather than the description of any real situation. The second introduces weak government authority such as actually prevailed in the nineteenth century American West.

We start with a lawless society that lacks any capacity for making or enforcing property rights over natural assets: physical control of the asset is all that matters. This gives rise to three problems: mal-distribution, rent-seeking, and inefficiency. Mal-distribution comes about partly because the strong are advantaged over the weak. But it is compounded by chance: some territories are better endowed than others. If we imagine the population distinguished in the two dimensions of strength and luck, the natural assets are acquired disproportionately by those who are lucky and strong. Rent-seeking comes about because if ownership is conferred by physical control of territory, people will divert their effort into violence. Since violence can be offset by counter-violence, in equilibrium the value of the rents from the natural assets will be dissipated by the costs incurred by the violent. Inefficiency comes about because of the uncertainty as to whether control can

be maintained in the future. If control is perceived as likely to be temporary, the private incentive is to deplete assets quickly even if this is socially more costly than necessary.

A further consequence is that the absence of property rights interacts with the problem of information. As with inventions, unless discoveries of natural assets are protected there is no incentive to undertaking search. It is more efficient to wait for others to find natural assets and then wrest control off them through superior violence. Hence, they remain undiscovered. Indeed, since the process of losing control of them is likely to be costly, there is even an incentive for suppressing discovery.

To summarize, in the absence of government the exploitation of natural assets is markedly socially dysfunctional. Few assets are discovered and those that are trigger violent and costly contests. Compounding these gross inefficiencies, outcomes are highly unequal, favouring those who are strong and lucky.

Finders Keepers: the Wild West

Now introduce a government with a modest degree of social control. The government is not sufficiently powerful to prevent the extraction of natural assets from its territory, but it is able to manage the process by conferring prospecting rights to private actors and to protect those rights from other private actors. Specifically, it is able to enforce the rule of 'finders-keepers'. Like the patent system of inventions, the finders-keepers rule depends upon socially constructed rights enforced by government. The opening of the American West depended upon the legal structure already in place in the American East. The government licenses plots to prospectors who then own what they find. This is how America opened its natural resource economy for exploitation.

The finders-keepers rule is in important respects an improvement upon lawlessness, but it is far from ideal in terms of distribution and rent-seeking. The distributional disadvantage is that the rents are captured by prospectors instead of being spread more widely. The rent-seeking problem arises from the fact that the chances of striking lucky on a plot are increased if neighbouring plots have had lucky strikes. Hence, the profit-maximizing strategy is to acquire many plots and leave them idle until discoveries are made, free-riding upon the prospecting efforts of others. This produces the economics of a gold rush: whole territories may be neglected for many years, and

then prospected in a surge following the first discovery. Both the period of neglect and the surge are inefficient. The period of neglect arises from a standard public goods problem: knowledge is a public good and so the outcome is a stalemate in which no one incurs the costs of acquiring knowledge. Eventually, a lucky strike occurs and this sharply increases the returns to search. In response, people crowd into search activities, lowering the chance of discovery for each other and driving down the expected returns to search. Entry may be limited if the size of the plots is set by government, but if plots are very small the standard rent-seeking outcome is that the value of the rents to be acquired through search is precisely offset by the costs that people incur. The rents from natural assets are thus dissipated. The finders-keepers rule thus produces a long period during which private returns to search are below their social value, followed by a short period in which they exceed their social value.

Research for inventions suffers from some of the same features as the finders-keepers rule in natural resources. This is one reason why public policy nowadays supplements private research with massive programs of public research on the more fundamental aspects of science: in effect fundamental science is equivalent to search in virgin territories that would otherwise remain unprospected for long periods.

Artisanal mining is in some respects analogous to the Wild West. As many prospectors crowd in to search the size of plot is reduced, either in response to political pressure to accommodate more people, or through the sheer physical inability of individuals to retain exclusive control over a large area. This creates an externality: each additional prospector reduces the chance that other prospectors will strike lucky. Hence, the private return exceeds the social return. A second respect in which artisanal mining is inefficient is technological: artisanal mining is not able to reap the scale economies involved in mining such as pumping out water. [1] Since large scale technology involves fixed capital investment, artisanal mining gives rise to a third form of inefficiency: plundering the future. With substantial fixed investment the appropriate pace of exploitation is gradual, so that the installed capital can remain employed for a prolonged period. This implies that some areas will initially be left unprospected. In contrast,

[1] Before consolidation the big-hole in Kimberly was worked by 430 separate claims each 9 metres square, although some subdivided to two metres square. Independent working of these claims went to a depth of several hundred metres. http://www.hsrc.ac.za/Document-1481.phtml

artisanal mining prospects all areas at once so that what would otherwise be future rents are dissipated in high current costs. The social inefficiency inherent in artisanal exploitation is demonstrated by the successful growth of De Beers. The company was able to buy out the claims of artisanal producers at their full value under artisanal exploitation and generate a large profit by internalizing these externalities.

Socially Constructed Ownership Rights: the Ideal

We now consider the ideal, such as might be achieved by a benign and competent government. This is, of course, a mythical entity: actual governments are composed of economic actors with private incentives. However, the ideal serves as a useful construct against which to benchmark all practical approaches to policy.

In what framework should a system for the management of the exploitation of natural assets be judged? The Utilitarian framework conventionally used by economists is open to philosophical challenge, most notably from a framework based on notions of rights: an outcome may be judged just because it respects a recognized right even if this results in a loss of utility. We consider how the ideal would vary according to Utilitarian and rights-based systems of ethics.

Utilitarianism gives equal weight to all people at the same level of income, regardless of their nationality and regardless of whether they are yet born. It assumes that marginal utility diminishes with income, so that a given total world income would maximize world welfare were it distributed equally. Within this framework both equity and efficiency are potentially welfare-enhancing.

The equity implication is that natural assets should be owned as equally as possible. This has both spatial and temporal implications. The spatial implication is that the larger is the geographic entity of government the more equal will be ownership. As we discuss in Collier and Venables (2008b), because Africa is split up into so many nations, if ownership rights are accorded to nations then the per capita distribution of natural assets will inevitably be highly unequal. Citizens of Equatorial Guinea have radically more natural assets than citizens of Ethiopia despite the fact that both groups are citizens of Africa. By extension, if sub-national groups acquire ownership by virtue of their proximity to natural assets then the distribution will be even more unequal. For

example, the tiny state of Sao Tome, Principe has recently discovered oil which privileges the 100,000 Africans who are citizens. However, the oil is closer to the tiny island of Principe than to Sao Tome, and predictably its 8,000 inhabitants have claimed ownership.

The temporal implication is that the benefits of natural assets should be spread equally over all future generations, this only being qualified to the extent that future generations are richer thanks to economic growth. Utilitarianism advocates such a distribution of all benefits, not just those from natural assets, but it has powerful implications for the management of natural assets. In particular it judges rapid depletion harshly unless offset by the accumulation of other assets: the utility of future generations is not being given sufficient weight.

Rights-based ethical systems assign the ownership of natural rights according to two broad principles, proximity and custody. The most common form of the proximity principle is that natural assets are owned collectively by the citizens of the country in which they are located. A variant is the rights of 'derivation' whereby sub-national government entities claim a privileged share of ownership. Some resource extraction companies operate according to a further variant whereby their corporate social responsibility to local communities is deemed to be broadly proportionate to their distance from the point of asset extraction.

Whereas the proximity principle concerns the spatial dimension of ownership, the custody principle concerns the temporal. Recall that from a perspective of rights, natural assets are distinctive: not having been built by human effort they do not naturally belong to anyone in particular. Further, they have only come through to the present generation because many previous generations have not depleted them. According to the principle of *custody* the current generation is merely the custodian of natural assets, not their owner. As such it does not have the right to deplete natural assets even if this would maximize its welfare at the expense of future generations.

Utilitarianism and rights-based ethical systems collide in respect of spatial inequalities but converge in respect of inter-temporal inequalities. Utilitarianism is unambiguous in preferring pan-African ownership of natural assets to national or sub-national ownership. Yet a rights-based ethics judges nations to be legitimate entities for

ownership. Nations reflect the maximum extent to which people have chosen to pool their autonomous powers: there is no world government because people have chosen not to have one and so a failure to respect national rights would be unjust. The current scramble for ownership rights in the Arctic and Antarctic reflects tensions between these two ethical systems, with self-interest largely determining which system a particular government supports. However, in respect of inter-temporal inequalities the rights-based approach reaches the same conclusion as the Utilitarian system based on a different argument: the rights of the future must be respected.

While economists are trained within a framework that has Utilitarian assumptions built into it, we do not wish to assert its superiority to the rights-based approach. The tensions between the two frameworks in respect of the spatial allocation of ownership have to be faced. Indeed, the very confusion may generate costs. Control, as opposed to ownership, unambiguously follows the proximity principle: those nearer to a natural asset have more control over it. If ownership is contested because of disagreements on ethical principles, then the behaviour of the controlling local interest may reflect anticipated changes in ownership.

While both frameworks agree as to inter-temporal ownership, they both conflict with the fundamental political principle of democracy. In a democracy the ultimate rules are that the government must be accountable to the electorate and that each eligible citizen should have one vote. Future generations do not and indeed cannot have votes. If voters wish to be selfish, plundering natural assets for the exclusive benefit of the current generation, the government lacks constitutional power to stop them unless granted it by voters. Given that the electorate is sovereign, the ultimate defence against the plunder of natural assets can only be that ethical standards, whether Utilitarian or custodial, are internalized by citizens. This can be brought about either through the top-down guidance of political leaders, or through the bottom-up mass movements which have periodically shifted ethical thinking. The recent global information campaign on climate change is a particularly pertinent example of how such a mass change in values can be brought about. It has swiftly convinced millions of people that the interests of future generations require them to reduce their emissions of carbon. Societies with depleting natural assets need an equivalent debate: indeed the message is easier for people to internalize: the pertinent

future is not as distant as the global warming scenarios, and the people adversely affected are citizens of the same country rather than the entire world population.

Compensating for environmental costs

The discrepancies between Utilitarian, rights-based and democratic principles are particularly important in respect of environmental damage. Such damage is likely to be spatially concentrated and to accumulate over time, leaving particular localities with a highly adverse legacy once the exploitation is over.

The Utilitarian framework is weak on whether those who lose should be compensated. It is more concerned to investigate whether they could be compensated and still leave others better off. In contrast, the rights-based framework is likely to judge that those who lose must be fully compensated. Whichever of these frameworks is the more ethically appealing it is likely that politically unless a rights-based approach is adopted there is a risk of violent opposition. However, the democratic principle makes it particularly difficult credibly to commit that compensation will indeed be paid to future losers. A possible solution is for the resource extraction company to bear a residual responsibility: should a future government fail to provide adequate compensation, it would be liable. As discussed below, this gives rise to a potential time-consistency problem, but companies can have resort to commitment technologies which overcome it.

2.2 Efficient Incentives for Extraction and discovery

We now arrive at the core of our analysis: how the government can maximize social value while allowing the extraction of natural assets to be undertaken by the private sector. We discuss later the use of state-owned companies for the extraction process. Usually, the public sector lacks a comparative advantage in directly managing the extraction process with its specialist skills and large capital requirements, and so the design of an incentive regime which maximizes revenue for the government while leaving the extraction process in the private sector is critical.

Inefficiency arises when the full consequences of an action are not internalized by the decision taker. The exploitation of natural assets is liable to be inefficient both at the

discovery stage and at the production stage. As discussed above, efficiency at the discovery stage depends upon efficiency at the production stage. Lawlessness induces insufficient search because discovery does not confer any rights which enable the costs of search to be recovered. Conversely, the finders-keepers system produces excess search because discovery confers the entire rents from the natural asset. Production requires an initial investment followed by continuous decisions on the deployment of variable inputs. The initial investment creates the potential for a commitment problem: a sovereign government has the power to revoke any undertaking. Any gap between ownership and control of variable inputs creates the potential for principal-agent problems.

Core Analysis 1: *Initial Investment and the time-consistency problem*

The commitment problem is in one sense standard to all investment. However, it is more acute in respect of natural resource exploitation for three reasons. One is that the capital investment required for resource extraction is typically far higher than for other activities and so more is at stake. The second is that the investment is typically lumpy: a country has one particular exploitable asset which requires investment of a particular scale. Once this is made opportunities for further investment may be limited. This contrasts with most other investment where opportunities gradually increase over time so that an initial deal is implicitly enforced by the prospects of further deals. The third is that the taxation of the rents from natural assets is necessarily distinct from general corporate taxation, and so a post-investment increase in taxation can be ring-fenced to the sector without damaging the wider investment process. This creates a severe time consistency problem: because the sovereign government cannot credibly make a commitment not to increase taxation once the investment has been made, the investment is deterred. Whether there is a solution to this problem depends upon the capacity of the government credibly to limit its own power. For this it needs either an alternative power within the country, such as a credibly independent judiciary, or an external power such as an international court or a donor.

For example, for many years the major resource extraction company ALCOA mined bauxite in Guinea. The company knew that it would be far cheaper to process the

bauxite into aluminium prior to shipping, but this would have required a huge fixed investment of around $1 billion. The company's board recognized the time-consistency problem: the government of Guinea had no means of pre-committing to refrain from capturing the profits generated by this investment once it had become irreversible. Hence, Guinea lost the opportunity for what would have been its single largest investment because of a lack of commitment technology.

The time-consistency problem applies in reverse if there are end-costs to resource extraction. In particular, there are likely to be costs of cleaning up the environment once the natural asset has been removed. The company has an incentive to make promises on which it subsequently reneges. Now it is the company which needs a commitment technology for its promises to be credible. For example, the company could pay a proportion of its profits into an escrow account which could only be accessed once all liabilities had been settled.

Core Analysis 2: *Production and the principal-agent problem*

The principal-agent problem is inevitable in the exploitation of natural assets because the ownership of the rents is separated from the control of the process of exploitation. The incentives for the agent who exploits the asset must therefore be aligned with those of the principal who owns it. Suppose that the government licenses a company to extract a natural asset which is owned collectively by citizens. The policy problem is to capture the rents from the natural asset while leaving the company with an incentive to extract the asset. How well this is done depends upon the design of the tax system. The problem arises because the company is making profits from two conceptually distinct processes, one being the capture of rents and the other being the return on its capital, skills, and risk taking. In other sectors of the economy companies only make profits from the second of these processes. If the government has complete information then the appropriate arrangement is to decompose the company's total profit into these two components and apply two distinct tax rates. An excess profits tax rate of 99% would be applied to the rents, and the normal tax rate used for other sectors would be applied for the remaining profits.

In reality, the government does not have complete information. Far from knowing how to decompose profits into their two components, even the true total profits of the firm are unobservable. The government observes only the figure reported by the company. Companies have many ways of concealing profits in costs and transferring them to other tax jurisdictions. Further, the shareholders of the company themselves face a principal-agent problem. In response to a high excess profits tax management may choose to raise costs at the expense of profits in order to improve the quality of life of employees. An alternative approach it to impose a royalty on resource extraction. The royalty is based not on profits but on either the physical quantity of the resource extracted, or upon revenues. An advantage is that both of these are far easier to observe than excess profits and so are less open to being gamed. A disadvantage is that royalties at some point diverge from the ideal excess profits tax sufficiently to introduce inefficiencies. In particular, if extraction costs rise as the natural asset is depleted, then extraction will cease prematurely: extraction will be insufficiently profitable to pay the royalty and so the last potential rents will not be captured.

While reliance only upon a high excess profits tax would require more information than a government is likely to have, reliance upon a flat-rate royalty under-uses available information. For example, the government will have some geological information as to the depth and age of a mine, and whether an oil well is onshore or offshore. Tax and royalty rates can be differentiated according to such observable geological features. Similarly, as the world price of the commodity varies rents change more than proportionately so that royalty rates can be geared accordingly, possibly with a threshold price below which royalty rates are zero.

Core Analysis 3: *Setting royalty rates: auctions as systems of value revelation*

In setting the tax and royalty rates the government is at a disadvantage vis-à-vis the resource extraction company with which it must reach agreement. It faces both an internal agency problem and an information problem. The agency problem is that the government must delegate the negotiation to a small group of its members. The company then has a strong incentive to bribe these individuals. To protect itself the government

needs to adopt a process that is transparent: secret negotiations are ideally suited to corruption. The information problem is that the government has considerably less knowledge as to the true value of its natural assets than does the company. The true value will depend upon costs of extraction which are the core business of the company but not the government. Hence, if a deal is reached by means of a confidential negotiation between a company and the government it is likely to be to the advantage of the company.

A solution to both the agency and the information problem is to auction the extraction rights, inviting bids on the royalty rate that companies would be willing to pay. The rate could be conditioned on any observable features such as the basic geology, world price, and accumulated past volume of extraction. However, there is a trade-off between complexity and transparency. Complexity would be necessary to get as close as possible to the ideal but unknowable excess profits tax, but it also introduces scope for corruption. A reasonable principle is that the proposed fiscal structure should be sufficiently straightforward that from the geological information provided by the prospecting phase and assumptions about world prices, likely revenues can readily be estimated.

There is a case for conducting an auction in two stages, the first of which pre-screens bidders for their technical competence and financial credibility and limits the auction to around four bidders. If there are too many bidders the chance of success is too low to warrant serious investment in the information necessary to formulate a sound bid and instead participants may submit unprepared bids that are safely low, in the hopes of being lucky. If there are too few bidders then bids may be too low because of insufficient competition. As long as around four informed bidders are competing for the rights to exploit the natural asset the government does not itself need information: the true value is revealed through competition in the bidding process. A transparent auction process also protects again the agency problem: there is far less scope for corruption than in a secret negotiation. The design of auctions is complex and is a specialist field of research (see Cramton 2006).

Core Analysis 4: *Depletion and the Hotelling Rule*

The rate of depletion of auctioned natural assets will be determined by the company that has acquired the extraction rights. However, the government can still often retain control of the overall rate of depletion of its natural assets by determining the pace at which rights are sold. We now consider what principles the government should apply in choosing the depletion rate.

If natural assets are left in the ground they will nevertheless earn a rate of return which depends upon the increase in the real price of the commodity. The pertinent economic principle here is the Hotelling Rule that over the long term the real price will rise at the world rate of interest. The explanation for the Rule is straightforward. If the current price was sufficiently low that people expected it to rise more rapidly than the interest rate then extraction would be less profitable than leaving the commodity in the ground. The reduction in supply would force the current price to rise. Conversely, if the current price was already so high that people expected it to rise by less than the world interest rate the most profitable strategy would be to extract as rapidly as possible and this would drive the current price down. The prevailing price should therefore normally be that from which it is expected to rise at the world interest rate. If expectations are not systematically biased then the price should on average actually rise at this expected rate. In practice for long periods the price of natural assets has diverged from the Hotelling Rule. Nevertheless, the Rule provides our best long term guide to depletion decisions.

As discussed in our companion paper, the typical African country has a rate of return on capital that is higher than the world interest rate and so has an interest in rapid depletion subject to the constraint of being able to absorb the revenue productively. The typical resource extraction company operates on an even higher discount rate than the return on government capital and so is likely to deplete even more rapidly that the government would wish. Hence, if the government sells all the natural assets at once the overall rate of depletion is likely to be socially excessive. *The optimal rate of depletion of the country's endowment should be determined by the absorption rate at which the marginal return to depletion equals the world interest rate*. In turn, this rate of depletion should determine the rate at which the extraction rights are auctioned.

Core Analysis 5: *Efficient Incentives for discovery*

The design of rent taxation is complicated by its effects on prospecting. Analogous to why fundamental science should be publicly funded, there is case for financing prospecting out of public funds. For example, the preparation of a cadastre would be a good use of aid money. However, since there are many other claims on limited public sector capacity to manage activities, an alternative is to rely upon private prospecting.

The challenge here is to separate as far as possible the generation of information from the process of conferring rights of extraction. Unless this is done, the prospecting company is acquiring rights of a highly uncertain value at the time when it acquires the rights to prospect. It does not know what it will find. Recall that a general problem with 'blue skies' private prospecting is the externality that accrues to subsequent prospectors and so the private return is depressed below the social return not only by the taxation of rents but by these gains to future neighbouring prospectors. Further, the initial prospector may not know the tax regime that will be put in place if it finds extractable assets. The government cannot plan for all eventualities and so may well not be able to pre-design an appropriate tax regime. Worse, whatever it designs may not be fully credible because of the time-consistency problem: if the regime turns out to be sub-optimal from the government's perspective, it has the power to change it unilaterally. All these factors depress the price that a prospector is prepared to pay for the right to prospect, given the reward structure that the prospector has the right to extract whatever is found subject to taxation. The deep discount on the price itself further undermines the credibility of any prior tax regime.

While the generation of discoveries should therefore be separated from their subsequent ownership, if the separation is total then the prospector has no incentive to discover anything: in effect, the company has been co-opted onto the civil service payroll. A possible solution is thus for the company to receive the right to a tax-exempt share of the government royalty on any subsequent extraction. This aligns the interest of the prospector with that of the government: both now wish to maximize the value of the rents since each receives a slice of them. The geological information generated by the

discovery process then forms the basis for informed bids in the auction process discussed above. The interests of the prospector and the government are now congruent in wishing to get the highest possible bid. The credibility of the geological information provided by the prospector will potentially be contaminated by this incentive. If the prospector is permitted to bid then the incentive is to understate the true value of the discovery: for this reason prospectors should be excluded from the auction of extraction rights. However, this leaves the prospector with an incentive to overstate the true value so as to encourage high bids. Since bidders can anticipate this problem the outcome would not in fact be high bids, but bids that were too low because the quality of the information would be discounted. The government therefore has an interest in maintaining the integrity of the information by choosing is an established prospector with a reputation to protect.

The discovery process is potentially also suited to an auction. As with the auctioning of extraction rights, it would be in two stages. In the first, potential bidders would be selected on the basis of technical competence and financial credibility. Selected bidders would then compete on the basis of the lowest share of the royalty that would be accepted subject to undertaking a complete cadastre of a specified area.

Core Analysis 6: *Signature bonuses*

In this proposed system the extraction process is decomposed into two stages: discovery and production. Each is made competitive through an auction in which bidders compete on royalty shares and rates. In this system there is no 'signature bonus' to be paid at the stage of awarding the rights to prospect. Signature bonuses are implicitly expensive since they discount future expected profits by all the uncertainties discussed above. They are equivalent to borrowing on highly uncertain prospects. As discussed in our companion paper (Collier and Venables, 2008a), only once the geological information has been generated is it appropriate to borrow in anticipation of future revenues. Assigning away rights to natural assets on the basis of whoever pays the highest signature bonus breaches medium term revenue maximization within the current generation, as well as both the Utilitarian and rights-based concern for future generations.

Core Analysis 7: *National companies*

An alternative to the above approach is to establish a nationally owned company. There are two variants of this model. In the one the national company is given a local monopoly, while in the other the national company operates alongside private companies. These two variants have very different rationales. The state monopoly is appropriate where the problems of designing an effective tax-cum-royalty regime for the private sector are judged overwhelming. However, if the state is not capable of taxing private activity *a fortiori* it may be even less able to manage the vastly greater range of activities involved in discovering and exploiting natural assets. In this eventuality it may be better to leave the assets unexploited until these deep problems of the public sector are addressed. The case for operating a national company alongside private operators is quite different: its rationale is to strengthen competition rather than impose a monopoly. A national company can increase competition not only by introducing another player, but one which manifestly cannot be induced to participate in a cartel, thereby reducing the risk of such behaviour among other players. Further, as the company learns by doing in the practical process of extraction, the government generates better information for efficiently taxing the activity. However, if a national company is to strengthen competition it needs visibly to operate on a level playing field with other companies: hence, its accounts must be transparent. It should also be subject to the same regulatory regime as other companies and so cannot itself be given a regulatory function over other companies.

Core Analysis 8: *Chinese-style contracts*

The Chinese mode of resource extraction in Africa is distinctive: typically it is a package deal of resource extraction in return for infrastructure, supported by an element of aid. This is in sharp contrast with the OECD approach in which the sale of extraction rights is in return for money paid into the budget. If either this revenue or aid is used to purchase infrastructure these are distinct transactions. An evident disadvantage of linkage is that the government is locked into a particular form of expenditure with a particular supplier.

However, locking in to the particular expenditure may in fact be advantageous. By doing so the government may avoid pressures from lobby groups to spend the money on consumption since the money does not appear in the budget, and it provides an effective commitment technology that locks future governments into investment of resource revenues. Further, by bypassing the normal systems of taxing and spending, the linked contract economizes on public administration. A well-motivated president or finance minister who is concerned about the agency problems that make the civil service dysfunctional may reasonably take the view that a bypass is efficient. However, as presently arranged the linked contract of resource extraction, infrastructure and aid is opaque: it is very difficult to evaluate the deal. This is not intrinsic to linked contracts but rather to the fact that currently China is the only actor offering such contracts. In principle, it would be feasible for governments to hold auctions on such packages, encouraging other actors, including bilateral donors, to form extraction-construction-aid consortia which put in bids alongside the Chinese. This would reveal whether the Chinese offers were good value while retaining their advantages.

2.3 Distinctive Issues for Renewable Natural Assets

Renewable natural assets, such as timber and fish, face all the issues pertinent for non-renewable assets, but have the added complication that they have a rate of return from a natural process of physical reproduction. The Hotelling Rule still applies, but now the expected change in price is the world interest rate minus this natural rate of return. Indeed, in one nineteenth century economic theory the relative price of renewable natural assets was assumed to be fixed so that the world interest rate was believed to be determined by the rate of growth of trees.

The natural rate of reproduction might itself be a function of the rate at which the asset is harvested. A high rate of off-take might reduce the capacity for renewal: the density of fish in the water becomes too low for efficient reproduction and trees are cut before they reach the age of maximum growth. For example, Robinson and Albers (2006) show that the Tanzanian system of game parks may inadvertently have made renewal more difficult. By creating privileged areas in which the rate of off-take is reduced to

zero, the system has induced households depending upon income from renewable assets to increase their off-take in neighbouring areas. Instead of having a sustainable rate of off-take over the entire area, one part now has a wastefully sub-optimal rate of off-take and the other has an unsustainably high rate.

The key problems of renewable assets again stem from the unnatural ownership rights of natural assets. Forests and fish are often common pool resources and so liable to the standard tragedy of the commons problem. While social conventions have successfully enforced limits on the rate of off-take, rapid population growth may have so increased the value of natural assets that the conventions break down. The attempt to replace local social conventions with national ownership and legislated control may accelerate this breakdown. As the Tanzanian example shows, controls may inadvertently worsen the problem. An alternative may be to use national power to bolster local systems of control, for example by vesting legal ownership in the community. While the issues are common with non-renewable resources, the consequences of misaligned incentives may be more severe, resulting in the physical exhaustion of an asset which it would be socially more valuable to harvest.

While in respect of non-renewable assets the Utilitarian and custodial principles largely coincide, in respect of renewable assets they are liable to diverge. The custodial principle implies that renewable assets *should* be renewed: the present generation has a responsibility to hand on renewable assets. In contrast, the Utilitarian principle argues that whether natural assets should be renewed is entirely analogous to whether physical assets should be renewed. It is normally a good use of resources to maintain physical assets, but at some stage, either due to changes in technology or relative prices, it usually becomes more cost-effective to let them depreciate. Similarly, with natural assets: at some stage the return on land is higher if it is switched from forest to other uses. *The Utilitarian attaches no premium to the preservation of the world as it is.*

This disagreement is distinct from arguments about global externalities from renewable natural assets. Switching land from natural forest to other uses releases carbon and reduces bio-diversity, both of which are global public bads. On such matters the Utilitarian reaches the same conclusion as the custodial principle, though for different reasons. However, these global public bads involve both inter-spatial and inter-temporal

redistributions of welfare. The present local population may gain from changing land use whereas the future global population will lose. Even if the future global population loses more than the present local population gains, some system of compensation is needed both on the principle of rights and on practical political considerations.

3. Practice: Ownership, Extraction and Discovery

While the main purpose of the paper is analytic, we briefly review recent African experience.

3.1 Ownership

In Africa since Independence the formal ownership of natural assets has been lodged with national governments, or occasionally with a sub-national government. Disputes about the assignment of rights between national and sub-national units of government have no 'natural' resolution, but unless resolved will have costs arising from uncertainty as discussed below. More drastically, at times governments have not been able to exercise effective control on the ground.

Induced violence

There is reasonable evidence that the presence of valuable natural assets increases the risk of rebellion. The most convincing evidence is provided by the link from changes in world prices to the risk of rebellion since prices can reasonably be taken as exogenous. In work as yet unpublished, Besley and Persson (2008) find such a result: an increase in the world price of commodities significantly increases the incidence of civil war in commodity-exporting countries. Evidence based on the value of natural resource revenues is consistent with this result (Collier, Hoeffer and Rohner, 2009). One reason for the link is that resource extraction makes rebellion easier. By controlling the territory in which such resources are located rebel groups are able to finance their revolt. The diamond-financed wars in Sierra Leone and Angola are important examples. A second reason is that the capture of valuable natural resources might motivate the rebellion. A

variant is that the discovery of such resources might increase the attraction of regional secession. There is some evidence that the Biafran secessionist war in Nigeria was related to the discovery of oil in the South East. This appears to have switched the Northern Region from seeking its own secession to wishing to maintain the Federation. The potential secession of Southern Sudan may also be related to the oil which, though only recently tapped, has been known about for decades.

Since many of the costs of rebellion do not accrue to rebels, if natural assets induce efficient rent-seeking rebellion the overall cost will exceed the value of the assets. In this case the possession of natural assets will be immizerizing. There is thus a strong case for public action to sever the link from natural assets to rebellion. In response to conflict diamonds the sector established the Kimberley Process which has made it considerably more difficult for illicit exploitation to reach the market. Currently, there is no equivalent to the Kimberley Process for oil. However, President Yar Adua has proposed such a scheme and it would be technically feasible. As with the Kimberley Process, by making the stolen commodity more difficult to sell, it would reduce the incentive to plunder.

Whereas rebellion is militarily demanding, since the state is being openly challenged, theft requires a lower threshold of organized violence. The objective is confined to looting the natural asset, rather than including an attempt to build a significant political organization and standing military capability. The main current example of such activity is oil 'bunkering' from Nigeria. While the Delta region of Nigeria has had a long history of political opposition, including rebellion, oil bunkering has evolved into something much closer to crime than to political rebellion. Oyefusi (2007) surveyed 1,500 young men in the Delta, trying to discover what made some more prone than others to being recruited into violence. The key characteristics bore little or no relation to politics: neither poor social provision in a locality, nor a sense of grievance, was related to recruitment. Rather, recruitment was concentrated among those with little education and no dependents: these were the cannon fodder for criminal organizations.

Whereas both rebellion and theft require substantial military capability, a third way to contest state ownership is by the mass assertion that the territory in which the valuable resources are located is a 'commons', permitting free or near-free access to the

proximate population. This is particularly important for those resources which do not require significant investment in order to be exploited and so are suitable for exploitation by artisans. An important example is the mining of alluvial diamonds in Sierra Leone. Until the 1950s the rights to discover alluvial diamonds were sold as a monopoly by the government. De Beers, the company which held the monopoly rights from the government, defended its rights by physically excluding other potential miners from its territory. By the end of the 1950s it became too costly to maintain the exclusion, partly because local politicians encouraged people to invade the territory, so that it became a common pool resource.

Ownership through hold-up

Sometimes the exploitation of a natural resource requires an input which is owned by a monopolist. For example, resource extraction may require a monopoly form of transport such as a railway line. In this case, if the ownership of the railway line is separated from that of the natural resource, the railway can subject the resource extraction company to 'hold-up', capturing some of the rents. While superficially the separation of railway ownership from extraction ownership might appear to introduce competition, in fact it mere shifts the rents. Such shifting of the rents is undesirable because they thereby escape the tax-cum-royalty system: a railway company will be subject only to normal corporate tax rates.

Uncertain tenure

A significant problem has been that rights are temporary or uncertain, thereby creating an incentive to those who have current control to strip the natural asset. For example, the oil in Southern Sudan is currently shared with between the Northern and Southern governments on a revenue-sharing formula. In 2011 there is to be a referendum on independence for the South, and this creates uncertainty in the North as to whether its share of ownership will continue. The government is reported to be accelerating extraction of oil, even to the point of damaging the wells. This is consistent with privately maximizing responses to the anticipation of possible loss of ownership. A second example is the behaviour of the transitional government of DRC, which sold off

extraction rights at generous prices during its brief tenure of office. A seemingly different type of example is the consequence of insecure tenure in smallholder agriculture. Goldstein and Udry (2006) find that in Ghana effective rights to tenure are linked to usage so that farmers are reluctant to leave land fallow. As a result the soil is over-exploited, resulting in a loss to GDP of 2%.

3.2 Discovery and extraction

Although Africans have 50 percent more land per person than citizens of the OECD, the value of the known natural sub-soil assets of that land is radically lower. A global inventory of sub-soil assets as of 2000 finds that in Africa the typical square kilometre contains known natural assets of only $25,000 in contrast to $125,000 in the OECD.[2] As noted in the introduction, when two such massive land areas are compared it is unlikely that the true average value of sub-soil assets should be so divergent. The most likely explanation is that there are far more sub-soil assets in Africa that are yet to be discovered. Indeed, since the OECD countries have been extracting their natural assets commercially for far longer than Africa a reasonable expectation might be that Africa has more of them left in the ground that the OECD. The major implication is that for Africa the discovery process is going to be very important. Assets worth several times those currently known probably await discovery. It also perhaps suggests that to date the discovery process has been inhibited.

As with other assets, natural assets can finance consumption both by generating income and by being depreciated. Whereas it has long been conventional to allow for the depreciation of physical capital, the extension to natural assets is only recent: it is termed Green Accounting. Reconstructions of national accounts for African economies taking into account the depreciation of natural assets have concluded that on average since Independence the region has been depreciating its natural assets more rapidly than its gross income has been increasing, so that even the appearance of modest growth is illusory: African standards of living have depended upon running down natural assets.

[2] We would like to thank Anke Hoeffler for calculating this from World Bank data, World Bank (2006).

3.3 *Renewables*

Climate change means that more attention is now being paid to one important renewable resource, forests. Africa accounts for 20% of world carbon emissions from land use change, most of this being deforestation in the Congo basin, in particular the Democratic Republic of the Congo.[3] The ideal system is that countries should be paid to maintain forests rather than to cut them down, thereby reducing carbon emissions directly and also sustaining the public good created by forests as a carbon sink. However, the Kyoto framework excludes deforestation from the principal funding mechanism for developing countries, the Clean Development Mechanism (CDM). The reason is the difficulty of enforcing and verifying any agreements that might be entered into. Work is under way in various agencies and countries to build up estimates of baseline levels of forests and forest emissions, and to pilot national schemes for reducing forest emissions below baseline levels. Such schemes might offer potential for substantial flows of funds to participating countries, as well as leading to more efficient forest management. But implementation and enforcement of these schemes may require a degree of effective and honest governance beyond the capacity of many African governments.

4. Conclusion

The effective exploitation of natural assets is important for Africa's economies. In one dimension the rents from extraction make process less difficult than a competitive activity such as manufacturing: it is not necessary to be efficient in production in order to prosper. Yet the socially efficient exploitation of resource rents is complex in different dimensions that are illuminated by the framework of the principal-agent problem. Within this general framework, the design of an efficient discovery process benefits from insights from the economics of information: resource discoveries are somewhat analogous to scientific discoveries. The design of an efficient capture of rents from resource extraction, and solutions to the clean-up problem, are fundamentally about the time-consistency problem and the need for commitment technologies.

[3] World emissions from land-use change amount to around 20% of total anthropogenic emissions.

The good news for Africa is that high commodity prices have massively increased rents from the extraction process, while the value of the natural assets awaiting discovery is quite likely to exceed those already discovered. To date neither extraction nor discovery have been socially efficient: the application of economic principles is likely to have a high pay-off.

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