Alluvial Diamonds: A New Resource Curse Theory

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Abstract

I develop the micro-foundations of a resource curse process in small-scale alluvial diamond mining in poor countries. I identify a commons problem and gambling for resurrection as sources of labour inefficiencies induced by mining institutions. I show that the commons problem lowers aggregate output. Thus, I provide another perspective to the debate on the role of institutions in economic development, focusing on the industrial organization of diamond mining. I also contribute to the literature on the commons problem and gambling for resurrection by showing that they occur in alluvial diamond mining. The labour inefficiencies help explain why Sierra Leone, with liberal access to its diamond mines, is poorer than Namibia and Botswana with restricted access; and why African countries with alluvial diamonds tend to be conflict-prone. One solution is to restrict access to the diamond deposits. However, in practice, enforcing property rights is often costly, economically and politically. Support to alternative activities is recommended.

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1. Introduction

Many countries rich in natural resources are poorer and more miserable than countries that are less well endowed (Soros 2007). The literature highlights three main processes that can lead to such a resource curse. First is the Dutch disease wherein a real exchange rate appreciation following a resource boom diverts factors of production away from sectors with positive growth externalities (Corden and Neary, 1982; van Wijnbergen, 1984). Second is through political economy channels like rent seeking and corruption; and political instability, including violent conflict (see for instance Torvik, 2002; and Collier and Hoeffler, 2004). Third is commodity price volatility (Aizenman and Marion, 1999; Ramey and Ramey, 1995).

In this paper I highlight a fourth resource curse process in small-scale artisanal mining of alluvial diamonds in a low-income environment: I identify a commons problem and gambling for resurrection as two sources of labour inefficiency induced by mining institutions. Thus, I provide a new perspective to the debate on the role of institutions in economic development, complementing others highlighting the effects of more generic geographical factors like the disease environment or location in the tropics (Acemoglu, Johnson and Robinson, 2001; and Easterly and Levine, 2003). I also contribute to the literature on the commons problem and gambling for resurrection by showing that they occur in alluvial diamond mining.

The institutions that I focus on are the industrial organization of diamond mining and the contract form for labour. The industrial organization is determined by a combination of geological and political economy factors. Alluvial diamond deposits are spatially dispersed and could be mined with crude, hand-held implements, in contrast to capital-intensive “point” resources like deep-pit Kimberlite diamond deposits, or other resources that dominate the resource curse literature. The difficulty of enforcing property rights over a vast space, and the scope for small-scale mining, tend to attract a myriad of miners, fostering open access. Sierra Leone testifies to this difficulty. Sierra Leone started with a monopoly in the 1930s which collapsed during the “diamond rush” of the 1950s when some 75000 miners invaded the concessions (van der Laan, 1965). In response, in 1956, the colonial government bifurcated the mines into an artisanal sector – with conditions approximating open access – and a monopoly corporate sector. However, pressure to liberalize access to the remaining corporate concessions continued. In 1967, the opposition was voted to power partly on promises to do so, leading to the eventual universalization of artisanal mining. (Davies 2007).

I show that failure to restrict access to the alluvial diamond mines, as in Sierra Leone, induces a commons problem: Finding a diamond is a matter of chance. As more and more miners search for diamonds, every new miner reduces other miners’ chances of finding a diamond. Thus, with open access, the last miner imposes a cost on all existing miners, raising private return above social return. Labour allocation, based on private return, becomes socially excessive. I present two models capturing the externality. A “lottery” model captures the lottery context in which the externality occurs. I use it to illustrate both the commons problem and gambling for resurrection numerically. The second, “spatial” model captures the spatial context in which the externality occurs and illustrates the implications for aggregate output.

In the traditional commons problem, free access to a finite resource ultimately dooms the resource through overexploitation (Hardin, 1968). In alluvial diamond mining, overexploitation leads to excessive employment. Also, uncertainty in diamond mining – and the fact that, ex post, some lucky miners might be rich and others poor – contrast with the traditional commons problem where uncertainty does not exist and ex post outcomes are the same for everyone. However, the inefficiency characterising the commons problem in diamond mining is unrelated to uncertainty or the ex post dimension. The source of the inefficiency is the externality in individual behaviour, like in the traditional tragedy of the commons.

The second source of inefficiency in artisanal diamond mining that I highlight also sets private returns above social returns, inducing excessive employment of its own. African artisanal diamond miners are generally very poor. They typically work on credit and share the profits with their creditors. In the event of a loss, they do not refund any part of the credit that cannot be recovered from their earnings (Partnership Africa Canada and Global Witness, 2004). I draw on the finance literature to show that this contract form induces "gambling for resurrection" – the tendency for a financially distressed firm to engage in excessive risk taking. The incentive is that the firm gains disproportionately if a risky project succeeds but bears too little of the cost if the project fails: it files for bankruptcy and walks away from its debt (Hart, 2000; Akerloff and Romer, 1993; and White, 2007 and 1989).

The identified labour inefficiencies help explain why Sierra Leone, which ranked bottom on the UNDP 1991 Human Development Index, is much poorer than Namibia and Botswana with restrictions to their diamond deposits that obviate the inefficiencies. Sierra Leone's per capita income in the 1980s was US$280 compared with US$560 in Sub-Saharan Africa, and US$1500 in Namibia and Botswana. Labour shortages have been reported as a constraint to Sierra Leone's agriculture (Food and Agriculture Organization, 2005). This suggests a positive marginal product of agricultural labour. That part of Sierra Leone's artisanal diamond labour force – estimated at over 100,000 in 2004 (Government of Sierra Leone, 2005) – could be excessive, in the face of a positive opportunity cost of labour, suggests that, on the whole, artisanal diamond mining could be immiserizing. Indeed, the regime change from monopoly to open access appears to have been costly to Sierra Leone. In the 1950s, the country turned from a net exporter of rice, the staple food, to a net importer, as farmers abandoned rice fields for the diamond mines (Saylor 1967). The country has remained a net rice importer ever since. By contrast, Namibia shows that open access in alluvial diamond mining is not inevitable. It has avoided the labour inefficiencies by restricting access to its alluvial deposits ever since 1908, allowing only a few wage-paying producers, obviating both the commons problem and gambling for resurrection. To an extent, Namibia has been lucky compared to Sierra Leone: Namibia's alluvial diamonds occur mostly in desert areas or offshore, facilitating market access restriction. Botswana's own luck is that it has Kimberlite diamond deposits which are a capital-intensive point resource. This tends to induce a natural monopoly.

The labour inefficiencies also help explain why African alluvial diamond producers like Sierra Leone, the Democratic Republic of Congo, and Angola, have tended to be conflict-prone: Warfare participation, driven by a desire to mine diamonds – as sometimes observed (Abraham 1997) – is, in effect, an employment choice for diamond mining. Thus, with open access in diamond mining, warfare participation may be susceptible to the commons problem. With profit sharing, it may also be susceptible to gambling for resurrection. Either effect induces overemployment in warfare. Thus, alluvial diamond mining makes it easier to attain a critical mass of combatants to initiate or sustain warfare.

2 The Two Sources of Labour Inefficiency

2.1 The Commons Problem

I first model the externality due to the commons problem in alluvial diamond mining as a lottery process with the number of diamond finds a probability distribution. The key idea to capture is that any diamond found is one diamond less for others to find. I then model the externality as a spatially constrained production process.

2.1.1 The lottery model

Assume X diamonds are randomly distributed over Y identical plots of land. For simplicity, assume X<Y and each plot contains one or no diamond. Each of L_d miners randomly searches a single plot for diamonds without revealing the outcome. The miners search sequentially, precluding the possibility of two or more miners simultaneously finding the same diamond, which would merely complicate matters. Thus, if A finds a diamond this reduces the probability that subsequent searchers will find a diamond. However, if A does not find a diamond, that probability is unchanged. With two miners, the probability that the first miner finds a diamond is X/Y. The probability that he does not find a diamond is $\frac{Y-X}{Y}$ since Y-X plots do not contain any diamond. The probability that the second miner finds a diamond if the first miner has already found one is $\frac{X-1}{Y}$: If the first miner finds a diamond, the number of remaining diamonds decreases to $X-1$.

Expected return, P^e, is given by the expected diamond finds (expected total return) divided by the number of diamond miners, L_d. Expected diamond finds is the sum of the product of possible diamond finds, N_i, and the respective probability, $prob(N_i)$:

$$P^e = \frac{expected\ diamond\ finds}{L_d} = \frac{\sum_{i=0}^{i\leq X} N_i.prob(N_i)}{L_d} \quad (1).$$

I assume risk neutrality, abstracting from risk as a source of inefficiency.

Table 1 presents the expected returns for X=2, Y=3, and $L_d = 1,2,3$. The elements in the outcome set are ordered: (1,0) reads “the first miner finds a diamond and the second miner does not”. Table 1 shows that expected marginal return (expected social return) is less than expected private return. For instance, for L=3, expected marginal return is 8/27 while expected private return is 38/81.

I have assumed that X<Y. However, the relative magnitude of X and Y does not matter. X could exceed Y. By implication, a miner could find multiple diamonds in one period. Also, I have assumed that the miners do not reveal the outcome of the search for diamonds. This assumption could be relaxed. If the outcome is revealed, the implication is that subsequent miners would

narrow their search, ignoring plots known to be "empty". The key idea to capture in any variant of the above scenario is that any diamond found is one diamond less for others to find.

Table 1: The Commons Problem in the Lottery Model

Number of miners L_d	Number of diamond finds N	Sample space	$prob(N)$	Expected total return (expected diamond finds)	Expected private return	Expected marginal return (expected social return)
1	0	(0)	$\frac{1}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	-
	1	(1)	$\frac{2}{3}$			
2	0	(0,0)	$\frac{1}{3}.\frac{1}{3}=\frac{1}{9}$	$\frac{10}{9}$	$\frac{5}{9}$	$\frac{4}{9}$
	1	(0,1) (1,0)	$\frac{1}{3}.\frac{2}{3}+\frac{2}{3}.\frac{2}{3}=\frac{6}{9}$			
	2	(1,1)	$\frac{2}{3}.\frac{1}{3}=\frac{2}{9}$			
3	0	(0,0,0)	$\frac{1}{3}.\frac{1}{3}.\frac{1}{3}=\frac{1}{27}$	$\frac{38}{27}$	$\frac{38}{81}$	$\frac{8}{27}$
	1	(0,0,1) (0,1,0) (1,0,0)	$\frac{1}{3}.\frac{1}{3}.\frac{2}{3}+\frac{1}{3}.\frac{2}{3}.\frac{2}{3}+\frac{2}{3}.\frac{2}{3}.\frac{2}{3}=\frac{14}{27}$			
	2	(1,1,0) (1,0,1) (0,1,1)	$\frac{2}{3}.\frac{1}{3}.1+\frac{2}{3}.\frac{2}{3}.\frac{1}{3}+\frac{1}{3}.\frac{2}{3}.\frac{1}{3}=\frac{12}{27}$			

The lottery model is similar in spirit to the Harris-Todaro (1970) model of rural-urban migration. In both models a negative externality sets social return below private return. In Harris-Todaro, migration generates the externality by increasing competition for a fixed number of higher-paying urban jobs, lowering the probability of urban employment. Output is fixed, setting the marginal product of an urban migrant to zero. In my model, marginal product of labour is positive since diamond output increases with employment, which is available to everyone due to open access. Output assumes a probability distribution.

2.1.2 The spatial model

Consider an economy with two sectors, diamond mining and agriculture. The return to agricultural labour, F, is constant. Mining occurs on diamond-bearing land of dimension, B, divided into identical plots and distributed among L_d miners. Thus,

$$plot\ size\ per\ miner = \frac{B}{L_d} \qquad (2).$$

Private return, P, is given by

$$P = \left(\frac{B}{L_d}\right)^{\alpha} = B^{\alpha}L_d^{-\alpha} \quad , \quad 0 < \alpha < 1 \qquad (3).$$

$$Total\ return = Q_d = P.L_d = B^{\alpha}L_d^{1-\alpha} \qquad (4).$$

$$Marginal\ return = \frac{dQ_d}{dL} = (1-\alpha)B^{\alpha}L_d^{-\alpha} \qquad (5).$$

Under open access, entry into the mines will continue until P equals F, the return to agriculture. Thus, equilibrium is attained when

$$B^{\alpha}L_d^{-\alpha} = F \qquad (6).$$

Equilibrium under a wage-paying monopoly is at the point where diamond marginal return equals F

$$(1-\alpha)B^{\alpha}L_d^{-\alpha} = F \qquad (7).$$

To compare the equilibrium levels of diamond employment under open access, L_d^{open}, and monopoly, L_d^{mono}, solve for L_d in (6) and (7):

$$L_d^{open} = \frac{B}{F^{1/\alpha}} \qquad (8),$$

and

$$L_d^{mono} = (1-\alpha)^{1/\alpha}\frac{B}{F^{1/\alpha}} \qquad (9).$$

Thus, $L_d^{open} > L_d^{mono}$, given that 0< $\alpha < 1$. Whereas monopoly employment is socially optimal (based on social return and not private return), open-access employment is socially excessive. The excess is given by:

$$excess\ employment = L_d^{open} - L_d^{mono} = \left\{\frac{B}{F^{1/\alpha}}\right\} - \left\{(1-\alpha)^{1/\alpha}\frac{B}{F^{1/\alpha}}\right\} = \frac{B}{F^{1/\alpha}}\left[1-(1-\alpha)^{1/\alpha}\right] \qquad (10)$$

Substituting (8) into (2) gives

$$open\ access\ equilibrium\ plot\ size\ per\ miner = \frac{B}{L_d^{open}} = \frac{B}{B/_{F^{1/\alpha}}} = F^{1/\alpha} \qquad (11).$$

Substituting (9) into (2) gives

$$optimum\ plot\ size\ per\ miner = \frac{B}{L_d^{mono}} = \frac{B}{(1-\alpha)^{1/\alpha}\frac{B}{F^{1/\alpha}}} = \frac{F^{1/\alpha}}{(1-\alpha)^{1/\alpha}} \qquad (12),$$

which is larger than the open access equilibrium plot size per miner, since $0 < \alpha < 1$. Thus, the commons problem lowers the plot size per miner relative to the optimum.

Implications for aggregate output

The commons problem lowers aggregate output, Y, given by

$$Y = Q_d + Q_a \tag{13}$$

where Q_a is agricultural output: Assume a fixed total labour supply L, given by
$L = L_d + L_a$ (14),

where L_a is agricultural labour. Using (14), agricultural output Q_a, could be written as

$$Q_a = F.L_a = F(L - L_d) \tag{15}$$

Substituting for Q_d from (4) and for Q_a from (15) into (13):

$$Y = Q_d + Q_a = B^\alpha L_d^{1-\alpha} + F(L - L_d) \tag{16}$$

Under open access, equilibrium employment is at the point where the return to agriculture F, equals the private return to diamond mining. Thus, aggregate output, Y^{open}, equals FL.[1]

Diamond output under monopoly, Q_d^{mono}, is

$$Q_d^{mono} = B^\alpha L_d^{1-\alpha} = B^\alpha \left\{(1-\alpha)^{1/\alpha}\frac{B}{F^{1/\alpha}}\right\}^{1-\alpha} = B\left\{\frac{(1-\alpha)}{F}\right\}^{\frac{1}{\alpha}-1}$$

Aggregate output under a diamond monopoly, Y^{mono}, is therefore

$$Y^{mono} = B\left\{\frac{(1-\alpha)}{F}\right\}^{\frac{1}{\alpha}-1} + F(L - L_d) = B\left\{\frac{(1-\alpha)}{F}\right\}^{\frac{1}{\alpha}-1} + F\left\{L - \left((1-\alpha)^{1/\alpha}\frac{B}{F^{1/\alpha}}\right)\right\}$$

$$= FL + B\left\{\frac{(1-\alpha)}{F}\right\}^{\frac{1}{\alpha}-1} - \left\{F^{1-\frac{1}{\alpha}}(1-\alpha)^{1/\alpha}B\right\}$$

$$= FL + BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}-1} - BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}} \tag{17}$$

To compare Y^{mono} and Y^{open}, i.e. $\left\{FL + BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}-1} - BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}}\right\}$ and FL, respectively, subtract FL from Y^{mono} and Y^{open}. Thus $Y^{mono} > Y^{open}$ if

$BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}-1} - BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}} > 0$ or

$$BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}-1} > BF^{1-\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}} \tag{18}$$

Multiply both sides of (18) by $\frac{(1-\alpha)^{-1/\alpha}}{BF^{1-\frac{1}{\alpha}}}$ to get

$$(1-\alpha)^{-1} > 1 \tag{19}$$

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[1] To obtain equilibrium diamond output under open access, Q_d^{open}, substitute the equilibrium diamond employment into the diamond production function: $Q_d^{open} = B^\alpha L_d^{1-\alpha} = B^\alpha \left(\frac{B}{F^{1/\alpha}}\right)^{1-\alpha} = BF^{1-\frac{1}{\alpha}}$. Thus, $Y^{open} = BF^{1-\frac{1}{\alpha}} + F(L - L_d) = BF^{1-\frac{1}{\alpha}} + F\left(L - \frac{B}{F^{1/\alpha}}\right) = FL.$

Thus $Y^{mono} > Y^{open}$, since $0 < \alpha < 1$ as defined in (3).

2.2 Gambling for Resurrection

The lottery and spatial models abstract from the presence of debt in diamond mining and the riskiness of the returns as a source of inefficiency. I now turn to this issue, highlighting the possibility of "gambling for resurrection", the tendency for excessive risk taking in financial distress. Consider a poor miner who needs a loan C, to mine diamonds. The loan will be repaid solely from the miner's diamond earnings, and, by way of compensation, the creditor will receive a share of any eventual profit.[2] There are two possible earnings: $P_r + G$ with probability p or $P_r - G$ with probability $1 - p$. $P_r + G > C > P_r - G$. Therefore, if the miner earns $P_r + G$ he repays the loan in full, keeps a proportion $\emptyset$, of the profit $P_r + G - C$, and gives the bank the rest of the profit. If the miner earns $P_r - G$, he makes a loss and repays only $P_r - G$, the part of the loan recoverable from his earnings. The bank forfeits $C - (P_r - G)$.

Since his net earnings are zero in the event of a loss, the

$$miner's\ expected\ profit = p(P_r + G - C) \qquad (20),$$

and the

$$miner's\ expected\ return = \emptyset p(P_r + G - C) \qquad (21).$$

However, shadow expected profit (incorporating the loss in full) is

$$p(P_r + G - C) + (1 - p)(P_r - G - C) \qquad (22).$$

Collecting terms,

$$shadow\ expected\ profit = 2pG + P_r - G - C \qquad (22a)$$

which is less than the miner's expected profit, from which his expected return is derived. The wedge between the miner's expected profit and shadow expected profit is a source of inefficiency, causing the miner to mine when it is economically inefficient to do so. This could result in "inefficient continuation" wherein a financially distressed firm continues to produce even though it is more economically efficient to file for bankruptcy:
Thus, if

$$[p(P_r + G - C) + (1 - p)(P_r - G - C)] < 0 < p(P_r + G - C) \qquad (23),$$

the miner will mine even though it is economically inefficient to do so (shadow expected profit is negative). Incorporating the agricultural sector in Sub-section 2.1 with fixed return, F, inefficient mining still occurs even with a positive shadow expected profit if

[2] In practice, creditors supervise and monitor the mining process. They do not give the loan money to the miners but spend it on their behalf. Thus, the creditor is about to enforce loan contract terms.

$$[p(P_r + G - C) + (1-p)(P_r - G - C)] < F < \emptyset p(P_r + G - C) \qquad (24).$$

i.e. if the miner's expected return exceeds the return to agriculture but the shadow expected profit is less than the return to agriculture. In this case, it would be more economically efficient for the miner to farm.

The volatility of the diamond earnings (captured by G) could also induce inefficiency: For $p < 0.5$, shadow expected profit (22a) decreases with G: The derivative of (22a) with respect to G is $2p - 1$, which is negative for $p < 0.5$. On the other hand, miner's expected profit (20) increases with G: The derivative of (20) with respect to G is p, which is positive since p is positive. Therefore, for $p < 0.5$, the wedge between shadow expected profit and the miner's expected profit increases with the volatility of diamond earnings. Thus, the incentive to mine increases with the riskiness of the return while the prospect for economically efficient mining decreases with the riskiness of the return.

Generalizing for multiple outcomes, let R_i be the gross earnings less total costs associated with outcome i and π_i the probability of i. Then

$$miner's\ expected\ profit = \sum \pi_i . R_i, \qquad \forall R_i > 0 \qquad (20a)$$

and

$$shadow\ expected\ profit = \sum \pi_i . R_i, \qquad \forall R_i \qquad (22b).$$

Table 2 uses the lottery model and the probability statistics in Table 1 and (20a) and (22a) to illustrate gambling for resurrection numerically. I assume unit cost of production C, is 1/3. Thus, return measures are now net of costs. The table shows that private return with gambling for resurrection exceeds private return with the commons problem alone. For example, with three miners, the respective figures are 4/27 and 11/81, while marginal return (social return) is negative, -1/27.

Table 2: The Commons Problem and Gambling for Resurrection

Number of miners L_d	Number of diamond finds N	prob(N)	Expected return = $prob(N).\{N-(L_d.C)\}$	Expected total returns with commons problem alone	Expected marginal return	Expected private return with commons problem alone	Expected total returns with commons problem and gambling for resurrection	Expected private return with commons problem and gambling for resurrection
1	0	$\frac{1}{3}$	-1/9	1/3		1/3	4/9	4/9
	1	$\frac{2}{3}$	4/9					
2	0	$\frac{1}{9}$	-2/27	4/9	1/9	2/9	14/27	7/27
	1	$\frac{6}{9}$	2/9					
	2	$\frac{2}{9}$	8/27					
3	0	$\frac{1}{27}$	-1/27	11/27	-1/27	11/81	4/9	4/27
	1	$\frac{14}{27}$	0					
	2	$\frac{12}{27}$	4/9					

Figure 1 illustrates the labour inefficiencies due to the commons problem and gambling for resurrection, based on Table 2. Total labour supply is fixed. It is measured on the horizontal axis with the origin of diamond labour on the left corner and agriculture on the right. Optimal employment – at point A, corresponding to L_{d1} units of diamond employment, and the rest, agriculture – is where the expected marginal return to diamond mining and the return to agriculture equalise. However, labour decision is based on comparing expected private return to diamond mining and the return to agriculture. The two equalise in equilibrium, at point B, with L_{d2} units of diamond employment. L3, the private return curve reflecting both gambling for resurrection and the commons problem lies above L2, the private return curve reflecting the commons problem alone. With L3, equilibrium diamond labour is L_{d3}, increasing the diamond overemployment beyond the level induced by the commons problem alone.

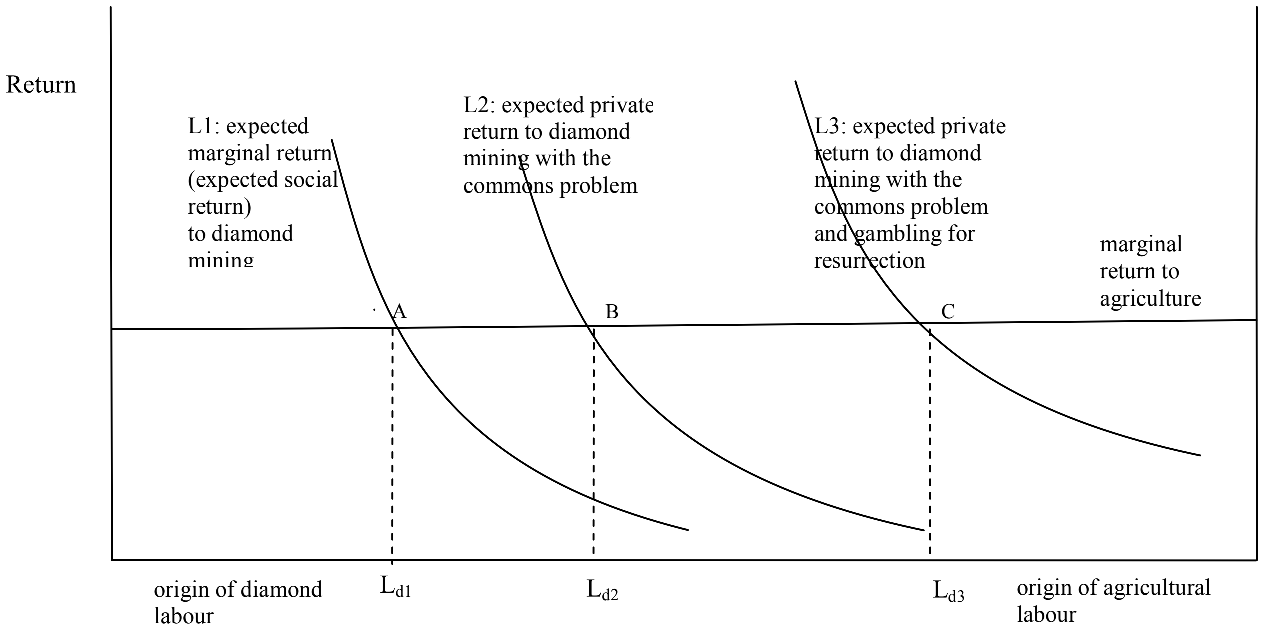

Figure 1: The Commons Problem and Gambling for Resurrection

The labour inefficiencies associated with the gambling for resurrection model are due to the contract form for hiring labour. I have abstracted from attitudes to risk which could either mitigate or exacerbate these inefficiencies. There is some evidence suggesting that miners may be risk loving. Partnership Africa Canada and Global Witness (2004) report estimates of average daily earnings under profit-sharing at between US$1.24 and US$1.46 in Sierra Leone, compared with US$2 under wage payment, but "historically, most diggers (miners) have preferred the casino system (profit-sharing), betting on a share of the winnings". Economic theory rationalizes such possible risk preference. For instance, a Friedman-Savage (1948) or Markowitz (1952) utility function with concave and convex segments implies that the miner is risk averse for increases in income that keep him within the same income class (small values of G), and risk-loving for large increases in income (large values of G) enabling movement to a higher class. On the other hand, risk aversion could mitigate the labour inefficiencies. However, risk-averse individuals could also opt for an actuarially unfair gamble like diamond digging, behaving like risk lovers in certain circumstances: when the marginal returns to wealth increase with wealth (Appelbaum and Katz 1981, Stark 1991); when utility is derived from wealth and social status (Katz 1983 and Stark 1991); or if the miner overweights low-probability events like a big diamond find (Tversky and Kahnemann, 1992).

<u>Some solutions</u>

Imposing loss and profit sharing, forcing the miner to pay a proportion $\emptyset$, of any eventual loss, the same as his profit share, eliminates the moral hazard of the miner bearing too little of the cost of bankruptcy relative to the upside benefits he stands to gain. His expected return now becomes $\emptyset(2pG + P_r - G - C)$, i.e. $\emptyset$ times shadow expected profit (15) or (15a). Since the miner's expected return is now a proportion of shadow expected return; inefficient continuation, and the incentive to mine as the riskiness of the return increases, are now eliminated. However, in practice, getting the poor miners to share the loss may be difficult.

A fixed rate of pay eliminates the option to gamble for resurrection by delinking the miner's return from the underlying riskiness of the diamond earnings. Given that a monopoly eliminates the commons problem, a fixed-wage-paying monopoly would eliminate both the commons problem and the option to gamble for resurrection. The miner would now cease to be an entrepreneur and would no longer be responsible for financing diamond mining. However, wage payment may be difficult to introduce, given that the miners have historically preferred profit sharing. Also property-rights enforcement costs, which I assumed away, may be high, rendering a monopoly unfeasible. Enforcing property rights may also be politically difficult. In Sierra Leone, governments have always come under pressure to liberalize access to the mines. The opposition was voted to power in 1967 partly on promises to do so (Smillie *et al* 2000). In fact, the difficulty of enforcing property rights is what often leads to open access in the first place. Thus, for countries like Sierra Leone, solutions involving large-scale property rights enforcement are no solutions.

In post-war Sierra Leone, donors have launched a credit scheme to support the miners, allowing them to keep all the profits after repaying the credit. While these terms are favourable to the miner relative to profit sharing, they increase the incentive to gamble for resurrection: In the event of a loss, the miner would still walk away from some of his debt. His expected return is now $p(P_r + G - C)$ which is higher than his expected return under profit sharing $\emptyset p(P_r + G - C)$, since he now keeps all the profit. Thus, the upside benefits the miner stands to gain has increased while the downside cost has not changed.

Finally, taxation could correct the market failures by reducing diamond returns. In Figure 1 taxation could shift the relevant expected private return curve inwards to intersect the return to agriculture curve at point A, for optimal labour allocation. However, this assumes away the ease of smuggling diamonds due to their high unit value. In reality, a high tax rate might simply induce smuggling, with low tax revenues and labour allocation close to the zero-tax level.

3. CONCLUSION

I have highlighted a process whereby alluvial diamond mining under open access in poor countries undermines economic development through a commons problem and gambling for resurrection, each inducing socially excessive labour allocation. The "solution" to the commons problem is to restrict access to the mines, with a monopoly being the limiting case. However, the economic and political costs of enforcing property rights could be prohibitive: In fact, the difficulty of enforcing property rights is what often induces open access in the first place.

Loss and profit sharing reduces the incentive to gamble for resurrection by eliminating the moral hazard of the miner bearing too little of the cost of bankruptcy relative to the upside benefits he stands to gain. However, that the miners are typically very poor casts doubts on whether they can be forced to share losses in bad outcomes. While fixed wage payment eliminates the option to gamble for resurrection, it may be difficult to introduce given that the miners have historically preferred profit sharing. Thus, countries like Sierra Leone may be "doomed" to open access and its possible resource curse. The challenge, in these circumstances, is to devise policies to mitigate the two sources of labour inefficiency. The first step is to appreciate the existence and magnitude of the problem. In Sierra Leone, aid donors have introduced a credit scheme that allows the miners to keep all the mining profit after paying back the credit. I have shown that while the scheme would benefit the miners, it increases the incentive to gamble for resurrection, and hence socially excessive employment. These dilemmas show that there are no simple solutions. Support to alternative activities such as agriculture, rather than to diamond mining, may well be the best feasible option to minimize the labour inefficiencies.

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