Mining in Zambia: Contemplations of Economic Development

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Abstract

This paper focuses on the implications of slumping copper prices for the Zambian mining industry, in an attempt to elucidate the poor economic performance of Zambia’s local economy over the last three decades. In the mining areas, copper extraction and charcoal burning constitute the main economic activities from which local dwellers derive their livelihood. A suppression of copper prices induces a relocation of labor towards informal charcoal production, depriving the local authorities from public revenues collected within the formal economy. This constrains the ability to improve labor productivity and welfare over time and simultaneously imposes pressure on the local environment through deforestation.

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1. Introduction

Recent empirical evidence and theoretical work provides strong support to a resource curse hypothesis; i.e. natural wealth tends to retard rather than promote economic growth (Auty 1994, Papyrakis and Gerlagh 2004, Sachs and Warner 1995, 1997, 1999a, 1999b, 2001, Rodriguez and Sachs 1999, Leite and Weidmann 1999, Gylfason 2000, 2001a, 2001b). The OPEC countries experienced a disappointing annual growth rate of −1.3% on average between 1965-1998 despite the significant injections of petrodollars into their local economies from the oil extractive industries (Gylfason 2001a). The expectations of many early development economists (Nurkse 1953, Rostow 1960, Watkins 1963) that resource endowments could potentially support economic expansion by attracting funds from foreign creditors, channelling the primary sector rents into productive investments and escaping “poverty traps” proved to be wrong. Similarly, any positive linkages between resource abundance and economic prosperity observed during the origins of the industrial revolution in Great Britain, Germany and the U.S. or more recently in countries, such as Botswana, Norway and Iceland appear to be exceptional cases rather than belong to a general applicable rule (Sachs and Warner 1995, Wright 1990).

Our analysis attempts to shed some additional light onto this paradoxical relationship between resource affluence and economic performance. We purposely explore the structure of the Zambian economy in order to obtain additional insights in this direction, but our analysis is relevant for a number of under-performing resource-dependent countries. As Figures 1 and 2 depict, Zambia’s economy contracted at an annual rate of 4% for a 21 year period. Figures 1 and 2 also highlight that Zambia is a country particularly dependent on the primary sector, specifically on copper. Focusing on the case of the Zambian economy, we expose how a stagnated mining sector (copper in particular) can have broader repercussions in terms of welfare. A mining sector in recession may induce labour shifts into other economic activities. In developing countries such activities often involve informal looting of common resources resulting, for instance, in deforestation or overfishing. As a consequence, there are immediate negative repercussions in terms of environmental degradation and the capacity to invest public revenues into welfare-improving infrastructure or education.

Section 2 provides an overview of the prospects and challenges of the copper industry in Zambia but also at a global level. There is a specific focus on copper due to the prominent position of copper mining in Zambia’s economy. In section 3 we develop our formal analysis, where individuals can derive their livelihood either from mining or from informal activities. Sections 4 and 5 derive the dynamic equilibrium and main proposition linking mining underperformance to increases in informal activities (such as tree-cutting for charcoal). Section 6 discusses possible repercussions for economic development from an expansion of the informal sector. In Section 7 we extend the analysis by discussing further implications of environmental degradation on welfare levels. Section 8 briefly discusses the direct environmental problems accruing from mining production, while Section 9 concludes.
2. The Prospects of Copper

2.1 Global Copper Production

There has been an accelerating growth trend in the production of copper the last three centuries, indicating the rapid expansion that the copper mining industry went through at a global level. At the beginning of the eighteenth century, the annual global production of copper did not exceed the amount of 2.4 thousand tones. Towards the beginning of the twentieth century, this amount was more than 2000 times higher. The following graph provides rough estimates of global copper production per year between 1725 and 2000 (see Schmitz 1979 and World Bank 2004).
Through time there has been a radical change in the geographical pattern of copper production. Through the eighteenth and nineteenth centuries, most of the world demand for copper was met by copper mines in the UK (mainly Cornwall and the island of Anglesey later on), Sweden (Falun) and Germany (Saxony). In fact, it has already been claimed that the industrial revolution that took off in Great Britain and Germany was supported to a large extent by vast deposits of ores and coal in an era of high transportation costs (Sachs and Warner 1995). New discoveries in remoter areas outside Europe, shifted the geographical distribution of copper production. Before the First World War, much of the copper production was originating from large open-pit mines in Utah, Arizona and Montana. In the 1920’s, some of the world’s largest deposits of copper (and much higher-grade ores compared to the ones extracted in the U.S.) were discovered in the Congo-Northern Rhodesia (Zambia) border (see Schmitz 1979 for an elaborate discussion). Nowadays, the most important copper producers are by far the U.S. and Chile, which account for almost half of the global production (see Thompson 1997).

Concerning the prospects of copper production, it is likely that the future major key players will be located in the South America region. Chile’s success in attracting foreign investment for its mining industry (initiated by the relaxation of its mining law at the beginning of the 1980’s) created a paradigm that other countries in the region soon attempted to imitate. Peru, Bolivia and Argentina offer a high potential for extensive extraction of high-grade copper. A hostile economic environment to foreign investment has discouraged the adoption of extensive mining projects till the 1990’s. New legal codes allowing for repatriation of profits and a more generous taxation scheme instigated interest in mining projects in those countries. In fact, steep increases in copper supply are expected to create a large surplus at a global level (see Thompson 1997 for an extensive analysis). Through that perspective, the prospects of Zambia’s copper supply appears to be less optimistic. The long history of Zambia’s mining industry (dating back to the late nineteenth century) implies a declining trend in the grade of Zambian copper (and thus a larger energy input in its production) and a small potential in increasing Zambia’s copper production. Therefore, Zambia’s role in the international copper arena is likely to be continuously downgraded and outweighed by more promising (in terms of production) countries.
2.2 Global Copper Demand

In order to conjecture on the trend of future copper demand, it is crucial to address the nature of industries that consume copper globally. Most of world’s copper is consumed in electrical and general engineering, building and transport. Less importantly, copper is also utilized in the production of domestic equipment and issuing coins. The majority of copper (more than half) is consumed globally within the electrical engineering industry in the production of electrical generation appliances. Therefore, the most important use of copper lies in electrical wiring. In that respect, copper demand is closely linked to the global need of electrification. If electrification is one of the first steps in the process of economic development, one may expect that as the economic development keeps on, the need for electrical wiring and copper may not remain robust for too long.

Copper demand is mainly driven by exports towards either the industrialized or newly-industrializing countries. This is also a significant characteristic of the global copper demand. Historically, the establishment of mines in developing countries was meant to cater for the needs of the colonial powers rather than those of the local markets. To some extent, this has not substantially changed over time. Copper in developing countries such as Zambia is almost entirely intended to reach foreign markets as exports (see Henstock 1996). In this respect, the Zambian economy (and the mining industry in particular) is dependent on demand mainly from other parts of the globe.

A third significant component of copper demand lies in the availability of substitute-inputs. To a large extent, copper competes with itself. Much of world’s copper demand is met by recycled copper. The high potential to use secondary copper recovered from scrap significantly influences the global demand level of primary copper and constrains the export capacity of the developing world. Henstock (1996) estimates the percentage of global copper supply attributed to secondary copper between 30 to 40%. Furthermore, aluminium is an important substitute for copper, especially in electrical engineering. Aluminium (whose laboratory isolation took place in 1825) was rarely exploited commercially until the end of the nineteenth century due to cost factors. Nowadays, the raw materials for its production are widely and economically available, which makes aluminium broadly used in the manufacturing of electricity cables and wires. For instance, it is estimated that 50% of electricity already flows through aluminium wires (Henstock 1996). To a lesser extent, titanium and steel are used in heat exchangers (for instance used in power plants) instead of copper. Moreover, plastics substitute for copper in water pipes and plumbing appliances. An extensive availability of substitutes (often at a lower cost) is undoubtedly creating negative repercussions on the global copper demand.

2.3 Copper Pricing

To a large extent, copper supply is inelastic and rather fixed for short-term time spans. In order to achieve increases in the stock of copper, long-term preparation is required. Often this involves high set-up costs and a large time gap between the moment the decision is made to invest in copper exploration and the time extraction takes place. A fairly inelastic supply of a commodity implies that its price is largely determined by the demand conditions. In the case of copper, this implies that the price of copper (and the economic situation thus in countries like Zambia) is much dependent on the economic behavior of developed and newly-industrializing countries (the main copper consumers). According
to this intuition, Figure 4 depicts the determination of world copper prices. The vertical line at \( Q_w \) depicts the world supply of copper, which is assumed to be rather inelastic in the short run. The negatively-sloped \( D_w \) line represents the global demand for copper respectively. The crossing point of the two curves determines the international price, at which copper is traded. Despite the vital role of the copper industry in her local economy, Zambia produces a small share of the global copper output (around 5%). This implies that Zambia cannot affect prices significantly through influencing world copper supply, but rather takes the world level of copper prices as given. Assuming that Zambia’s copper supply amounts to \( Q_z \) (depicted as fairly inelastic as well), the shaded rectangular represents the level of local mining revenues.

\[ \text{Figure 4. Copper Pricing.} \]

The world price of copper will depend intertemporally on the prospects of both the demand and supply side. Increases in global supply, mainly by new mines in Latin America, will exert a contracting effect on the international level of copper. In the same direction, as more recycled copper from scrap and aluminium replaces primary copper, demand for copper exports is likely to become weaker and prices will fall. In fact, copper supply between the end of the nineteenth and the twentieth century grew by a factor of 20, while aluminium production increased by more than 7000 times (which nowadays exceeds the annual production of copper) (Schmitz 1979). Furthermore, as the grade of copper extracted falls over time for some countries, such as Zambia, low-grade copper is also prone to experience more drastic price adjustments. Prices of copper, volatile as they tend to be from time to time, they seem to follow a negative trend. Schmitz (1979)
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calculates that the real price of a tonne of copper in 1976 was more than 30% lower compared to the price of copper 100 years earlier on.\(^1\)

3. Model Set Up

In this section we analyse a Ramsey-Cass-Koopmans type of model, where the labor endowment of infinitely-living agents is divided between a formal and an informal sector. We describe such a model, as it bears close resemblance to the economic reality that the majority of workers faces in the Copperbelt. The formal sector is dominated by the mining industry, mainly copper (and to a lesser extent lead and zinc). Informally, though, workers can alternatively derive their livelihood by harvesting the Copperbelt’s wood for charcoal production. The model incorporates an endogenous growth mechanism, where investment in labor productivity (e.g. human capital improvement or infrastructure development) is financed by taxes on the formal economy’s output. Under this scenario, reduced mining rents will offload labor to the informal sector and thus restrict the government’s potential to finance growth-promoting activities. Such a contraction of formal economic activities will directly hamper the potential of the local economy to improve intertemporally the level of welfare. Furthermore, we extend the model by taking into account the potential negative externalities of informal production (tree-cutting) on the environment and possibly on other economic activities.

3.1 Consumers

We assume that the economy consists of identical infinitely-lived agents. Population \(N(t)\) remains constant at each point in time. Thus,

\[
N(t) = N
\]  

For the type of model we employ, a stable population growth is a convenient assumption that precludes an ever-increasing growth rate for income per capita and allows the economy to converge to a balanced growth path.

Individuals have a constant labor time endowment per period., which is normalised to unity. Therefore, \(N(t)\) stands for the total work effort in the economy as well. The working time of each agent can be allocated between two activities. First, we assume that a proportion \((1–\gamma)\) of work effort is devoted to formal production, which comprises of mining activities. As the analysis proceeds, it will become apparent that this share is endogenously determined by the model parameters. The rest of the representative agent’s work effort involves engagement into deforestation and charcoal burning, activities that take place mostly informally in the economy.\(^2\) Therefore, the level of the formal labour input \(L(t)\) in the economy is determined respectively by:

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\(^1\) Although we abstract from issues of imperfections in the copper market, we have to mention that speculation and non-transparent dealings may also influence the international price of copper. For instance, there is some suspicion of previous attempts to manipulate copper prices by dealers within the London Metal Exchange (LME), where most of world’s copper is traded.

\(^2\) Alternatively, one may conceive the share \((1–\gamma)\) as the proportion of employees (in terms of the total work force) engaged into mining.
\[ L(t) = (1-\gamma(t))N. \] (2)

Each representative agent maximizes the following inter-temporal utility function depending positively on the stream of her current and future consumption levels:

\[ U = \int_{0}^{\infty} u(c(t))e^{-\rho t} \, dt \] (3)

where \( C(t) \) stands for total consumption at time \( t \) and \( c(t)=C(t)/N(t) \) denotes consumption per person, \( \rho \) is the rate of time preference and it is assumed to be time-invariant and positive, implying that agents value future utility less comparatively to current utility. Thus, \( U(t) \) is a weighted sum of all future discounted utility flows \( u[c(t)] \), where \( u[c(t)] \) represents the instantaneous utility function (also referred to as felicity function) of each agent at a given date.

For convenience, we assume that the instantaneous utility function \( u[c(t)] \) is logarithmic in consumption \( c(t) \) and we omit any time references for the rest of the analysis, unless there is need for clarification. Each individual faces the following budget constraint when maximising utility:

\[ \dot{v} = w(1-\gamma)(1-\tau) + rv(1-\tau) + \frac{Q}{N} - c \] (4)

where \( v=V/N \) stands for the total value of assets hold per person, the dot denotes the derivative over time, \( w \) and \( Q/N \) stand for the (formal) wage per unit of labour input and the amount of informal rents (from charcoal production) per person, and \( r \) for the real interest rate obtained per unit of asset value. Both wage and interest income are taxed at a constant rate \( \tau \). As in Torvik (2002), only the formal sector is subject to taxation, since the charcoal burning takes place informally and as such is treated as a non-monitored activity. In order to achieve simple solutions, we assume symmetry across agents, meaning that they have a homogeneous economic behavior and are rewarded equally for their work effort: in other words they receive the same level of formal wages and charcoal rents per person (as in Leite and Weidmann (1999) and Torvik (2002)). Each household, thus, maximises utility subject to the budget constraint of equation Error! Reference source not found.. Therefore, we set up the following Hamiltonian:

\[ H = \int_{0}^{\infty} (\ln c)e^{-\rho t} + \mu[w(1-\gamma)(1-\tau) + rv(1-\tau) + \frac{Q}{N} - c] \] (5)

The first order conditions with respect to the control variables \( c \) and \( \gamma \) and the dual variable \( \mu \) lead to the Ramsey Rule (6) –adjusted for the taxation effect on capital income– and equation (7), which represent the evolution of consumption over time and the labour arbitrage between mining activities and charcoal burning respectively. The charcoal rents depend on the work effort \( \gamma \) devoted to informal production, but we will postpone adopting an explicit specification until we address production in both sectors in the following section. Therefore, we have:

3 Namely, agents have a two-fold decision with respect to consumption-saving and formal-informal employment.
3.2. Producers

As mentioned earlier, the model focuses on labor movements between the mining sector and informal charcoal production. Therefore, our analysis focuses on these two predominant sectors in the Copperbelt, where individuals can seek employment. First, there is a formal mining sector combining physical capital $K$, formal labor $(1-\gamma)N$ and a labor-augmenting variable $A$ (which can be conceived as labour productivity, human capital, the stock of knowledge or infrastructure development). We assume production in the mining sector takes place with constant returns to scale with respect to its inputs, namely effective labour and physical capital. $P$ stands for the world price of the final good produced in the mining sector.

$$Y = P[A(1-\gamma)N]^\alpha K^{1-\alpha}, 0<\alpha<1, 0<\gamma<1.$$  \hfill (8)

Firms in the mining sector choose the level of formal labor and capital that maximize their profits. Thus:

$$\max_{(1-\gamma)N,K} P[A(1-\gamma)N]^\alpha K^{1-\alpha} - w(1-\gamma)N - rK.$$  \hfill (9)

The first order conditions imply that firms in the mining sector face the following demand for formal labor and physical capital:

$$w = \alpha PA^\alpha [(1-\gamma)N]^{1-\alpha} K = \alpha PA \tilde{k}^{1-\alpha},$$  \hfill (10)

$$r = (1-\alpha)P[A(1-\gamma)N]^\alpha K^{\alpha} = (1-\alpha)P \tilde{k}^{1-\alpha},$$  \hfill (11)

where lower letter variables with hats denote variables expressed relative to formal labor supply in effective terms $[A(1-\gamma)N]$. Equations (10) and (11), illustrate that firms pay labour and capital the value of their marginal products.

Secondly, we assume there is informal charcoal production, where individuals can alternatively direct their work effort.\(^4\) We follow Eliasson and Turnovsky (2004) in assuming that charcoal production (and wood harvest) from applying a given work effort is independent of the stock size of the resource base. Eliasson and Turnovsky (2004) assert that this is a plausible assumption for forests where the location of the resource is easily ascertained. This is an assumption that will relax as the analysis proceeds in order to capture the long-term complications of resource scarcity. The charcoal production depends on the labor effort allocated to such activities $\gamma N$ (in other words the level of informal la-

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\(^4\) Since our focus is mainly on labor movements, we assume that all physical capital is employed in the mining sector. This is not an unrealistic assumption to the extent that mining remains capital-intensive relative to charcoal production.
The parameter $A$ captures a side-effect of economy-wide labor productivity improvements. In other words, as the governments invests more in infrastructure (e.g. road construction or school building) charcoal burners benefit as well. They will also be able to transfer the charcoal easier or adopt more sophisticated techniques. The constant $B$ captures a charcoal-specific productivity measure. This can be related to an unanticipated fire that reduces the forest’s biomass or to an institutional change that facilitates informal activities (e.g. a relaxation in the penalization scheme). We will analyse further the technological-productivity parameter $B$ and relate it to the negative production externalities of forestry depletion. The price of charcoal produced is normalized to unity for simplicity. Therefore, charcoal-making takes place in accordance with the simple proportional production function,

$$Q = AB(\gamma N).$$

### 3.3. The Evolution of Labor Productivity and Capital

We assume that the government collects all taxes levied on labor and capital income in mining.\(^5\) The government directs all tax payments to finance improvements in labor productivity $A$. This can be thought of as improvements in labor skills, educational standards, infrastructure or technologies in use. For instance, the government may use tax payments to improve the work-related knowledge, finance research, import technologies, or develop a reliable transportation system.\(^6\)

$$\dot{A} = \tau\nu(1 - \gamma)N + \tau rK = \tau Y.$$ \hspace{1cm} (13)

The evolution of physical capital in the economy depends on the non-consumed level of income both from mining and charcoal production. The commodity flows are, thus, closed by setting total income (after taxes), from the formal and informal sector equal to consumption $C$ plus capital accumulation $\dot{K}$:

$$(1 - \tau)P[A(1 - \gamma)N]^aK^{1-a} + AB(\gamma N) = C + \dot{K}.$$ \hspace{1cm} (14)

### 4. Dynamic Equilibrium

In this sub-section, we determine the equations that govern the dynamics for consumption, the capital stock, and the share of work effort involved in charcoal burning.

We start with the dynamics for consumption. We rewrite equation (6) in its intensive form, and substitute equations (8), (11) and (13):

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\(^5\) For our analysis, taxing either the mining revenues directly or the inputs’ income will not have a qualitative implication on our consequent findings.

\(^6\) Assuming that the government would acquire all mining revenues and distribute a share of them as inputs’ payments would lead to similar conclusions. In that respect, we abstract from the nature of mining ownership.
\[
\begin{align*}
\dot{c} &= r(1 - \tau) - \rho - \frac{\dot{A}}{A} (1 - \gamma) = (1 - \alpha)(1 - \tau) P k^{-\alpha} - \rho - \tau P (1 - \gamma) N k^{1 - \alpha} - \frac{1 - \gamma}{1 - \gamma} \\
\end{align*}
\]  

(15)

Subsequently, we rewrite the motion function for physical capital (14) in its intensive form:

\[
\dot{k} = (1 - \tau) P k^{-\alpha} + \frac{\gamma}{1 - \gamma} B_k^{-1} - \frac{c}{k} - \tau P (1 - \gamma) N k^{1 - \alpha} - \frac{1 - \gamma}{1 - \gamma}.
\]

(16)

Combining equations (7), (10) and (12) provides us with the following equation, connecting the level of physical capital with the world price of minerals:

\[
k = \left[ \frac{B}{a(1 - \tau) P} \right]^{-\frac{1}{1 - \alpha}}
\]

(17)

Together, these three equations determine the dynamics for \( c, \dot{k}, \text{ and } \gamma \).

5. Steady-State

Along a balanced growth path, capital \( K \), consumption \( C \), output \( Y \) and technology \( A \) grow at the same rate, which implies that the levels of \( \dot{k}, \dot{c} \) and \( \dot{y} \) remain constant along the path. Furthermore the share of work effort allocated to mining \( (1 - \gamma) \) remains constant (for consistency reasons with the hypothesis that \( (1 - \gamma) \) remains in the \([0,1]\) region). Therefore, along the balanced growth path equations (15) and (16) become:

\[
(1 - \alpha)(1 - \tau) P k_{ss}^{-\alpha} - \rho - \tau P (1 - \gamma_{ss}) N k_{ss}^{1 - \alpha} = 0
\]

(18)

\[
(1 - \tau) P k_{ss}^{-\alpha} + \frac{\gamma_{ss}}{1 - \gamma_{ss}} B_{k_{ss}}^{-1} - \frac{\dot{c}_{ss}}{k_{ss}} - \tau P (1 - \gamma) N k_{ss}^{1 - \alpha} = 0
\]

(19)

where the subscript \( SS \) denotes the steady-state value of each variable along the balanced growth path. Equation (17) illustrates that the level of physical capital depends solely on the model parameters and adjusts instantaneously:

\[
k_{ss} = \left[ \frac{B}{a(1 - \tau) P} \right]^{-\frac{1}{1 - \alpha}}
\]

(20)

Equations (18) – (20) constitute a system of three equations depending on the three steady-state levels \( \dot{c}_{ss}, \dot{k}_{ss} \text{ and } \gamma_{ss} \). Equation (20) determines the steady-state level of physical capital \( \dot{k}_{ss} \), while equations (18) and (19) determine consecutively the steady-state levels of consumption \( \dot{c}_{ss} \) and mining effort \( (1 - \gamma_{ss}) \). From equation (20) we ob-
serve that the level of physical capital is strictly decreasing in the world price of minerals produced (copper):

\[
\frac{d\hat{k}_{ss}}{dP} = -\frac{1}{1-\alpha} \left[ \frac{B}{a(1-\tau)P} \right]^{\frac{\alpha}{1-\alpha}} \frac{B}{\alpha(1-\tau)P^2} < 0
\]

Equation (20) can be re-written as \( P = \frac{B}{a(1-\tau)} \hat{k}_{ss}^{\alpha-1} \). Substitution of the world copper price into (18) yields an expression linking employment in mining to physical capital \( \hat{k}_{ss} \):

\[
(1 - \gamma_{ss}) = \frac{(1-\alpha)(1-\tau)}{\tau N} \hat{k}_{ss}^{-1} - \frac{\alpha(1-\tau)\rho}{\tau BN}.
\]

This clearly implies a negative relationship between physical capital \( \hat{k}_{ss} \) and employment in mining \( (1 - \gamma_{ss}) \), since

\[
\frac{d(1 - \gamma_{ss})}{d\hat{k}_{ss}} = -\frac{(1-\alpha)(1-\tau)}{\tau N} \hat{k}_{ss}^{-2} < 0.
\]

From equations Error! Reference source not found. and Error! Reference source not found. we can derive that an increase in the world price of copper (or mineral production in general) as captured by \( P \) results in a decrease of employment in the mining sector at the steady-state (or consecutively to an increase in charcoal involvement, since

\[
\frac{d(1 - \gamma_{ss})}{d\hat{k}_{ss}} = \frac{d\gamma_{ss}}{d\hat{k}_{ss}};
\]

\[
\frac{d(1 - \gamma_{ss})}{dP} = \frac{d(1 - \gamma_{ss})}{d\hat{k}_{ss}} \times \frac{d\hat{k}_{ss}}{dP} > 0
\]

As pointed out earlier, the mining industry has experienced a sharp and prolonged fall in world copper prices since the mid 1970’s. As follows from identity, such a decline in copper prices would reduce mining revenues and employment opportunities in the mining sector. A reduced level of copper price will deprive the mines of the potential to sustain the same level of employment. A reduced output price essentially suggests that inputs (in that case formal labor) are valued less by companies in monetary terms. When a mining firm receives reduced revenues for the same level of copper production, this bears an impact on the level of wages and employment. Necessarily, this implies that a number of employees in the mining sector are forced to seek employment in alternative activities in order to derive their livelihood. In the Copperbelt case, such a scenario will

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7 A higher level of copper prices makes physical capital less needed to sustain the same level of wages in mining.
most likely induce a shift of labor towards charcoal burning. In other words, charcoal burning as an income-supporting activity becomes more profitable in relative terms. We state this finding as a proposition:

**Proposition 1.**

The steady state level employment in mining \((1-\gamma)\) is decreasing in correspondence to falling copper prices. Subsequently employment shifts in charcoal burning and the informal sector expands.

### 6. Economic development

As mentioned earlier, the formal sector (mining) being the main source of formal production and employment in the Zambian economy, constitutes the major supply of revenues to the government. An extensive informal sector obviously deprives the government of such income. Charcoal burning takes place informally; it is on the whole an unmonitored activity and as such not subject to taxation. On the other hand, a sophisticated system of taxation (through royalties and export or income taxes) provides the government with a large share of the value of mining production (Harvey 1972).

In order to achieve improvements in living standards over time, governments are expected to take initiatives in that direction. Ministries support projects that involve improvements in education, health, telecommunication systems, electrification, and many kinds of infrastructure development that enhance labor productivity. Such initiatives involve high set-up costs and benefits that accrue to broad layers of society. Therefore, private enterprises have a low incentive to undertake such projects, since they do not reap directly such social benefits. Particularly in the developing world (where private entrepreneurship plays a minor role) the responsibility of government is vital in financing such initiatives through taxation. In that respect, development projects funded through public revenues are decisive in targeting poverty and achieving welfare progress.

The model incorporates an endogenous growth mechanism, where improvements in labor productivity \(A\) (e.g. human capital improvement or infrastructure development) are financed by taxes on the formal economy’s output. A decrease in the level of world copper price is expected to limit the government’s capability to improve labor productivity by restricting public revenues. The rate of increase in labor productivity at the steady-state (which is the overall rate of economic growth in the economy) is given by equation (13), which we rewrite as:

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8 Saying that, there is an extensive literature on how governments in resource-abundant countries misuse resource revenues (Baland and Francois (2000), Ross (2001)). Although issues of corruption and rent-seeking are not the focal point in our analysis (implicitly assuming a benevolent governmental body utilizing mining taxes) we recognize that often mismanagement is widespread. Assuming that government officials appropriate either a proportion of mining revenues or public taxes, would reduce the funds invested in labor productivity, as described by equation (13). Still, though, even if a much smaller share of tax revenues reaches the productive base of the economy in the end, the result in terms of supporting economic development is expected to be more fruitful when compared to an informal sector that generates no public revenues.
Substitution of the level of physical capital from equation (20) into (25) yields:

\[ \chi_{ss} = \left( \frac{\dot{A}}{A} \right)_{ss} = \frac{\tau BN}{(1-\tau)\alpha} (1-\gamma_{ss}). \]

From equation (26), we can see that labor productivity progress (and economic expansion in that respect) depends positively on the level of copper price:

\[ \frac{d\chi_{ss}}{dP} = \frac{\tau BN}{(1-\tau)\alpha} \frac{d(1-\gamma_{ss})}{dP}, \]

since the derivative \( \frac{d(1-\gamma_{ss})}{dP} \) is positive from equation (24). Equation (27) indicates that a fall in the price of copper will reduce the value of mining production and the amount of public revenues in the economy. As a consequence, such a drop in copper prices, will subsequently restrain the government’s potential to direct such funds in productivity improvements. This is an immediate corollary of the contraction of the formal sector and the successive expansion of informal charcoal burning due to labor shifts between economic activities. We state this as our second proposition:

**Proposition 2.**

Improvements in economic productivity \( \chi \) (and thereof economic growth) are decreasing in the level of copper prices. Reduced public revenues (in parallel with an expansion of non-taxable informal charcoal burning) restrain the capacity of the government to direct funds into projects that reach the productive base of the economy.

So far, we have mainly focused on the impact of copper prices on productivity growth and therefore treated the issue of economic expansion mainly through the perspective of mining. As a small extension to our analysis, we would like to pay some attention to the effect a change in the magnitude of the charcoal-specific technological parameter \( B \) would have on the overall economic growth. Combining equations (20), (22) and (26) we derive a relationship connecting the rate of productivity growth \( \chi_{ss} \) with the charcoal-specific productivity parameter \( B \):

\[ \chi_{ss} = (1-\alpha)\alpha^{1-\alpha} (1-\tau)^{1-\tau} P^{1-\tau} B^{1-\alpha} - \rho, \]

which implies that overall productivity growth depends negatively on the charcoal-specific productivity parameter \( B \). An exogenous increase in the constant \( B \) facilitates the shift of labor towards charcoal burning, since it allows workers to achieve a higher income in the informal sector for the same level of effort. For instance, an increase in \( B \) may indicate reduced police patrolling in the area, a higher tolerance of local authorities
in illegal deforestation, adoption of more advanced tree-cutting equipment, easier access to the forest, a higher demand for charcoal and so forth. Such changes will render mining less attractive in terms of working opportunities, since an increase in $B$ implies an increase in productivity solely in the charcoal-burning sector.

7. Extensions

As mentioned above, informal production, namely deforestation for charcoal burning, is likely to generate negative externalities on the environment and possibly in other economic activities. Unsustainable timber harvesting is prone to upset ecological functions and reduce economic benefits related to them (see van Beukering et al., 2003 for an extensive discussion on the issue). The degradation of forests has potentially a negative impact on a number of environmental services such as water availability, flood and drought control, carbon sequestration and soil erosion. For instance, forest degradation is likely to upset the hydrological functions of relevant protected watersheds and deregulate the water supply system. Such irregularities in water supply will undoubtedly impose costs on water-dependent economic activities such as farming and hydro-electricity power generation.\footnote{9} Since it is estimated that approximately 50,000 ha of forested area is cleared annually for charcoal production in Kitwe alone, it is self-evident that the current trend in deforestation in the Copperbelt is likely to create extensive ecological disruption.

For the time-being, we will treat charcoal production as loss in forestry biomass. In that respect, $Q$ also represents the level of timber extraction. Let us also assume that $S$ represents the stock of forest biomass (e.g. the extent of wooded area) and that charcoal production results in reductions of the wooded area. In other words, the rate of change of forestry can be described by

$$\dot{S} = -Q.$$  \hspace{1cm} (29)

In other words, equation (29) implies that $S_{t+1} = S_t - Q_t$: at each point in time the forested area decreases by the amount of trees cut down for charcoal production.\footnote{10} Charcoal production inevitably reduces the density of the wooded area in a one to one correspondence

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\footnote{9} We keep in mind, though, that mineral production has also potentially damaging consequences for several ecological functions. This has already been widely observed in many parts of the world (Navine 1978) and to some extent in the Copperbelt region (Republic of Zambia 1985). Since mining, though, is a formal economic activity, it is relatively easier to undertake a thorough assessment of mining-caused environmental problems, monitor environmental degradation and adopt measures to meet a set of environmental standards. In the case of deforestation and charcoal burning, we deal with an informal activity, that is mostly unmonitored and non-controlled. In that respect, although our analysis’ focal point lies in the negative externalities of deforestation, we keep in mind that mining as an economic activity is not only a substantial income generator in the economy but also an important polluter.

\footnote{10} In equilibrium, the amount of timber extraction remains constant at $Q_{ss} = AB(t_s N)$, at each point in time, as suggested by equation (12). This implies, that if the initial stock of forest is of $S_0$ magnitude, after $S_0/Q_{ss}=\tau$ periods, the whole resource stock will vanish and charcoal burning will not remain a viable economic activity.
As we mentioned above, environmental services such as water availability and flood and drought control depend positively on the ecological status in the Copperbelt, and the extent to which wooded areas are preserved in specific. We summarize the status of such environmental services (in qualitative and quantitative terms) under a variable $E$. Higher values of this variable will correspond to rather undisturbed environmental services and a high-quality environmental status. To a large extent, such environmental services depend on forest cover (see van Beukering et al. 2003) and therefore positively on the forest stock $S$:

$$E = \phi(S), \text{ where } \phi'(S) > 0.$$

To combine the environmental aspect of forest services to the work effort division among sectors in the Copperbelt, we come back to the issue of falling copper prices. A fall in world copper prices will offload labor from mining towards informal charcoal burning, as stated by equation (24). Since an increase in labor in charcoal burning will result in more deforestation and charcoal production (see equation (12), there will be a subsequent negative impact on the stock of forest.

Consequently, this will downgrade the capacity of forest to regulate environmental services such as drought and flood control. The chain linking price $P$ changes to the status of forest environmental services $E$ has the following structure:

$$\frac{dE}{dP} = X \frac{dE}{dS} X \frac{dS}{dQ} X \frac{dQ}{d\gamma} X \frac{d\gamma}{dP} > 0 \quad (31)$$

making use of equations (12), (24), (29) and (30) respectively.

So far, we assumed that the status of the environment $E$ does not affect the productivity either in the formal (mining) or informal (charcoal) sector. Although, we predominantly focused on these two sectors, since they offer the majority of labor opportunities in the Copperbelt, it has to be mentioned that other sectors may coexist and depend on the environmental services of the forest. For instance, hydropower generation or sugar plantations in the region are likely to depend on the watershed functions of the Kafue river regulated to a large extent by the forest cover. Let us assume, for instance, that a third sector $M$ (a sugar plantation) depends solely on land $G$, the average level of labor productivity in the economy $A$ (as a positive spillover) and the status of forestry-related environmental services $E$. For instance, deforestation is likely to increase irrigation costs or

\[ \text{In the long-run the forest may replenish itself, and therefore naturally increase its stock level.} \]

We assumed that there is a natural rate of growth $\delta$ close to zero for our analysis. For short-time intervals and in case of intense deforestation, the forest may not have the opportunity to reproduce itself. In case, though, a positive reproduction rate $\delta$ exists, equation (29) becomes equivalent to $S_{t+1} = (1 + \delta)S_t - Q_t$. In that case, for a sufficiently high rate of reproduction, there can be no forest stock losses. Since, deforestation in the Copperbelt, though, takes place at such a ferocious pace, and deforestation is widely observed (Chidumayo, 1989) we believe that abstracting from the case of natural reproduction does not distort the true picture in terms of environmental degradation.
disrupt production in cases of extreme droughts and floods. Furthermore, for simplification, we assume that labor is not employed in the plantation farm. Therefore:

\[ M = AEG, \quad \text{where } 0 < \beta < 1. \]  

Under such a specification, the sugar plantation sector expands at the same rate as the rest of the economy at the steady-state \( \chi_{ss} \). This is due to the spillover effects of the overall productivity improvements that diffuse throughout the whole economy. We already demonstrated how increases in the world price of copper increase charcoal production and contract labor productivity advancements. This is relevant also for the sugar plantation, as long as investment in labor productivity reaches its productive base as well. As we illustrated by equation (31) though, price changes in copper may also ultimately degrade environmental services due to increased deforestation through charcoal burning. In that respect, environmental degradation (a fall in \( E \)) due to forest depletion will hamper productivity in sugar production as well. To summarize:

\[
\frac{dM}{dP} = \frac{dA}{dP} E G + \frac{dE}{dP} A E < 0
\]  

using equations (27) and (31). Last, let us consider another extension of the analysis bringing back in mind how charcoal production takes place (see equation (12)). It is likely that the charcoal-specific productivity measure \( B \) depends endogenously on the model parameters. Specifically, a higher forestry stock \( S \) is assumed to be positively correlated with the charcoal constant \( B \). A decrease in the forest’s biomass due to increased charcoal burning (initiated by falling copper prices) may indirectly hamper productivity in timber extraction. For instance, it is likely that retrenched miners will first exploit the most easily approachable sections of the forest for charcoal production. As tree-cutting continues and the stock depletes, charcoal burners will need to resort to more remote parts of the forest to make their living. For many of the ex-miners, still settled around the mines (since they either acquired lodging during their mining employment period or as part of their compensation scheme when fired), this implies longer walking hours to reach the forested areas and transport the charcoal produced. Therefore, we assume that there is a negative correlation between the charcoal-specific productivity measure \( B \) and the depletion of forest stock \( S \), namely: \( B = \zeta(S), \) where \( \zeta > 0 \). From equation (12), we can see that a decrease in the forest stock \( S \) (induced by labor shifts due to falling copper prices) will in that case restrain the charcoal production.

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12 Allowing labor to shift between three sectors would not have any substantial contribution to our qualitative analysis, apart from perplexing the dynamic division of labor among sectors. Furthermore, since most labor is anyway employed in mining or charcoal burning, such a simplification does not impose a significant deviation from reality.

13 For simplicity, it is assumed that there is no connection between the land use in the sugar plantation \( G \) and deforestation. In other words, there is no land clearing in wooded areas to make space for cultivation of sugar. Assuming there was one, there would be one additional channel imposing environmental pressure on the forest.
8. Environmental Repercussions of the Mining Industry

Although beyond the scope of our analysis, we believe that we ought to make a brief comment on some additional negative externalities of the mining industry; namely the impact of copper production on environmental amenities. Extracting and processing copper ores involves significant environmental hazards affecting the quality of soil, water and air (Navine 1978). It is needless to say that such environmental problems will directly bear an influence on livelihoods related to activities such as agriculture, fishing, hydroelectricity production and tourism.

The extraction of the ore itself entails an enormous amount of waste in terms of earth material and tailings (ore residuals). Milling and smelting the ore in order to increase the purity and concentration of the metal imply additional environmental problems. Many tons of water are needed in order to produce a single ton of copper during milling and smelting (Navine 1978). Furthermore, copper smelters are associated with substantial amounts of SO$_2$ emissions emitted in the atmosphere. Such activities undoubtedly impose an enormous burden on the local habitat and the capacity of the local population to escape poverty. Waste material often ends up in river streams and contaminates soil and water. Large amounts of water are used to purify the metal and are often disposed back to the water basin. This can potentially result both in changes of water regimes and contamination of surface and sub-terrain water flows. To the extent that contaminated river streams connect to major rivers (such as the Kafue river and consequently the Zambezi), the scale of the environmental externalities of mining increases. Additionally, SO$_2$ emission may cause acid rain, soil erosion and crop damage. Especially at the first stages of commencing mining production, there is also a large impact on wildlife and its local environment.

Mining industries in developing countries often lack the technological know-how, equipment and funds either to monitor or deal with environmental degradation. The capacity to minimize environmental impact depends undoubtedly on the world metal price and the generated industry profits. The willingness to do so, on the other hand, depends on a series of factors, among which the public concern (local and international) on environmental issues (and accordingly on the livelihoods of affected societal layers), the eagerness of governments to impose legislation in that direction or the efforts of NGO’s and international bodies (such as the UN and the World Bank) to accentuate the importance of such action and share expertise.

9. Conclusions

Our analysis attempts to shed some additional light into the disappointing performance of mineral-based economies, a phenomenon often referred to as the “resource curse hypothesis”. Mineral-dependent countries such as Zambia, Sierra Leone, Mauritania, Liberia and Niger are often deemed as prominent development failures. They all lag behind in terms of infrastructure, social capital and educational standards even when compared to resource-scarce countries of similar welfare level. Recently, there has been an invigorated interest on resource affluence and economic performance in the economic growth
domain. In this direction, there has been a great interest in novel attempts to elucidate the paradoxical underperformance of resource-affluent regions.

We claim that a stagnated mining industry is likely to have negative repercussions extending beyond the mineral sector and therefore influence the livelihoods of a broad array of societal layers. A mining industry in decline, irrespective to whether this originates from slumping world prices or increased operational costs, is most likely to offload workers to the rest of the economy. It is very plausible that miners will directly feel (fully or partially) the impact of a mining industry under recession on their real income and seek alternative livelihoods (either deliberately or forcefully). In developing countries a lack of alternative formal economic activities implies that such labour surpluses are (at least partially) absorbed into informal sectors involving looting and exploiting unprotected common resources. An immediate corollary of such labour shifts comprises the degradation of environmental services in the surrounding areas and a constraint to accumulate formal public revenues that can be reinvested into improving labour productivity.

References


