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Socioeconomic Impact of Mining on Local Communities in Africa

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Contents

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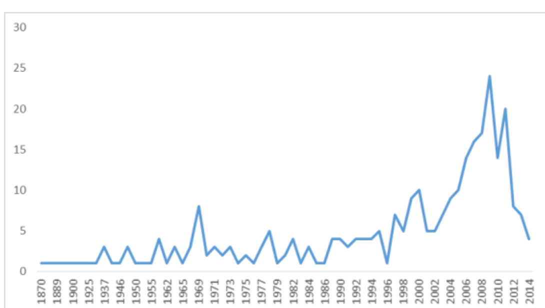
Chapter 1 Overview

1.1 Introduction

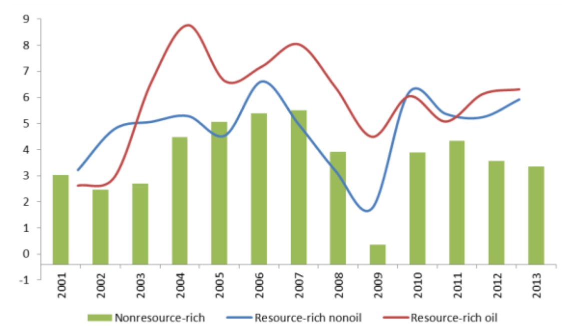
For more than a decade, Africa has enjoyed a mineral boom[1]. This has fueled exports, government finances and hope for a sustainable growth trajectory (figure 1.1). During 2001-12 extractive industries (including oil) comprised three-quarters of exports—with metals and minerals alone accounting for 60 percent. This gain in export share, and by consequence government revenues, went to some (but not all) countries, which explains partly why resource-abundant countries have grown faster than non-resource rich countries.[2] And although there has been a recent slowdown in exploration due to the weakness in the global economy, natural resource extraction, is expected to contribute significant shares of exports and public finance in all but five of the region's countries in the years ahead (Devarajan and Fengler 2013).

Figure 1.1: Mineral extraction has fueled exports and GDP growth

Number of mines opening



GDP growth by country groups (in percent)



Minerals and metals as share of exports

SSA Merchandise Export (Median Values)	1990-00	2001-10	2011-13
Manufacturing Commodities (% of Merchandise Export)	22%	22%	14%
Primary Commodities (% of Merchandise Export)	73%	74%	75%
Fuel and Metals (*% Merchandise Export)	48%	59%	64%
Agricultural Commodties (% Merchandise export)	24%	15%	11%

Source: WITS, September, 2014

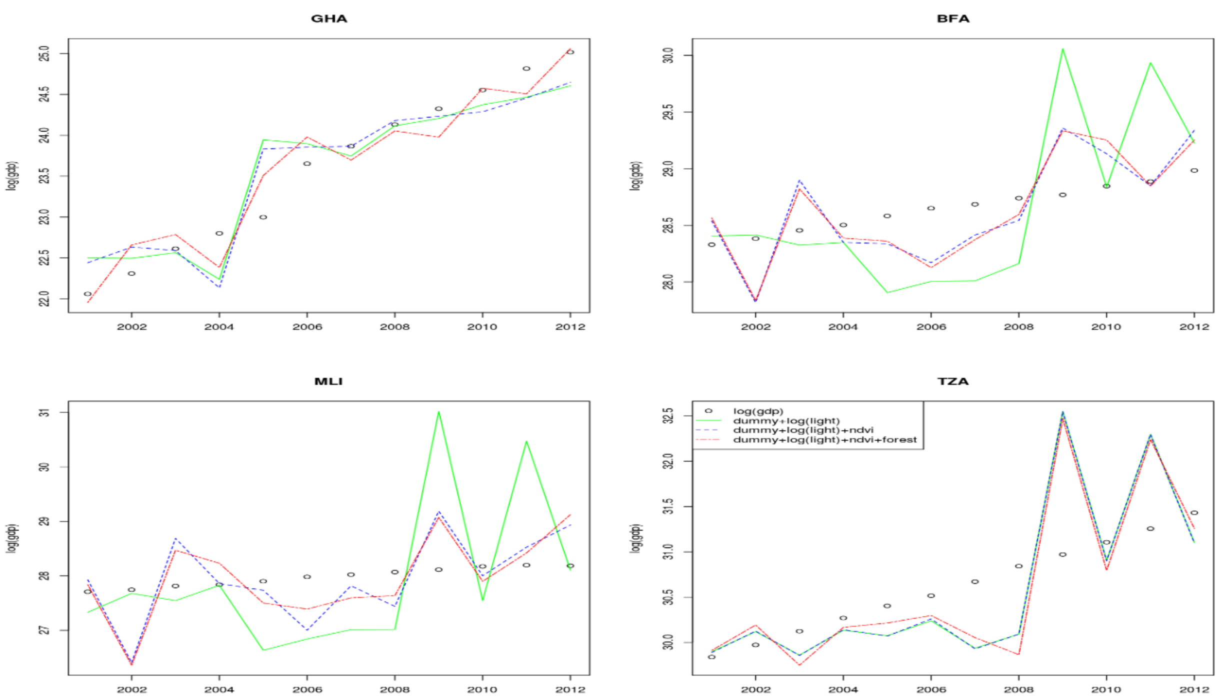
In general, African countries do not collect sub-national economic data. Therefore, it is often difficult to assess how much of the growth that is reported is happening at the local

[1] The FDI inflow that is driving this boom has been dubbed "The Second Scramble for Africa," after the first scramble, also attracted by natural resource, which preceded European colonialism. The recent sharp drop in commodity prices is believed to have reined in this boom, but the slowdown is expected to be temporary.

[2] See *Africa's Pulse*, Volume 8, World Bank, Washington, DC, October 2013.

level. In particular, is the growth mostly happening in isolated places, sectors and periods? We use geo-referenced data collected by satellite to estimate local economic activity, using nighttime lights and vegetation index as proxies for economic activities. Since these satellite data can be collected at very small geographic areas, we can aggregate them to any administrative level and measure progress. We find that local-level economic activity confirms the observed growth in aggregate economic output (figure 1.2).

Figure 1.2: Local economic activity predicts aggregate economic trends



Although Africa's resource boom has spurred growth, questions remain whether it has also improved living standards. The conversion of growth into poverty reduction is considered to be much lower in Africa than in the rest of the developing world (Christiaensen, Chuhan-Pole, and Sanoh 2014), and the low growth elasticity of poverty is attributed to natural-resource-led growth, a factor that underlies the disappointment that is often felt following a natural-resource-led boom. The disappointment is all too familiar at the national level, but increasingly there is a growing interest in understanding whether local mining communities benefit from the resource boom and, if they do not, what the possible reasons are that might explain it.

The focus on local impacts of this study is motivated by the observation that, in general, the socioeconomic effects of large-scale mining are not well understood. In fact, to the extent that there is a public opinion on impacts of gold mining on local communities, it is likely to be unfavorable. This is partly because, despite contributing substantially to countries' gross domestic product (GDP) and export revenue, the total employment numbers generated country-wide by mines are generally modest. For instance, in Mali, large-scale mining activity accounted for about 7 percent of GDP in 2013, but less than 1 percent of the population was employed by the industry (Sanoh and Coulibaly 2015). Adding to the negative perception of the sector is the concern that the industry also brings with it negative environmental and health impacts, which the community feels is not adequately compensated. Furthermore, mining and oil companies want government concessions and often require government cooperation. They will, therefore, have a tendency to exaggerate (or hype) the local and national benefits. To navigate divergent, and sometimes motivated thinking, this study develops a simple framework to evaluate the welfare impacts of large-scale gold mining on local communities in three African countries—Ghana, Mali, and Tanzania.

The approach adopted in this study is two-pronged. First, through case studies, including the results of fieldwork, mining's impacts are examined in a country-specific context for each of three countries, Ghana, Mali, and Tanzania; and second, a statistical analysis is used to test whether the indicators of welfare improve with proximity to a mine.

1.2 Analytical framework

The avenues for extractive industries to impact local communities and regions are somewhat restricted in developing countries. In most of these countries, local residents and landowners do not have property rights to subsurface minerals. These are "owned" by the country and all its citizens, and the national government is the guardian of this wealth on their behalf. With this in mind, Chapter 2 of this report provides a framework for understanding how the benefits from the mineral sector are captured by local communities. Drawing on Aragón, Chuhan-Pole and land (2015), it delineates three broad channels through which the local areas and regions may be affected:

- ***Income, employment, and linkages.*** Extractive industries employ local workers and purchase some goods and services locally and regionally. This should raise nominal wages and other incomes and increase non-mine employment opportunities and generally improve local welfare and reduce poverty. There could, however, also be some negative spillovers from this. Often, the start of an extractive industry, say, the opening of a mine, will attract workers from other districts. This could temper the rise in wages, put a strain on local services such as health and education, and raise the price of nontradable goods and services such as housing rents and, therefore, actually reduce the real incomes of some local residents. Figure 1.3 presents an analytical framework of market-based transmission channels and possible outcomes of a natural resource boom.

- ***Government as the owner of the resources on behalf of the people,*** *and collector of public revenues from resources,* is the conduit of the benefits to the rest of the economy (via public spending). The benefits from a natural resource will depend to a large extent on whether the revenues received are put to good use. A fiscal revenue windfall eases the hard budget constraint of local governments, and supports higher public spending. If history is a guide, there is ample reason to be cautious. In particular, the areas where mines are located have no property rights to the minerals and may feel deprived of the benefits while bearing the bulk of the costs. In all three cases, the central government owns the resources and therefore the revenues. The fiscal arrangements between the central and local governments at various levels will therefore determine how much of the benefits from mining find their way back to the mining areas. Among the case studies, Mali had the highest degree of fiscal decentralization and, therefore, the local authorities received the largest proportion of the revenues compared to the other two. Ghana is in the middle of the three in this regard, but its decentralization efforts are relatively new, so it may be premature to evaluate them. Tanzania has a rather rigid centralized mechanism. All revenues are garnered by the central government. Transfers from the central budget fund 90 percent of local government. The funds are allocated according to criteria and priorities unrelated to the location of mines or the source of the funds.

  In so far as the windfall is used to improve the quantity or quality of local public goods and services, there would be the potential to improve human welfare, such as health and education outcomes. Moreover, to the extent that public goods are productive inputs, or create positive spillovers, as in the case of transport infrastructure, a resource boom could also increase local income and growth. The positive effect of revenue windfalls is underpinned by several assumptions: namely, local politicians are responsive to the broad population, which requires well-functioning local institutions and a healthy degree of political competition[3]; and local bureaucracies have the technical capacity to provide those public goods and services. Therefore, the general competence, honesty, and, overall implementation capacity of the local-level government will be key to enhancing welfare and development. Lacking these, may undermine the positive effect of revenue windfalls on public good provision and local living conditions.[4] Hence, both nationally and locally, the quality of governance and the influence on it of resource revenues will be a key determinant of the welfare impacts of resource exploitation.

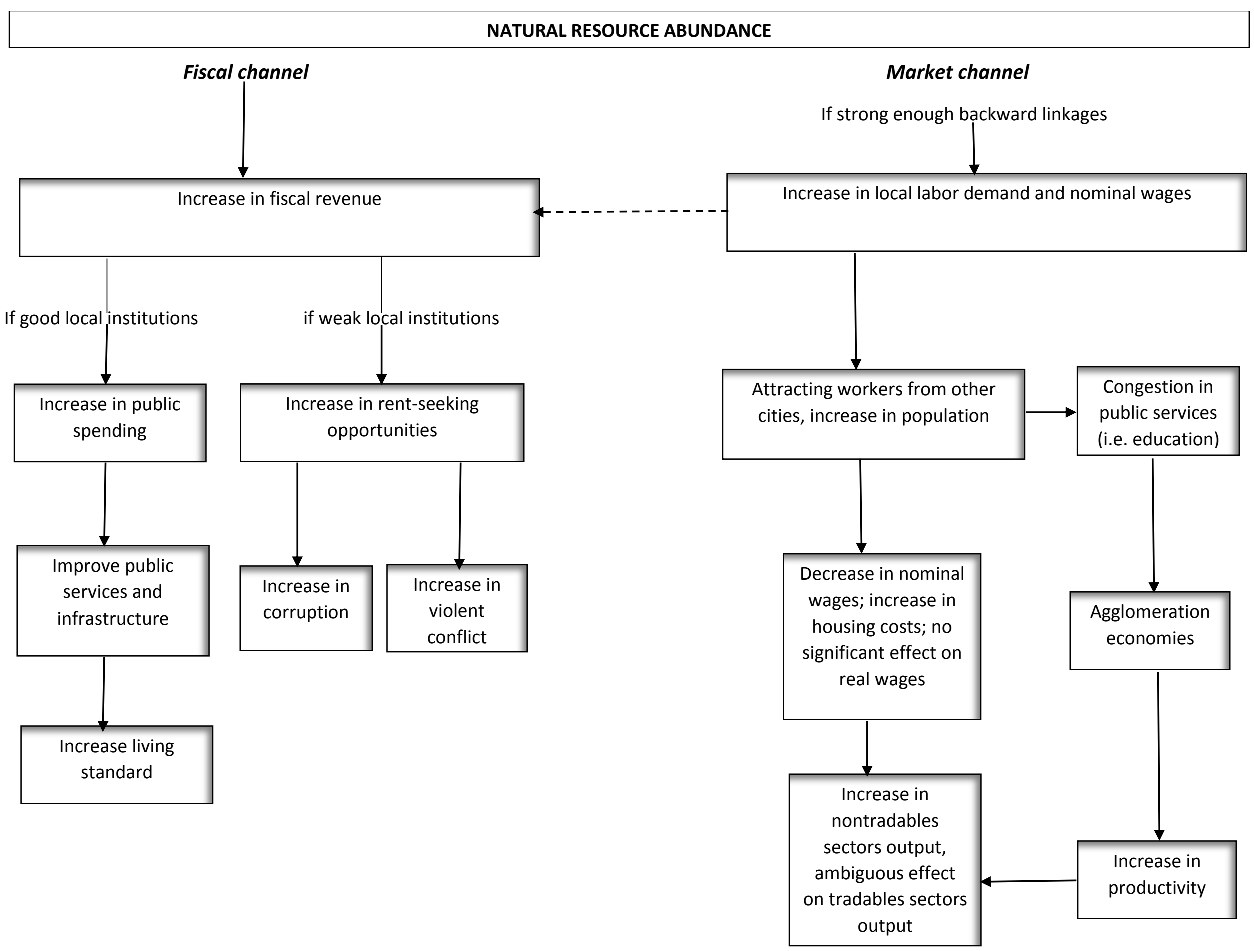
[3] In the absence of good democratic checks and balances, the revenue windfall can fail to significantly improve public good provision (Caselli and Michaels, 2013) and lead instead to corruption and worsening of political selection (Brollo et al. 2013). Also see Besley and Burgess 2002.

[4] The "rapacity" and "opportunity cost" effects discussed in the country-level literature on conflict, may also explain a failure of resource windfalls to be converted into welfare gains at the local level.

Figure 1.3 depicts some of the paths discussed in the literature through which a revenue windfall would impact local welfare.

- ***Externalities.*** There may be positive spillovers from the extractive industry in addition to the wage and linkage effects noted above. These could include improvements to productivity through worker training and education, which often spread beyond the mine or oil field. Also, there may be improvement to public goods through investment in roads, bridges, ports, and similar facilities, which are required by the extractive industry. However, there are always some negative externalities, such as pollution, congestion, pressure on other scarce natural resources, and social dislocation. Environmental and health issues are a big concern (see box 1.1).

Figure 1.3: Channels through which natural resource abundance affects welfare at local level



Box 1.1 Environmental and health issues in gold mining areas

Like many other industries, gold mining (both industrial and artisanal) is associated with environmental degradation and pollution which have severe health implications. The environmental degradation is manifest through effects on landscape and land use, spread of gold ore-related heavy metals such as arsenic and lead to nature, discharge of cyanide to nature, spread of mercury from artisanal mining, or air pollution. In Ghana, air pollution around industrial gold mine has been linked to increased cough incidence (Aragon and Rud, 2013a). Similarly, pollution from heavy metals contamination has been shown to have detrimental health impacts. For example, von der Goltz and Barnwal (2014) in their study of 800 mines in 44 developing countries found that lead and other heavy metal pollution are linked to a 3 to 10 percentage points increase in anemia incidence among women living in mining communities. In addition, children of the same communities experience a 5 percentage point increase in the incidence of stunting. In general, there are controversies surrounding studies linking environmental degradation around mines to health outcomes due to the possibility of omitted variable bias where exposure to these pollutions may be linked to individual lifestyles habits (Tolonen, 2014).

In 2008, a Ghanaian environmental impact assessment of 61 major mines and several smaller-scale operations sites found that mining areas have higher concentration of arsenic particularly within the areas of old, large mines like Obuasi, Bibiani and Prestea. For example, in the influence area of Obuasi mine, the mean arsenic concentration over one year of sampling is 525 µg/l, which is more than 50 times the WHO guideline for drinking water. High concentration of cyanide is infrequent in Ghana because the great majority of companies stick to stringent procedures.

Environmental and health issues for artisanal scale miners are concerned with the use of mercury to cheaply separate gold from other minerals. Mercury usage tends to always exceed the World Health Organization (WHO) limit for public exposure of 1.0 µg/m3. In southwest Ghana, artisanal and small-scale gold miners have a significantly higher burden of mercury than other residents who live or work in mining areas (Kwaansa-Ansah et al., 2014). In Tanzania, a review of several studies points to the existence of major health and safety risks for mining communities (World Bank, 2015). In the artisanal mining areas of Matundasi and Makongolosi, mean mercury level in hair samples among miners is 2.7-times higher than the 4-5 µg/L reference limit of the U.S. EPA. Approximately two-thirds of the hair samples exceeded this reference limit. In addition, another study in Tanzania looked at mercury levels in breast milk of mothers living at ASGM sites and found that 22 of the 46 children from these mothers had a higher total mercury intake.

Local impact of gold mining

The mineral sector in Sub-Saharan Africa is large and diverse. The aim of the research is to apply the above framework (from Chapter 2) to a single mineral. The choice of gold for this study was predicated on the following important factors:

- Gold mining is now an important industry in several countries in Africa, and is behind only crude oil as a top export earner for the region. In 2013, four African countries—Ghana, Mali, South Africa, and Tanzania—were among the top 20 gold-producing countries in the world.
- Since the aim of the research is to assess the socioeconomic impact of the mining activity on local communities, it is relevant to select an activity that can have a potentially important local footprint. Gold mining is onshore, unlike oil drilling, which is often offshore, so it can be expected to have an impact on local populations.

Three countries were selected for study: Ghana, Mali, and Tanzania. Gold mining in each of the three countries has a number of common characteristics that make them suitable for this study. While industrial gold mining has a long history in Africa (especially for Ghana), there has been a sharp acceleration in gold production in the last two decades in each of these countries (figure 1.3), which makes a study of its impact timely. It also lends itself to the "before" and "after" type of analysis reported in Chapter 4.

1.3 Case Studies

Every country is a special case

As noted above, gold mining activity in the three case study countries has accelerated in recent years. Overall, these three countries are among the top gold-producing countries in the region, collectively accounting for about 35 percent of the region's gold production in 2015. In addition, gold is a large component of export earnings in all three countries. Along with an increase in gold production, government revenue from gold has been on an upward trend (figure 1.4). Gold production is an important contributor to government revenue, particularly in Mali, and its share is rising in Ghana and Tanzania. However, these elements are national and do not directly impact local communities. A key channel for transmitting benefits to the local community is through direct employment by the mining companies and also the indirect effects through linkages with other sectors and increased expenditure due to higher wages (these are sometimes called multipliers). However, gold mining is capital-intensive and the country studies show that the linkages are likely to be quite small. Direct employment in gold mining in Tanzania, for example, was around 7,000 in 2013. The direct employment figures are likewise low for Ghana (about 17,100 in 2014) and Mali (averaging about 3,635 during 2008–13). If the "multiplier" is 2 (and it is probably lower), then the total number of jobs supported by mines would be 14,000 in Tanzania, which is trivial in a workforce with 70,000 new entrants per year. So, other than the immediate vicinity of the gold mine, it is not likely to be a large employment generator.[5]

Figure 1.3 Trends in gold production (tons) in Ghana, Mali, and Tanzania

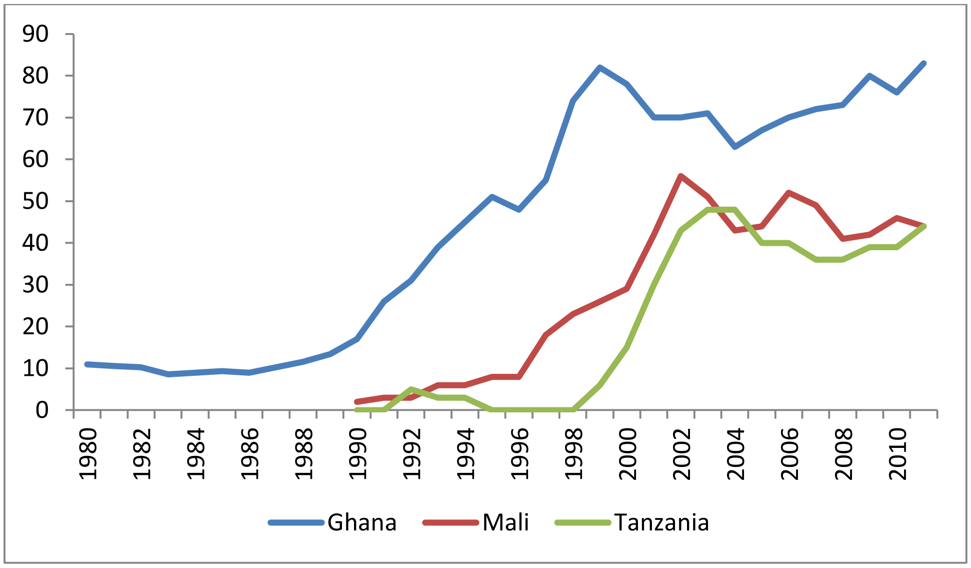
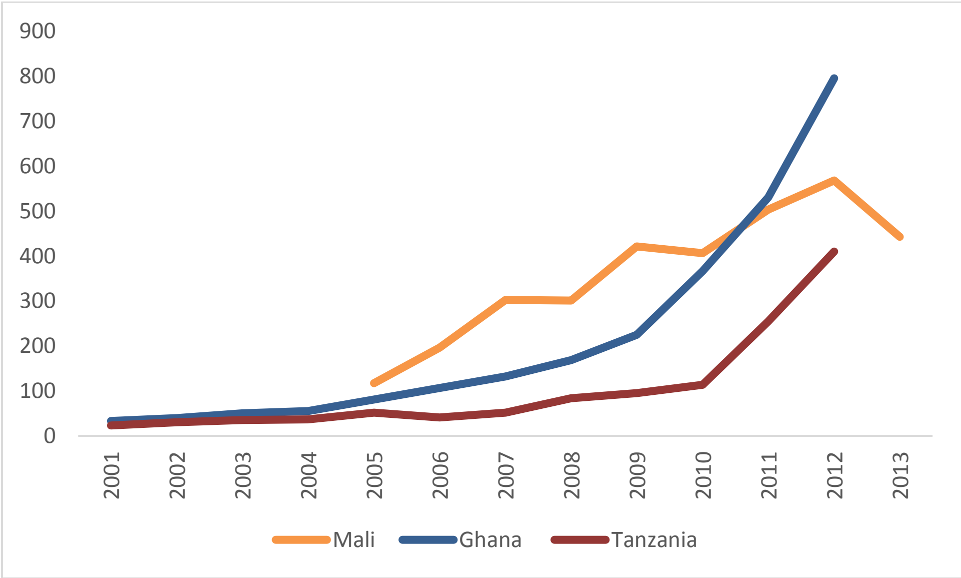
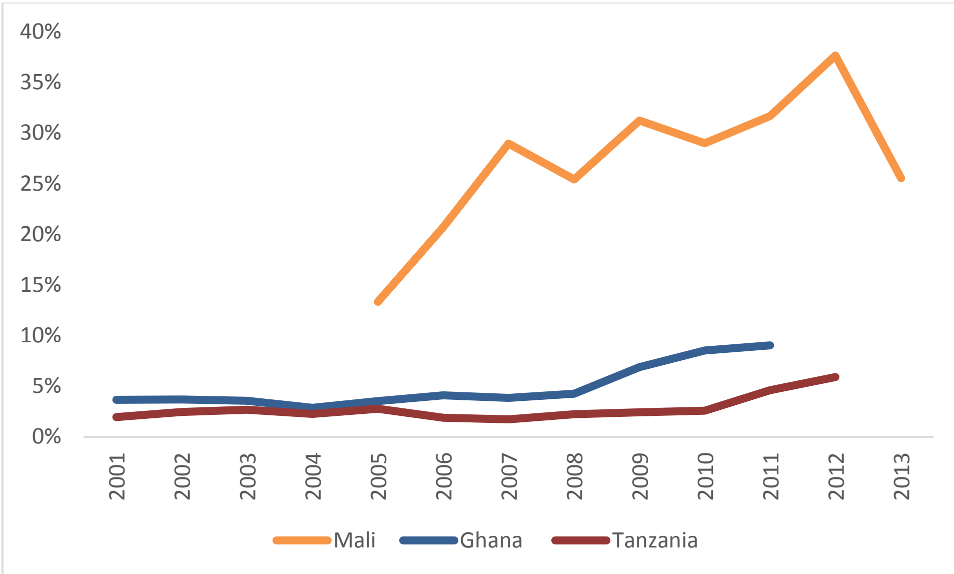


Figure 1.4 Fiscal revenues from mining (US$ millions and as % of total revenue)



[5] The absolute size of employment is also important. In South Africa, the mining linkages are thought to be minor, that is, they have low multipliers. But half a million workers are employed in gold mining, so any shock, positive or negative, will have a significant impact on income and employment in the country. In Tanzania, Ghana, and, perhaps, Mali, the absolute numbers are not (yet) that significant.



The multiplier effects are limited partly because of the capital intensity of the industry, but mostly because of the lack of local cost-effective procurement opportunities. This could change over time as the companies become better acquainted with local markets and suppliers, and also as local entrepreneurs learn to take advantage of the relatively new developments. In Tanzania, efforts have been made to improve the potential for local procurement, including in services such as catering, vehicle repair, machine shop services, welding, metal work, electrical work, and plumbing (Smith and Kinyondo 2015). However, the proportions of inputs sourced locally remain low, a situation mirrored in Ghana and Mali.

Being capital-intensive and in the absence of strong backward linkages, the key benefits from gold mining will lie in its contribution to exports and government revenues. The central government is the key local recipient of the rents. During 2005–13, gold mining provided the government with US$362 million per year on average in Mali, compared to US$300 million per year in Ghana and US$137 million per year in Tanzania. Therefore, much of the local benefit from the industry will depend on how much of this revenue finds its way back into the local community, and also on the quality of public sector expenditure. Thus, fiscal arrangements for transfers—specifically, redistribution of resource revenues—are important in understanding the local impact of mining activity.

The fiscal arrangements differ in all three countries. Tanzania and Ghana tend to be more centralized, while Mali is more decentralized. However, in Ghana, the government has mandated that 10 percent of revenues (mining royalties) be returned to the local government in the areas of the mines. In Tanzania, all revenue accrues to the central government (with the exception of recent annual payments of US$200,000 per mine), and there is no link between government transfers to the local authorities and the revenues raised from mining in those areas: Funds are allocated according to criteria and priorities unrelated to the location of mines or the source of the funds. In Mali, the fiscal system is decentralized, so fixed percentages (ranging from 60 percent to 15 percent on various taxes and licensing fees) are transferred back to the local area governments. There may be some payoff from this in Mali, since school enrollment rates in mining areas exceed those of nonmining areas.[6]

Positive externalities are also few and far between. Corporate social responsibility spending by mining companies has had limited impact, according to the data examined. The case studies show that while investment in schools and public health facilities has occurred, the results have been disappointing.[7] The effect of mining on investment in local roads and bridges, while not zero, has not had a large impact in any of the countries. The mines tend to build infrastructure just sufficient for their needs, and the case studies show that these are rather limited.

Negative externalities are always present in mining, including pollution, particularly from cyanide, and other environmental and social risks.[8] Corporate responsibility and regulatory vigilance are important to ensure that these costs, borne entirely by local communities, are minimized.[9]

The case studies do not note any evidence of local Dutch disease symptoms, however. For example, in Tanzania, there was a slight increase in manufacturing employment in mining areas. While this shows only minor linkages from mining to manufacturing, the fact that manufacturing did not decline reveals an absence of Dutch disease affects.

The country studies suggest that overall, the effects of mining are not likely to be harmful to the local areas (although pollution is always a danger that needs monitoring). Mining is also likely to be somewhat transformative in terms of the quality and quantity of employment in mining areas. However, these effects are quite limited. The key beneficiary of mining is the government, which therefore is the conduit of benefits to the country as a whole, and to the local communities as well. Transparency of governance and extractive industry revenue collection is therefore fundamental to guarding against the governance curse that so often accompanies resource-based economies.

An important caveat is that the focus of the study is on large-scale “industrial” gold mining and not artisanal and small-scale gold mining that often takes place in proximity to large-scale mining. The data cannot be disaggregated to distinguish between these two

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[6] See Chapter 7.

[7] See Chapter 6.

[8] A best practice international code for the use of cyanide in gold mining was established in 2002 following a tailing spill in Romania: http://en.wikipedia.org/wiki/International_Cyanide_Management_Code.

[9] von der Goltz and Barnwal 2014 found that negative pollution impacts were likely to be disproportionately borne by households close to the mine implying that net benefits could vary significantly between the average household in a local community and the particular impacted households.

classes of mining, nevertheless, large-scale mining, in all but a few mining areas, accounts for a very high percentage of the volume and value of gold produced in such areas.

1.4 Empirical methodology

Measuring local effects of mining: Proximity of mines

The aim of the research is to assess whether local communities benefit from mining activity or not. The empirical approach builds on the earlier studies that used quasi-experimental events to estimate the impact of localized shocks on economic outcomes (Card and Krueger 1994). The identification strategy in these approaches is based on comparing outcomes in local units of observation (districts, municipalities, regions, and so forth) affected by a particular event or intervention to units where such events or interventions are absent. The empirical approach adopted treats industrial gold mining as a quasi-experiment similar to a clinical trial. The vicinity of the mine can be thought of as the "treatment area," and areas outside of this as nontreatment areas. In addition, since the areas chosen represent relatively recent gold mine starts (or restarts), it is also possible to compare outcomes "before treatment"' and "after treatment," the "treatment," of course, being the start or existence of a mine. The object of the exercise is to discern differences in the outcomes of those in mining and non-mining areas.

Specifically, regression analysis is used to test whether indicators of welfare show improvement with proximity to a mine. This is done on different levels. First, the size of the treatment area—that is, the area in the vicinity of a mine—has to be determined. How large the mine's influence extends is an empirical exercise. The analysis includes households within 100 kilometers (km) of a mine location, with the baseline treatment distance being 20 km from a mine (figure 1.5). In order to allow for nonlinear effects with distance, the analysis also employs a spatial lag model. The spatial lag model divides the area around a mine into small concentric distances (or bins), such as 0–10 km, 10–20 km, 20–30 km and so on, up to within 100 km of a mine.[10]

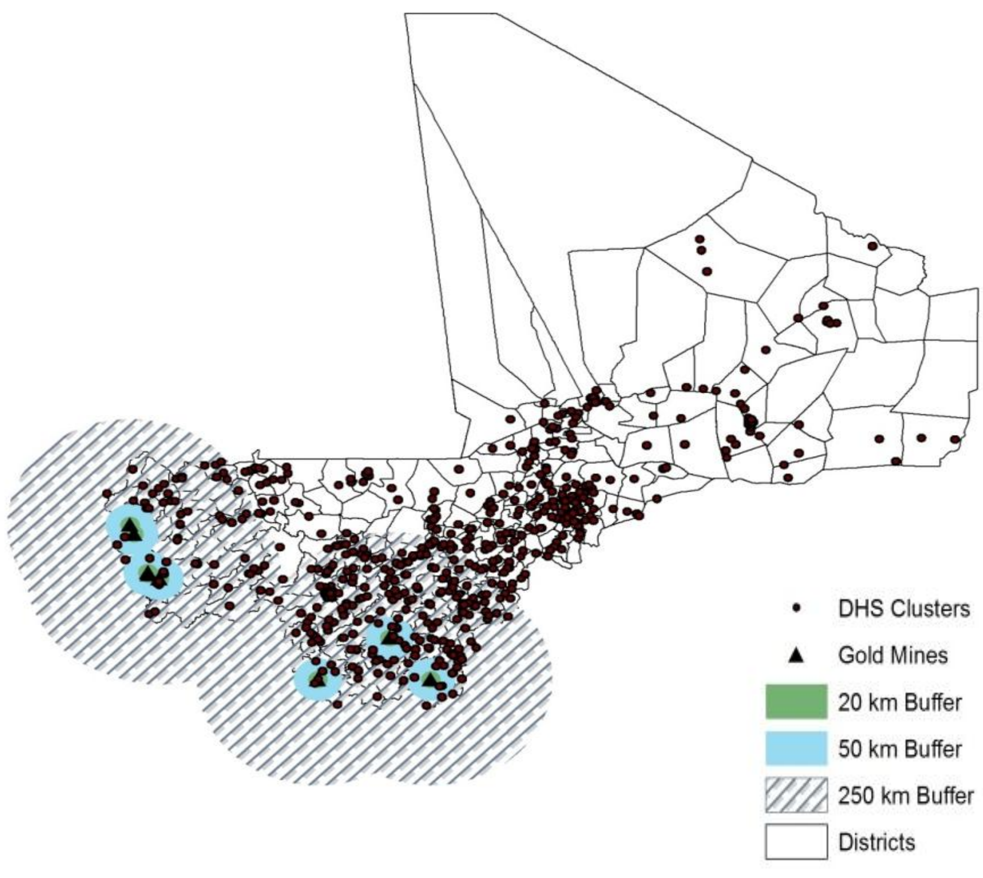
As argued earlier, mining can have additional impacts beyond the neighborhood of the mine if mining royalties and revenues are spent on populations living in districts where the mine is located. Injection of additional expenditures into the district could increase spending on welfare-enhancing services, such as schooling or health care. Thus, a second level of analysis is done with the treatment area as the district in which the mine is located. District refers to political or administrative units that have spending authority. For some of

[10] In the regression specification, each distance bin can have its own coefficient. The model thus allows for nonlinear effects with distance. Moreover, it allows us to understand whether there are spillovers from large-scale gold mining farther away than the baseline treatment distance.

the selected countries, the district has authority to raise revenue and spend it. In some, it has no taxing authority but instead implements projects on behalf of the central government as part of devolved functions. Districts themselves are relatively arbitrary, and looking for impacts in only the districts that have a mine could miss the potential spillovers that result from mining. So spillover effects across districts are also considered, and the analysis compares outcomes in mining districts, neighboring districts, and non-mining districts. Thus, the study identifies both local- and district-level effects of large-scale gold mining in Ghana, Mali, and Tanzania.

As with clinical trials, it is important to be able to choose a control group (in this case, the non-mining group) that is as similar as possible in all other characteristics to the control group (in this case, to the group in the mining area). Only then can the researcher reasonably attribute any statistical difference between the two groups to the "treatment," in this case the mine. The control group is chosen by the characteristics of the individuals so as to maximize their similarity to those of the treatment group. The groups chosen in this way are called "synthetic."[11] The synthetic control group is one of the methods used in the study to define a comparison group.

Figure 1.5 Gold mines in Mali and spatial buffers



[11] The method of constructing the synthetic group is described in Chapter 3 and the references therein.

A difference-in-differences estimation strategy is used,[12] which compares districts with and without gold mines (or groups based on their distance), before and after the mines started producing. The method allows for initial differences across districts. However, it makes a crucial assumption—called the parallel trends assumption—which is the idea that these initial differences will not affect estimates of outcomes that will be due to the presence of a mine, as long as the trends of the socioeconomic development in the districts were similar before the extraction from the mines began. Under this assumption, it can be deduced that the change that happened in mining districts at the same time as the mine opening is in fact a result of the mine (assuming that no other confounding changes happened at the same time). The regression shows the change in the chosen indicators as a function of proximity to a mine.

Mining and household data

The analysis combines mine-specific information and a rich dataset collected from various sources (household surveys). Mine-level data on first year of production and production volumes are from the Raw Materials Database of IntierraRMG; mine location information (GPS coordinates) is obtained from online sources such as *mine-atlas.com* and *google.maps*, and IntierraRMG for Ghana.

Data on households and/or individuals are from the following main sources: Demographic and Health Surveys (DHS), Household Budget Surveys (HBS), Living Standard Surveys (LSS), and Censuses of Population.[13] Some of the surveys, especially the DHS and LSS, are geocoded. Since the mines are also georeferenced, it is easy to determine how far a household observed in such surveys is from the mine. The estimation strategy that uses individuals and households makes use of this information to identify the impacts of the mines. Table 1.1 shows the survey years that were used.

Table 1.1 Household survey data

	DHS	LSMS	Census
Ghana	1993, 1998, 2003, 2008	1999, 2004, 2012	
Mali	1995, 2006, (2001)	1989, 2001, 2010	1987, 1998, 2009
Tanzania	1999, 2010, (2007, 2012)	1992, 2001	1988, 2002
used for	Individual analysis District analysis	Individual analysis District analysis	Synthetic control analysis

Note: Survey years in parentheses are used in some parts of the analysis.

[12] The methodology is described in Chapter 3 and the references therein.
[13] See Chapter 3 for details.

1.5 Results

The purpose of the analysis, as noted above, is to test for improvement or deterioration in welfare in areas close to a mine. Four areas are considered as indicative of welfare:

- ***Occupation indicators for both men and woman.*** Whether there is expansion of employment opportunities and increases in incomes.
- ***Asset accumulation.*** If there is a discernable increase in family asset accumulation (for example, a radio, bicycle, car, or toilet) with proximity to a mine, then one could conclude that the mine, at least in this respect, is welfare enhancing.
- ***Child health outcomes.*** Again, the analysis tries to determine whether there are improvements in key indicators of child health. The key indicators here are infant mortality, fever, cough persistence, and diarrhea in children under age 5.
- ***Access to infrastructure.*** The key variables here are access to electricity and water, which is indicative of provision of services by local governments.

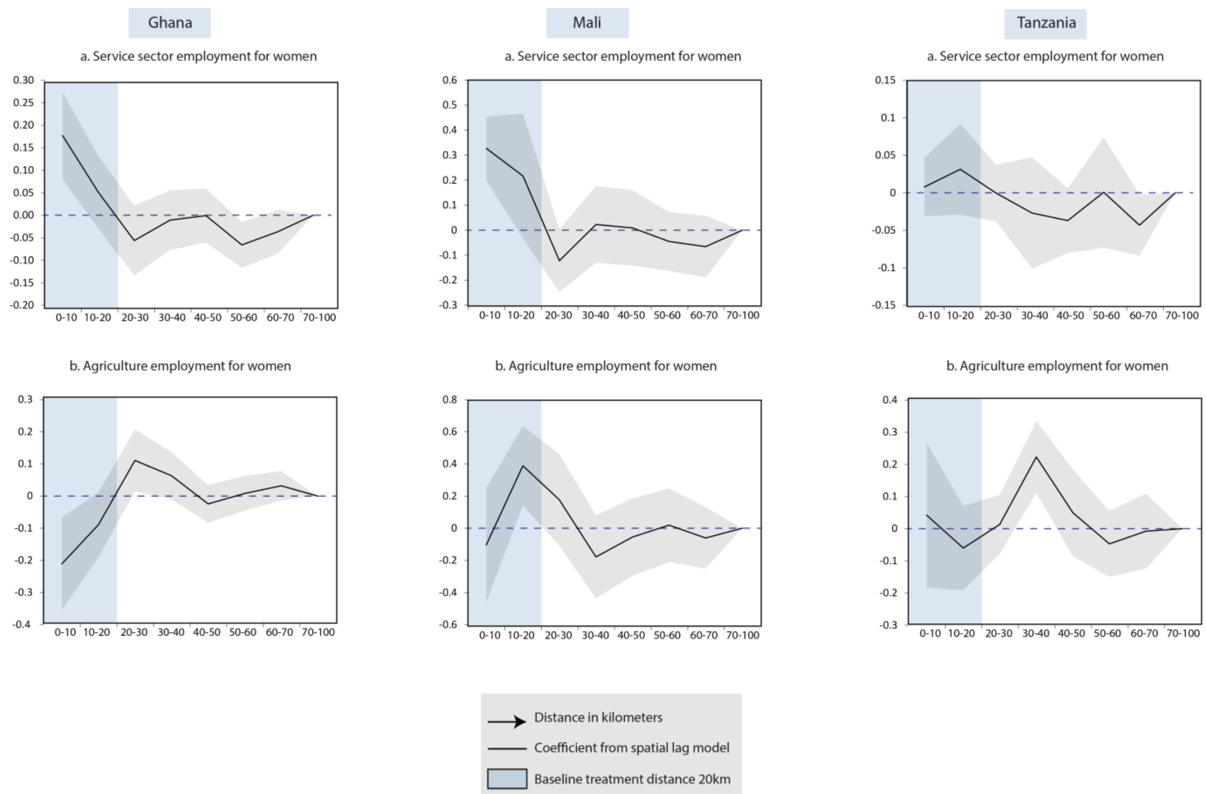
In short, the study takes a close look at the impacts of mines on individuals' employment prospects and wages, asset accumulation, child health outcomes, and access to infrastructure when they live closer to a mine or in a mining district.

Occupation – Is local structural transformation occurring?

Using the methods outlined above, the study analyzes how gold mining has changed the livelihoods of people (in mining areas) in Ghana, Mali, and Tanzania. The econometric results from the spatial lag model, which allows for nonlinear effects with distance, shows service sector employment for women is significantly higher close to active mines (figure 1.6). In fact, the effects are stronger 0 to 10 km from a mine than 10 to 20 km from a mine. In Mali, the probability that a woman works in services and sales increases by 30 percentage points, and in Ghana by 17 percentage points, in the very closest distance. For Ghana and Mali, agricultural participation drops close to mines, at roughly 20 to 10 percentage points, respectively. In Tanzania, there is no evidence of a clear change either in services and sales or in agricultural employment.

For Ghana, where data are available on mining employment from the Ghana Living Standards Survey (GLSS) dataset, the results show that there is a 10-percentage-point increase in the likelihood that a man living close to a mine works in mining (figure 1.7). This contrasts with the findings for women, who are not benefiting (or benefiting very little) from direct employment in mining.[14] The GLSS data also show that men have (marginally) significantly higher wages. The DHS data for Ghana and Mali reveal that men are less likely to work in agriculture if they live within 10 km of a mine (statistically significant in Mali). There is a pattern in the data that indicates that there might be a geographic displacement of farming activities from very close to a mine to slightly farther away (20 to 30 km), especially in Ghana. Results also show that men are not more likely to work in manual labor in Ghana or in Mali.

Figure 1.6 Spatial lag model illustrating geographic distribution of effects on service and agricultural sector employment

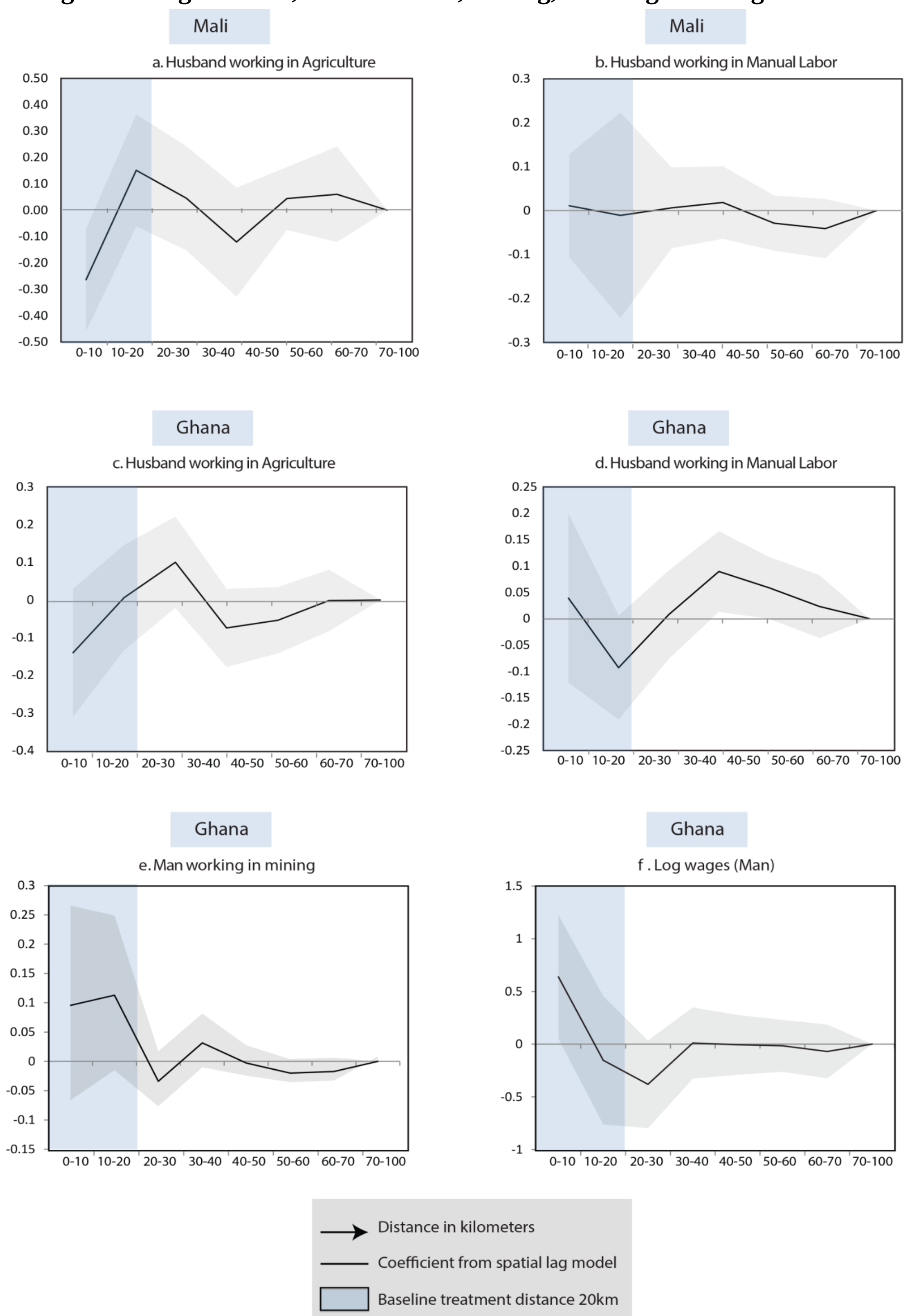


District-level analysis, which compares outcomes between mining and nonmining districts, for all three countries confirms the above finding that agricultural employment decreases in mining districts. For Ghana, the results indicate that agricultural employment decreases in mining districts relative to nonmining districts, by 5.2 percentage points for men and 8.5 percentage points for women. In addition, the probability of a woman working all year increases by 5.4 percentage points, as does the probability of working in manual work.

[14] Chuhan-Pole et al. (2015) find that, using GLSS data, women are 7.4 to 10.4 percentage points more likely to work in services or sales if they live close to a mine, and 2.5 to 2.6 percentage points more likely to work in mining.

There are no such significant increases in employment in other sectors for men (the DHS does not have information on employment in mining for men).[15]

Figure 1.7 Agriculture, manual labor, mining, and wage earnings for men



[15] However, the insignificant point estimates indicate that men might be shifting toward service sector employment and manual work.

Results from a district analysis for Tanzania and Mali show that there are significant increases in the likelihood of mining employment. In Mali, men are almost 10 percentage points more likely to work as miners, and women 2.3 percentage points more likely to work as miners, compared with before. Note, however, that these changes can also be due to increases in small-scale mining in these districts over the same time period. Overall, men's and women's agricultural employment decreases insignificantly. For Tanzania, there is no recorded information on mining employment, but as in Mali, we see a decrease in agricultural employment—8 percentage points for men and 11 percentage points for women—but these estimates are not statistically significant.

The empirical evidence provides signs of an incipient structural transformation around mines. Essentially, there are some visible shifts in the structure of employment of the local economy away from "traditional" farming—defined by low inputs and low capital per worker—to mining, services, and other activities.[16] The increase in service sector employment as well as other sectors can be understood as "local multipliers" (Moretti 2011), where for each job created directly in mining, there are additional jobs created in the tradable or nontradable sector. The size of the multiplier will depend on total mine employment, miners' wages and spending habits, and how the mining company sources inputs (such as food, electricity, and housing for its workers). Companies can try to boost the multiplier, for example, by ensuring that it sources inputs from local suppliers. In addition, there are local fiscal multipliers. A mine may result in local tax contributions which, when spent by the local government, can help stimulate the local economy.

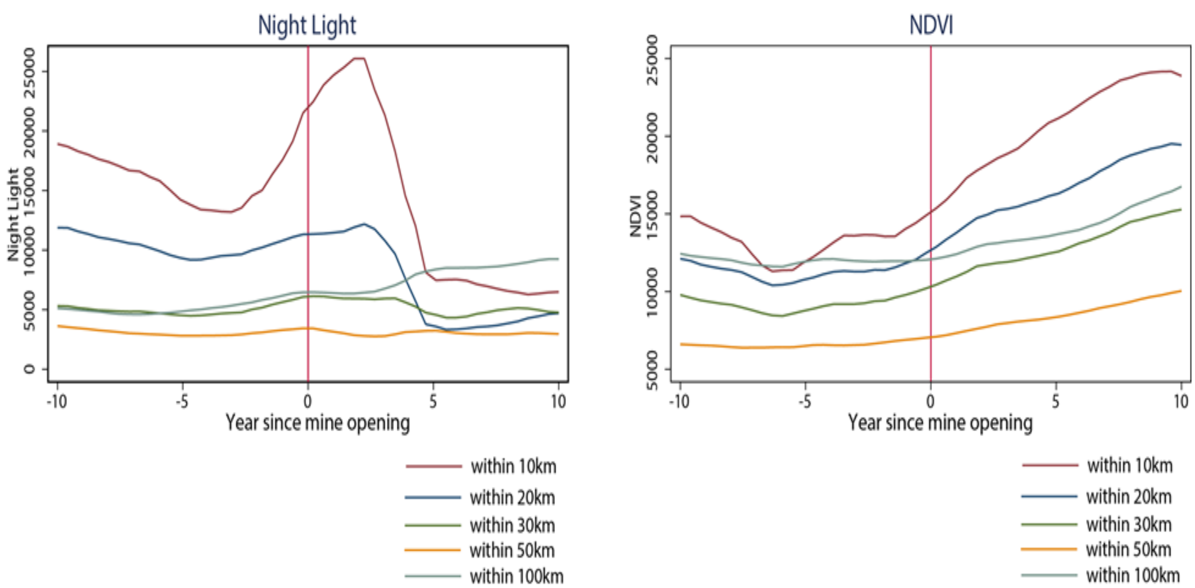
The study provides another perspective on the impact of resource extraction on agriculture by using remote sensing data to estimate levels and changes in agricultural production in mining and non-mining localities in Burkina Faso, Ghana, Mali, and Tanzania (chapter 5). It investigates the spatial relationship between mining activities and local agricultural development by using a vegetation index (the Normalized Difference Vegetation Index) as a proxy for agricultural production. The issue of interest is whether the opening of mines has spillover effects on the agricultural sector.

Agricultural production could be affected by mining activities in several ways. Mining could lead to a rise in local wages, reduce profit margins in agriculture, and lead to the exit of many families from farming—something akin to a localized Dutch disease problem. Negative environmental spillovers such as pollution (as found by Aragón and Rud 2015) or local health problems could also dampen productivity of the land and of the farmers, and thereby reduce the viability of farming. Alternatively, mining could create a mini-boom in the local economy through higher employment and higher wages that can lead to an increase in local area aggregate demand, including for regional food crops.

[16] Results show that in some countries, women shift from agriculture to service sector employment in the close vicinity of mines. These results have previously been confirmed for different minerals and in more countries (see Kotsadam and Tolonen 2013, and Tolonen 2015).

Figure 1.8 explores the change in the different distances from the mine, over the lifetime of the mine. On the horizontal axis is the mine year, counting from 10 years before mine opening, highlighted by the red vertical line, to 10 years after mine opening. The figures are based on summary statistics, and do not control for any systematic differences across the mines. Overall, it seems like areas very close to mines are on a steeper trend in nightlights than are areas farther away, especially as one gets closer to the mine opening year, which is highlighted by the red vertical line. One interpretation of this pattern is that from a few years before the mine starts extracting gold, economic activity that emits nightlight increases in these areas. One reason why this happens before the actual mine opening year is because mines are capital-intensive and the local economy is stimulated during this investment phase, a pattern confirmed in previously mentioned econometric studies. For NDVI, no big difference in patterns is observed across the areas. Although both areas seem to be on an upward sloping trend, this needs to be interpreted with caution, because it can be driven by the unbalanced sample[17]. If anything, we detect that areas close to mines are getting relatively greener over time compared with areas further away.

Figure 1.8 Nightlight and vegetation index over mine lifetime



Note: Nonparametric (local polynomial smooth) measures of nightlight and NDVI close to mines. Years since mine opening on the x-axis counts the number of years from mine opening, with before the opening on the left of the 0, and years after mine opening to the right of the 0. Nightlights and NDVI are measured as averages across limited geographic areas, varying from within 10 km from the mine center point, to 20 km, 30 km, 50 km, and 100 km.

[17] The sample is unbalanced as the data on nighlights start in 2002, but mines may have opened long before 2002, as well as after. If the mines opened before 2002, we will have night lights data only during the active period of the mine. Such mines would then add to the estimates of night lights on the right side of the red line, but not to the left. There are too few mines for which we have night lights the whole 20-year period to do these figures on a perfectly balanced subsample.

The difference-in-differences analysis for 32 mines across four countries does not find a robust decrease in NDVI in mining communities (20 km) compared with farther away (20 to 100 km). The treatment coefficient *active_close* (table 1.2) is negative but not statistically significant, meaning that there was no major difference in agricultural output per area between areas near the mines and those further away (the control areas).

In light of the finding from the spatial lag model where we saw workers exiting agriculture, the finding that mining has had no impact on agriculture when using NDVI may seem contradictory. However, there are two things to keep in mind. One, the results from the spatial lag model are about employment on the extensive margin—that is, the fraction of workers in agriculture. By contrast, the results from the remote sensing data are about yields (production—proxied by NDVI —per area). It is possible to have a net exit of workers without lowering agricultural yields if the productivity of the entrants is marginally higher than those who are exiting. A similar result will obtain if there is now more land per worker, and the marginal productivity is higher. Therefore, these two results actually are consistent with a story of nascent structural transformation.

Income, wages, and expenditure in mining communities in Ghana

While there are signs that there is a shift out of nonfarm activities, is there similar evidence available for wages? The available household surveys listed above have two drawbacks for understanding wages and mining. First, they are not geocoded, so the workers cannot be linked to a mine. Second, most have no wage data. The exception is Ghana, where household data have geocoordinates. Therefore, how wages, income, and expenditure evolve in mining communities can be mapped. The analysis shows that household total wages increase, as do women's wages (table 1.2). Men's wages increase too, but the increase is not precisely estimated. (Note wage earnings are only recorded for those who are engaging in wage labor; in fact, only 13.3 percent of people in the GLSS sample for Ghana have recorded wage earnings.)

The data also show that regional food prices are higher in mining areas, which is similar to the findings in Peru (Aragón and Rud 2013), but regionally deflated food expenditures do not increase, nor does the share of food in total household expenditure (column 6). By contrast, total household expenditure on housing increases by 31.6 percent (not regionally deflated prices) with the onset of mining, as does the share of this component in total expenditure. The same is true for energy costs, such as electricity and gas, which rise by 29.7 percent with the onset of mining. This might be due to the rise in electrification that is noted below.

Table 1.2 Mapping changes in income, wages, and expenditure in Ghana

	(1) Ln Wages All	(2) Ln Wages Men	(3) Ln wages women	(4) Ln pc exp.	(5) Total Household exp.	(6) Food share	(7) Education & health share	(8) Housing share	(9) Electricity and gas share
active*mine	0.520**	0.391	0.694***	-0.178*	-0.126	-0.022	-0.097	0.404***	0.267**
	(0.226)	(0.238)	(0.241)	(0.093)	(0.089)	(0.053)	(0.186)	(0.121)	(0.129)
controls	Y	Y	Y	Y	Y	Y	Y	Y	Y

Note: (1) Annual wages and salaries for individuals in all ages (nondeflated).
(2) Annual wages and salaries for women in all ages (nondeflated).
(3) Annual wages and salaries for men in all ages (nondeflated).
(4) Real per capita annual food and nonfood expenditure (regionally deflated).
(5) Total annual regionally adjusted household expenditure (local currency).
(6)–(9) All expenditure and food share variables are used in natural logarithms. All regressions control for household head, household size, district fixed effects, and year fixed effects.
***p<0.01, **p<0.05, *p<0.1. All regressions control for year and district fixed effects, urban dummy, age, and years of education.

Asset accumulation

How does the opening of a mine close to a community affect the household's probability of having access to assets such as a cement floor, radios, and cars? The regression results using the baseline specification show that households in Mali are 30 percentage points more likely to have floors made of cement, tile, wood, or materials other than earth, sand, or dung, and 5 percentage points more likely to own a car (but 11 percentage points less likely to own a bicycle, at a 90 percent confidence level) (table 1.3). Households in Ghana are 14 percentage points more likely to own a radio. In some cases, there are differences for migrants and never-movers in the same communities. For example, in Mali, the positive effects on household assets seem to be driven by migrant households. In Tanzania, decomposition by migrant status shows that radio ownership in fact increased among nonmigrant households. In Ghana, on the other hand, radio ownership increases for both migrant women and nonmigrant women.

Table 1.3 Effects on ownership of assets

	(1) Floor (cement)	(2) Bicycle	(3) Car	(4) Radio
Ghana				
active*mine	-0.000	0.036	0.010	0.137***
	(0.044)	(0.026)	(0.011)	(0.038)
Observations	14,099	14,114	14,112	14,102
R-squared	0.235	0.280	0.093	0.146
Mali				
active*mine	0.299***	-0.113*	0.049**	0.003
	(0.091)	(0.068)	(0.023)	(0.081)
Observations	6,861	6,884	6,847	6,881
R-squared	0.311	0.204	0.087	0.049
Tanzania				
active*mine	0.048	0.011	-0.003	0.024
	(0.054)	(0.107)	(0.007)	(0.049)
Observations	6,942	6,945	6,938	6,942
R-squared	0.363	0.175	0.082	0.054

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy, and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. All outcome variables are indicator variables that take value 1 or 0. *Floor (cement)* captures is flooring made of cement, tile, wood, or other materials other than earth, sand, or dung. Bicycle, Car, and Radio capture whether the household has these assets. *p<0.05, **p<0.01, ***p<0.001.

Child health outcomes

Large-scale gold mining can affect child health in different ways. First, it could change household income. Higher income enables the household to buy better or more nutritious food. Second, it could affect child health through changing the environment where the child lives. Higher income could improve child (and household) health by reducing the disease environment through making it possible for the household to buy better-quality housing—with proper sanitation and clean water. Higher incomes can also directly buy better health care. However, if large-scale gold mining decreases local agriculture, it could increase food insecurity among households in the vicinity. Finally, if it leads to environmental degradation and pollution that is harmful for humans, the effects on child health could be negative.[18] Therefore, a priori, how a mine affects child health remains theoretically ambiguous.

Child health improves in Mali

In Mali, the study finds positive effects of mine opening on access to health care and health outcomes (table 1.4, column 2). Pregnant mothers receive many more prenatal health visits. Infant mortality decreases by 5.3 percentage points (although it is not significantly estimated), and stunting decreases by 27 percentage points, which is equivalent to a 45 percent decrease in the prevalence from the pre-mine average rate of stunting. Stunting is an indicator of chronic malnutrition, which affects children's growth pattern and thus makes them short for their age. By contrast, wasting measures acute malnutrition. Wasting can be a life-threatening condition if the child rapidly loses weight and becomes severely malnourished. For Mali, the estimated effect is negative but insignificant for wasting, but negative and significant for underweight, which is a composite measure of acute and chronic malnourishment.

Table 1.4 Child health outcomes in infancy and for children under age 5

	(1)	**(2)**	**(3)**
Country	**Ghana**	**Mali**	**Tanzania**
Treatment distance	**20 km**	**20 km**	**20 km**
Outcomes in infancy			
Prenatal care	-0.151	0.398***	0.007
	(0.331)	(0.086)	(0.018)
Infant mortality	-0.041*	-0.053	0.027
	(0.022)	(0.035)	(0.017)
Anthropometrics (under 5)			
Stunted	0.148	-0.274***	0.123*
	(0.120)	(0.066)	(0.067)
Wasted	0.095	-0.063	0.004
	(0.119)	(0.056)	(0.022)
Underweight	0.065*	-0.160***	0.113***
	(0.037)	(0.06)	(0.032)
Health outcomes last 2 weeks (under 5)			
Cough (last 2 weeks)	-0.061*	-0.195*	0.103
	(0.033)	(0.104)	(0.075)

[18] A recent study focusing on different types of mineral mines across developing countries finds that mines associated with lead pollution lead to increased rates of anemia in women and stunting in children (von der Goltz and Barnwal 2014), in very close proximity to large mines (<5 km).

Fever (last 2 weeks)	-0.035	-0.154	0.074
	(0.037)	(0.102)	(0.074)
Diarrhea (last 2 weeks)	0.042	-0.164**	-0.002
	(0.027)	(0.065)	(0.023)

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. See table A.4.1 in chapter 4 for variable definitions.
** p<0.05, ** p<0.01, *** p<0.001.*

Furthermore, the results show that the prevalence of cough, fever, and diarrhea decrease, although all but fever are only marginally statistically significant. The significant drop in diarrheal incidence of children in mining communities in Mali is a welcome development, since diarrhea remains a serious threat to children in developing countries, even though it is a disease that is easy to cure and prevent. Access to safe water and sanitation are important in fighting diarrheal diseases, and this could be a way in which a mine affects diarrheal incidence in Mali.

By contrast to Mali, the effects on child health are ambiguous in Ghana and Tanzania. The likelihood that a child is stunted increases by 12.3 percentage points in Tanzania, and underweight increases in mining communities in both Ghana and Tanzania. However, there are some positive effects of mine openings. For instance, in Ghana, there is a large decline in infant mortality and a marginally significant decrease in cough prevalence. The effect of the mine on diarrheal incidence in Ghana is positive but insignificant. When this outcome is disaggregated by groups, it reveals that migrants experience higher rates of diarrhea and never-movers lower rates.

There are some positive effects on access to health services for children in Ghanaian gold-mining districts. District-level analysis for five measures of child health care access show that mothers in gold-mining districts have 0.759 more prenatal visits per child, and they are 12.5 percentage points more likely to be attended by a trained midwife (table 1.5). Moreover, infant mortality is 8.5 percentage points lower in active mining communities. District-level results for Malaria and Tanzania show improvements in children's nutrition status in mining and neighboring districts compared to control districts (using a synthetic control method).

Table 1.5 District-level effects on access to health services for children in Ghana

	(1)	(2)	(3)	(4)	(5)
	Prenatal visits	**Prenatal: physician**	**Prenatal: midwife**	**Health card**	**Infant mortality**
Panel A. Mine districts					
active district	0.759***	0.055	0.125***	0.039	-0.085***
	(0.244)	(0.115)	(0.033)	(0.059)	(0.031)
Observations	9,245	9,462	9,462	11,047	9,270
R-squared	0.242	0.160	0.154	1.161	0.138

Note: Robust standard errors clustered at the district level in parentheses. All regressions control for year and district fixed effects, urban dummy, mother's age, and mother's years of education. Active is active status of mine in the birth year, except has health card, which is a measure of contemporary health care access. ***p<0.01, **p<0.05, * p<0.1.

To summarize, the results for children's health are somewhat ambiguous. For instance, there are improvements in important areas of child health, such as the observation that infant mortality declines in all regions with proximity to the mine. But there are also some notable exceptions. Thus, it is not clear why stunting and wasting increases in mining areas in both Ghana and Tanzania; this is not the case in Mali. Similarly, the incidence of diarrheal disease decreases in Mali but rises in Ghana and Tanzania, although in the case of Ghana this appears to be driven by poor outcomes among migrants who live near the mines.[19]

Access to infrastructure services

Does the opening of a mine close to a community affect the household's probability of having better access to infrastructure services such as electricity, a private toilet facility, and water? The regression results using the baseline specification in table 1.6 show that those households close to a mine are generally more likely to have access to a private toilet facility. For example, households in mining communities in Tanzania are 24 percentage points less likely to share the toilet facility with other households. There are differences for migrants and never-movers in the same communities. Thus, migrants in Ghana are seemingly less well off than never-movers and have less access to electricity. In Mali, the relationship is reversed, with migrants having better access. District-level analysis shows very small insignificant effects on access to electricity in mining districts in all three case

[19] The migrant communities may be economically and politically weaker and have less access to health services and infrastructure.

study countries, and on access to sanitation in Mali and Tanzania. In Ghana, there is a large positive, yet insignificant, effect on access to water in mining districts.

Table 1.6 Household access to infrastructure

	(1) Electricity	(2) Shared Toilet	(3) Water >10 minutes
Ghana			
active*mine	-0.046	-0.050	-0.001
	(0.052)	(0.044)	(0.054)
Observations	14,112	6,059	11,552
R-squared	0.494	0.127	0.162
Mali			
active*mine	0.134	-0.046	-0.065
	(0.086)	(0.110)	(0.094)
Observations	6,876	4,230	6,009
R-squared	0.169	0.064	0.173
Tanzania			
active*mine	0.007	-0.235***	0.048
	(0.033)	(0.070)	(0.070)
Observations	6,941	4,681	6,862
R-squared	0.415	0.113	0.192

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. All outcome variables are indicator variables that take value 1 or 0. *Shared toilet* is whether the household shares toilet facilities with other households rather than having a private toilet facility. *Water >10 minutes* indicates whether it takes more than 10 minutes from the home to fetch drinking water. *p<0.05, **p<0.01, ***p<0.001.

1.6 Conclusion

This study examines the impacts of mines on individuals' employment prospects and wages, asset accumulation, child health outcomes, and access to infrastructure when they live close to a mine or in a mining district. Overall, the results suggest that mining is welfare-enhancing, though the results are not strong. While the evidence leans toward improvements in welfare in most categories with proximity to a mine, this cannot be said to be uniformly true. There is little indication, however, of deteriorating outcomes with proximity. The results for employment and occupation suggest a move from farm labor to other occupations (especially for women, for whom there are better data). This is most evident from the spatial lag model. Thus, although mining is capital-intensive and its direct labor effects are relatively small, there is some indication that the indirect effects are transformative. Where wage data are available, such as Ghana, results indicate that wages for those in mining are higher.

The results also point to better access to infrastructure and asset accumulation. The evidence of an increased share of household expenditure on housing and energy is considered a strong indicator of rising access to electricity and asset accumulation.

Finally, child health outcomes have mixed results. Overall, health outcomes such as child mortality have declined in mining communities and districts. But decline in stunting (ratio of height to age) and wasting (ratio of weight to age) for households in mining districts and for individuals who live closer to mines is evident only in Mali. In both Ghana and Tanzania, these outcomes appear worse for mining areas. Similarly, the incidence of diarrheal disease decreases in Mali but rises in Ghana and Tanzania, although in the case of Ghana this appears to be driven by poor outcomes among migrants who live near the mines.

Migration patterns may explain some of the differences in child health outcomes across countries. For instance, Mali, which shows the most positive changes, is also the country with the lowest level of migration around the time of mine opening, and migrants in mining areas in Mali seem less vulnerable than in Ghana or Tanzania. Tanzania, which shows little evidence of structural transformation and few gains in child health, seemingly has the largest increase in migration flows after mine opening.

In short, the econometric and case studies reveal little evidence that the local mining communities suffer a resource curse due to resource abundance. If anything, these communities experience positive, albeit, limited welfare benefits on average. Most of these positive effects are experienced through the market channel. One question that arises is whether the market effects can be enhanced. There is always a temptation to increase the backward linkages via local content laws. Local content requirement (LCR) implies replacing some imported inputs with costlier domestic ones. As with all protection, resources are thus pulled into activities in which they do not have a comparative advantage. Advocates for LCR usually propose two reasons why this is beneficial: First, they argue that over time producers of these inputs become more productive as they acquire new technology and skills—learning by doing. This is essentially an infant industry argument,[20] which claims that developing countries need time through protection to nurture their true comparative advantage. Secondly, there may be other positive spillovers from these linkages, such as increased worker training and managerial skills and experience, which raise the productivity of other sectors as well. For these reasons the adoption of LCRs has become widespread in general in Africa and quite ubiquitous in the oil and gas sector.

But there are problems associated with LCRs. For example, many LCRs are too vague to be workable. The main reason for this is that regulators often have no special insights into what is feasible. Local capacity, often, simply does not exist and attempts to calibrate the impossible will either be ignored, circumvented or, in the worst case, prohibitive, thus choking off the flow of foreign investment. Moreover, protection is a major cause of rent seeking. The application of LCRs is likely to encourage rent-seeking behavior by all stakeholders. In addition, LCRs actually imply national rather than local procurement. Mining often takes place in remote areas where the capacity to provide intermediate inputs is constrained. So firms source the inputs nationally, which may benefit the national economy but have little local impact. In fact, the local impact may be negative: if firms reduce output in response to the higher costs imposed on them they will reduce employment thereby hurting the local economy. Lastly, if firms do in fact reduce output in response to the LCR and if corporate revenues are reduced, which is likely (some would say 'inevitable') then government revenue will be reduced as well. These costs may completely or partially offset the benefits from LCRs.

Thus, governments may be better advised to focus on developing the conditions for improved procurement than mandating it. As McMahon and Moreira (2014) warn: "the failed experience of many import-substitution plans suggests that linkages cannot be forced upon the mining sector without enabling business conditions." To create enabling business conditions, they cite improving fundamentals such as better power and transport infrastructure, adequate human capital, access to finance, economies of scale, and outreach or technical assistance programs. What policies will be effective in improving local supply chain linkages will in the end depend on country conditions.

Broadly, it is clear that most benefits from extractives, in an African context, are likely to be fiscal and national, because the government, as the owner of the resources on behalf of

[20] The infant industry argument, strictly speaking, requires the presence of a positive externality. If the domestic inputs were potentially cheaper through learning by doing there would be no need for protection: it would pay the companies to invest in them themselves. Some of the benefits will be external so the companies themselves will not get the benefit. Alternatively, one may argue that the multinationals have limited information about local potential and therefore government intervention is needed.

the people, is the conduit of the benefits to the rest of the economy, including to local communities. The empirical evidence shows that the size of resource-related intergovernmental transfers to local communities has been modest so far. There is, thus, considerable potential to improve welfare at the local level through larger transfers that can support investment in much-needed infrastructure and development of human capital. By improving worker productivity, the public sector will help strengthen the impact of market forces unleashed by extractive activities. Moreover, it will also help diversify the local economy, which will be important in sustaining growth after the large-scale mining boom ends. Of course, both nationally and locally, the quality of governance and its influence on how resource revenues are used will be a key determinant of the welfare impacts of natural resources. Enhancing the capacity of local jurisdictions—bureaucrats and policy makers—to deliver public spending programs will need to be high on the policy agenda.

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Chapter 2 Local Impacts of Resource Abundance: What Have We Learned?

There is a well-developed academic literature examining the socioeconomic impacts of resource abundance, especially at the country level. The focus of this literature has been on whether natural resource abundance is bad for economic development—the so-called natural resource curse. Aragón, Chuhan-Pole, and Land (2015)[21] systematically review the evidence and theoretical arguments behind the so-called resource curse, along with other impacts at the country level. A simple analytical framework is then developed to understand how resource booms could impact local communities. The framework identifies four possible ways in which a resource boom could exert a local economic impact. Among these are the market channel of increase in demand for local labor, goods, and services and the fiscal channel of increase in public spending on local services through the taxation of natural resource wealth. The analysis highlights the importance of the market compared to fiscal mechanisms to create positive impacts, and shows that the channel through which resource rents reach a local community matters. Given that resource wealth creates rents, often very large, that can be easily appropriated when institutions are weak, the review also underscores the importance of local institutions for the effectiveness of the fiscal channel in creating a beneficial impact.

Available empirical evidence on the impact of resource abundance on local growth, employment, and living standards is examined to better understand the importance of these different mechanisms. Similar to recent country-level findings, the evidence suggests that a local resource curse is not inevitable, and that in some cases extractive activity has lifted local growth. It also supports the importance of the channel through which resource rents are distributed. When resource rents are distributed using public channels, a resource windfall does not seem to improve welfare. By contrast, when resource rents reach a local community through the market channel, there may be some positive effects. More research is needed to see if developing local supply chain linkages may be more effective in improving local living standards than sharing the revenue windfall with local governments when institutions are weak. Despite the paucity of empirical evidence, especially for developing countries, the emerging literature is opening new ways to think about the relation between natural resources and economic development.

[21] The content of this chapter is a summary of Aragón, Chuhan-Pole, and Land, "Local Impacts of Resource Abundance: What Have We Learned?" 2015.

2.1 Theory and evidence on the impact of resource abundance at the country level

The literature on the economic impact of natural resources in developing countries has been largely dominated by the phenomenon that some resource-rich economics tend to have worse economic performance than resource-poor countries, that is, the resource curse.[22] Examples abound of poor outcomes in countries with abundant natural wealth. For instance, Nigeria's oil revenues increased almost tenfold between 1965 and 2000, but in that same period, real income stagnated and both poverty and inequality increased (van der Ploeg 2011). Similarly, Venezuela, a primary beneficiary of the increases in oil prices in the 1970s, suffered a steep decline in per capita output of 28 percent from 1970 to 1990 (Lane and Tornell 1996). In Zambia, Africa's largest copper exporter, the incidence of poverty remained virtually unchanged at 60 percent during 2000–10, despite a doubling of economic output during this period. There are exceptions to this rule of resource curse—notably, Botswana, Chile, and, Norway, all of of which have been successful in transforming their resource wealth into economic prosperity. Moreover, resource-abundant countries, such as the United States, Canada, and Sweden, which are now high-income countries, were long ago able to diversify their economies and reduce their dependence on natural resources.

2.1.1 Analytical underpinnings of the impact of resource abundance

Theoretical explanations for the resource curse can be grouped into three broad categories. First, a boom in extractive industries can crowd out other industries, such as manufacturing, that are more conducive to long-term economic growth; this is the Dutch disease argument. Second, dependence on primary sectors could leave an economy vulnerable to changes in commodity prices, which may be more volatile. Third, the windfall from natural resources can exacerbate rent-seeking, corruption, and conflict in a society. These phenomena can lead to bad economic policies, deterioration of institutions, and lower income and growth.

Dutch disease. One of the earliest explanations of the link between resource abundance and lower economic growth is provided by the Dutch disease (Corden 1984; Corden and Neary 1982). Dutch disease models typically assume that an economy produces traded goods (manufacturing) and nontraded goods (services). In these models, a boom in natural resources exports represents an income windfall[23] that increases aggregate demand and raises the price of nontraded goods relative to traded goods. In the short run, this relative

[22] This literature is vast and has been reviewed extensively. See Deacon (2011); Frankel (2011); Rosser (2006); Stevens (2003); and van der Ploeg (2011), for example.
[23] See van der Ploeg (2011, section 3.1) for a formal exposition.

price movement, which is effectively an appreciation of the real exchange rate,[24] causes the output of the nontraded sector to expand, while the traded sector contracts, and factors of production (such as labor and capital) reallocate from the traded sector to the nontraded sector. The effect on the wage-rent ratio depends on the labor intensity of the nontraded industry. In particular, if this industry were more labor intensive, the wage-rent ratio would increase.[25,26]

This market response to a revenue windfall is not by itself negative. In order to explain why resource booms may weigh down economic growth, one needs to assume that the traded sector crowded out by extractive industries is somehow more conducive to supporting growth. This would be the case if the traded sector benefits most from learning by doing and other positive externalities, such as human capital externalities (Krugman 1987; Matsuyama 1992; Sachs and Warner 1995; Torvik 2001). If the traded sector exhibits increasing returns to scale, as in big push models (Murphy et al. 1989), then a shift of resources away from this sector could also be detrimental to growth.

Exposure to changes in commodity prices. A second argument for the negative effect of resource abundance on growth relies on the observed pattern of higher volatility and, until early 2000, long-term decline of commodity price. Thus, natural resource exporters may be exposed to higher volatility of terms of trade. The uncertainty stemming from this volatility could, in turn, reduce investment in physical or human capital.[27] If technological progress is assumed to be driven by learning by doing or human capital externalities, then the decline of investment associated with price volatility can constrain economic growth. In resource-exporting countries, fiscal revenue is often heavily dependent on resource revenue. For example, Angola, the Republic of Congo, and Equatorial Guinea rely on oil for around 75 percent of government revenues. Price volatility, and associated boom-bust cycles, can make it more difficult to implement prudent fiscal policies.

Rent-seeking, corruption, and conflict. Increasing attention is being given to political economy channels in explaining poor development outcomes in resource-rich countries. This is because resource abundance creates rents that can be easily appropriated when institutions are weak. In the absence of strong institutions, resource rents may foster rent-

[24] This happens because the price of nontraded goods is set domestically, while the price of traded goods is set in international markets.

[25] Note that in this context, short run and long run refer to whether capital is fixed or not.

[26] A more realistic model would assume that the extractive sector also employs labor and capital. In that case, in addition to the short-run changes in relative prices and crowding out of the traded sector (the spending effect), there would also be a reallocation of resources to the extractive sector, with negative effects on both traded and nontraded sectors.

[27] Aghion et al. (2009) argue that with imperfect financial institutions, firms exposed to exchange rate fluctuations are more likely to hit liquidity constraints and be unable to invest. Gylfason et al. (1999) propose a model in which price volatility deters firms from moving toward high-skilled tradable sectors, which demand investments in human capital, and instead keep them producing commodities.

seeking behavior, increase corruption, erode quality of institutions, and, in extreme cases, even generate violent conflict.

Aragón et al. (2015) identify at least five political economy channels in the literature through which resources can hinder economic growth and welfare. First, resource abundance may increase rent-seeking—for example appropriation of resource rents via production taxes or other transfers—and reduce net return to investment (Lane and Tornell 1996; Tornell and Lane 1999). The implications of lower investment on growth follow the argument presented above. Second, resource windfalls can attract entrepreneurial skills away from productive activities to more profitable, but socially inefficient, rent-seeking (Mehlum et al. 2006; Torvik 2001). Third, rent-grabbing possibilities can increase political corruption (Brollo et al. 2013) and undermine the development of democratic institutions (Ross 2001). With additional revenues, politicians can appropriate rents, while increasing spending to appease voters. The increased opportunities for grabbing rents, in turn, attract other corrupt individuals to the political arena, leading to a deterioration in the quality of politicians. The high reliance of budgetary revenue on natural resources, as opposed to taxation of citizens, also weakens government incentives to build (or strengthen) institutions of accountability. Fourth, resource booms can increase the returns to predation and promote rapacity over these resources, which can fuel violence and civil conflict (Collier and Hoeffler 2005; Grossman 1999; Hirshleifer 1991). Conflict can have adverse consequences on a country's capital stock and investment, reversing development gains. It can also weaken state capacity. But resource booms do not necessarily increase violence. Dal Bó and Dal Bó (2011) argue that if resource booms raise the opportunity cost of participating in violence, for example, by increasing the returns from productive activity, it could actually reduce violence. Finally, ethnic differences allow the formation of stable coalitions which can facilitate resource-fueled conflict (Caselli and Coleman 2013).

2.1.2 Country-level evidence of the natural resource curse

Several studies have systematically examined the empirical evidence on the resource curse. While early analysis from a cross-section of countries found a negative association between resource abundance (measured as the relative size of primary exports) and GDP growth (Gylfason et al. 1999; Leite and Weidmann 1999; Sachs and Warner 1995, 2001; Sala-i-Martin 1997), recent empirical studies (Lederman and Maloney 2007, 2008) find that evidence of the natural resource curse is far from conclusive. Recent empirical work questions the robustness of the results to alternative specifications and measures of resource abundance. A fundamental critique offered in the recent empirical work is that the measure of resource abundance (usually the relative size of commodity exports) is endogenous. For instance, there may be other confounding factors, such as quality of institutions, which may affect both growth and size of commodity exports. In that case, the resource curse would just reflect the fact that countries with bad institutions have lower growth and are less industrialized, thus more dependent on primary sectors. For instance, Sala-i-Martin and Subramanian (2003) and Bulte et al. (2005) find that when adding measures of institutions as additional controls, the relation between resource abundance and growth disappears. Brunnschweiler (2008) and Brunnschweiler and Bulte (2008) go a step further by arguing that the usual measures of resource abundance are actually a measure of resource dependence. They treat this variable as endogenous and find that the negative relation between resource dependence and growth disappears.

One possibility emerging from the empirical literature is that the effects of resource abundance on growth may be heterogeneous, and could depend on quality of institutions. For instance, the effect could be negative in a country with bad institutions, but positive when institutions are good (Robinson et al. 2006). Failing to account for this heterogeneity may lead to the wrong conclusion that the effect is insignificant.

Political economy explanations for the resource curse

The cross-country empirical evidence points to the relevance of institutions, while offering mixed support for Dutch disease and terms-of -trade volatility as explanations for the resource curse. This suggests that rent-seeking and deterioration of governance may play an important role in explaining the resource curse. Three sets of results point to the importance of institutions in understanding the natural resource curse.

The first set of results suggests that the resource curse may be associated with the so-called "point source" resources. These are resources (such as oil, minerals, and plantation crops) whose production is concentrated in a few geographic or economic areas. This concentration makes it easier for interest groups to control and capture their rents. For instance, Isham et al. (2005) and Bulte et al. (2005) find that point source resources are associated with worse political institutions and lower growth. Boschini et al. (2007) extend this analysis by interacting the type of resource with quality of institutions. They find the combination of abundance of point source resources with low-quality institutions is detrimental for economic growth.

The second set of results suggests that resource abundance seems to be associated with an increase in corruption, deterioration of democracy, and armed conflict, especially in countries with weak democratic institutions. These results are consistent with the rent-seeking explanation of the resource curse. For instance, using a cross section of countries, Ades and Di Tella (1999) find that natural resource wealth is correlated with worse subjective measures of political corruption. Bhattacharyya and Hodler (2010) use a panel data of countries and find that natural resource abundance is associated with perceived corruption only in countries with a history of nondemocratic rule. They interpret this as evidence that resource rents lead to corruption if the quality of democratic institutions is poor. One paper (Tsui 2011) uses a panel data of countries and oil discoveries to show that oil discoveries indeed reduce the quality of democratic institutions, but only in already nondemocratic regimes. Oil does not seem to affect institutions in countries with established democracies. A large body of cross-country evidence points to a positive relation between resource abundance and civil war (Collier et al. 2004; Fearon 2005; Fearon and Laitin 2003; Humphreys 2005; Lujala 2010; Ross 2004). This relation seems to be driven by point source resources, such as oil, diamonds, and narcotics. These results, however, may not be robust to including country fixed effects, which accounts for several time-invariant unobserved omitted variables. For example, using a panel data of countries and including country fixed effects, Cotet and Tsui (2013) fail to find a significant effect of oil discoveries (large and small) on conflict. But there might be nonlinearities in the relation between resource abundance and conflict, because, using a similar approach, Lei and Michaels (2011) do find a positive relation between large oil discoveries and conflict.

Finally, the negative relation between resource abundance and growth seems to be present only in countries with already bad institutions. In an influential paper, Mehlum et al. (2006) show that the resource curse is essentially driven by countries with low-quality institutions. By contrast, in countries with high-quality institutions, resource abundance does not affect growth. Using a panel dataset of countries, Collier and Hoeffler (2009) find similar results. In particular, the resource curse seems to be avoided in countries with strong democratic checks and balances. Boschini et al. (2007) extend these results by adding differences in the type of resources. They find that the curse is present only in countries with low-quality institutions and easily appropriable resources, such as precious minerals and diamonds.

2.1.3 Insights from the country-level literature

Three conclusions emerge from the literature examining the impact of natural resource abundance at the national level. First, natural resources, by themselves, do not seem to be bad for economic growth. But they do become a problem in the absence of good institutions. Second, the problem is bigger for some type of resources that are easily appropriated, such as oil, minerals, and diamonds. Finally, deindustrialization and price volatility may also matter, but not as much as initially believed.

The policy implications that flow from these insights, at the country level, relate to savings and investment of resource rents and macroeconomic measures to address commodity price volatility. The country-level empirical evidence, however, suggests that the main challenge is not to identify the right policies, but to make societies willing (or able) to adopt them. Hence, the main policy recommendation from this literature is that resource-rich countries should improve their institutions in order to make the best use of a resource boom, and avoid its more deleterious effects. This is consistent with several efforts to improve governance in resource-rich economies and to understand how to build durable and effective institutions. This recommendation is consistent with the vast literature in development economics that highlights the importance of institutions (especially the ones that improve property rights) for economic development.

The use of country-level data has significantly advanced our knowledge on the impact of resource abundance. This literature, however, has several limitations. First, there are still relevant concerns regarding the causal interpretation of results. The presence of omitted variables, reverse causality, and measurement error are important empirical challenges in this literature. Scholars have tried to address them by including richer set of covariates, exploiting panel datasets, and using instrumental variables. These solutions, however, still fall short relative to experimental and quasi-experimental approaches currently used in applied economics.

Second, the impacts (positive or negative) of resource abundance are unlikely to be uniformly distributed in a country. For instance, many negative spillovers (such as pollution and population displacement) have a local geographic scope. Distribution of resource rents usually targets certain populations. Similarly, the impact of the demand of extractive industries for inputs may be felt more intensively in specific local markets. These local phenomena cannot be studied by looking at cross-country variation.

Finally, the main policy implication, that is, that countries need to improve institutions to benefit from a resource boom, may offer only limited practical policy insight. An unsolved question is what stakeholders, such as extractive firms, local communities, or funding agencies could do, short of fostering an institutional reform, to ameliorate the negative effects of resource abundance and enhance its potential benefits. Exploring the local impacts of resource abundance may shed some light on this question.

2.2 Assessing the local impacts of resource abundance

Increasingly, attention is turning to analyzing the impact of resource windfalls on local communities where these resources are sourced. In contrast to the country-level literature, which focuses on the country as a unit of observation, the focus is instead on subnational units such as states, counties, or municipalities. By exploiting variation *within a country*, the literature is able to improve the empirical strategy for assessing the impact of resource booms and explore novel mechanisms. There are, however, new empirical challenges that need to be taken into account, in particular confounding changes in prices and population that may affect the interpretation of results.

2.2.1 Analytical framework

The economic literature suggests at least four possible ways to analyze the local economic impact of natural resource booms. One way is to analyze resource abundance as a change in local endowments, leading to specialization in primary sectors (and corresponding changes in relative prices) at the expense of other traded sectors, such as agriculture and manufacturing—in effect, a local Dutch disease. Another is to consider natural resources as a source of fiscal revenue to local communities, so that a resource boom translates into a fiscal revenue windfall. This fiscal channel is at the center of the country-level literature. A more novel approach relies on viewing resource booms as an increase in the demand for local goods and inputs, that is, a positive demand shock. Finally, there are the impacts of resource abundance on local environmental and social conditions, such as pollution, which have received some empirical attention of late.

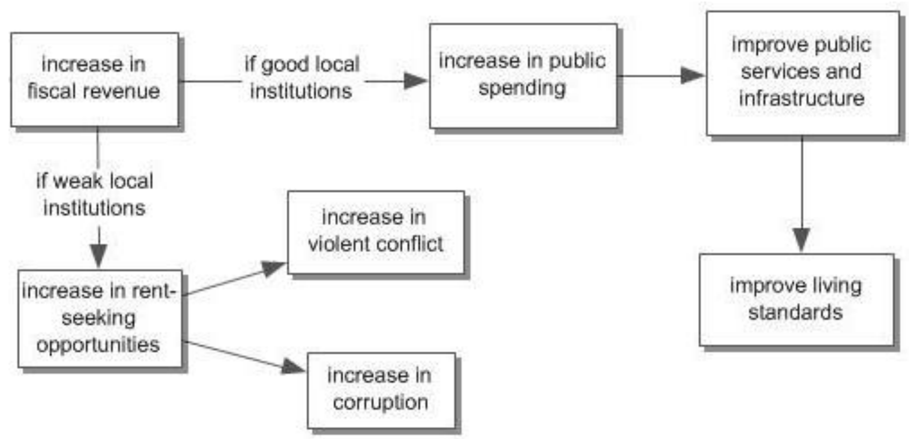
Resource endowments and specialization

If we treat local areas as small open economies, then we can study this change in endowments within the framework of the standard Hecksher-Ohlin model of international trade. Specialization in the primary sector would involve an increase in input prices, such as wages, prompting a reallocation of inputs. In turn, this would increase the cost and price of nontraded goods relative to traded goods. If traded sectors experience faster productivity gains, then specialization in natural resources would hinder long-term economic growth and local income, assuming the population is fixed. A schematic of this model is presented in Annex A.2.1. Predictions from models incorporating this specialization mechanism can be tested empirically: change in relative prices, with the price of nontraded goods rising relative to traded goods; a reduction in the local size of industries producing nationally traded goods—for example, measured by employment shares, share in wage bills, or share in local income; and a negative impact on local economic growth and income.

Local fiscal revenue windfall

Natural resources can be considered as a source of fiscal revenue to local communities, that is, a fiscal revenue windfall. This windfall eases the hard budget constraint of local governments, and supports higher public spending. The revenue windfall could have both positive and negative effects on economic welfare. Figure 2.1 presents an analytical framework of the transmission channels and the impact on local outcomes. In so far as the windfall is used to improve the quantity or quality of local public goods and services, such as roads, hospital, schools, and housing, there would be the potential to improve human welfare outcomes, such as health and education outcomes. Moreover, to the extent that public goods are productive inputs, or create positive spillovers, as in the case of transport infrastructure, a resource boom could also increase local income and growth. The positive effect of revenue windfalls is underpinned by several assumptions: local politicians are responsive to the broad population, which requires well-functioning local institutions and a healthy degree of political competition (Besley and Burgess 2002)[28]; and local bureaucracies have the technical capacity to provide those public goods and services. Lack of responsiveness of local politicians to demands from the broad population or lack of technical capacities of local bureaucrats, may undermine the positive effect of revenue windfalls on public good provision and local living conditions.

Figure 2.1 Fiscal revenue windfall



At the local level, a vast literature suggests that clientelism and vote buying are important distortions. Clientelism refers to transfers made by a political elite to a narrow group of poor or disadvantaged voters to secure their votes and maintain political power. Evidence shows that this targeted redistribution may deteriorate provision of public goods.[29] For instance, in the Philippines, Khemani (2013) documents a negative relation between vote-buying and delivery of primary health services. Using the case of local governments in rural Maharashtra, Anderson, Francois and Kotwal (2014) argue that clientelism may lead to poor governance, even in a context of free and fair elections and active political competition.[30]

[28] In the absence of good democratic checks and balances, the revenue windfall can fail to significantly improve public good provision (Caselli and Michaels, 2013) and lead instead to corruption and worsening of political selection (Brollo et al. 2013).

[29] For a comprehensive review of the literature see Bardhan and Mookherjee (2012) Vicente and Wantchekon (2009), and references therein.

[30] In contexts with weaker democratic institutions, political capture may also be relevant. We discuss this literature in more detail in Section 4.2.

The “rapacity” and “opportunity cost” effects discussed in the country-level literature on conflict, may also explain a failure of resource windfalls to be converted into welfare gains at the local level. Booms associated with “point” resources such as oil and gold (as distinct from “dispersed” resources), may be more prone to generate a rapacity effect, since they mostly increase appropriable rents, but may have a relatively smaller impact on local wages.[31] The literature also indicates that an absence of adequate reallocation and compensation policies, amid competition for scarce resources, will have negative redistributional consequences and can lead to conflict.

The fiscal revenue windfall channel highlights the importance of local institutions, especially political institutions and fiscal decentralization arrangements. These institutions are the subject of increased focus in the local-level literature. The theoretical political economy literature has emphasized the importance of political institutions, such as electoral rules and the form of government (Lizzeri and Persico 2001; Persson 2002). Subnational evidence is consistent with these predictions. For instance, Besley and Case (2003) find that different political institutions between U.S. states such as voter registration procedures, use of primaries, restrictions on campaign contributions, or supermajority requirements affect the degree of political competition and representativeness of elected authorities. In turn, this translates into differences in spending and taxation. Pande (2003) finds that in India, political reservation (wherein some seats in state legislatures are reserved to candidates from minority castes) affects the size of public transfers to some disadvantaged groups. Zhang et al. (2004) find that in China, the use of elections to select local authorities (instead of appointment by the central government) was more conductive to a better allocation of public expenditures. Similarly, Besley and Coate (2003) find that elected utility regulators implement more pro-consumer policies than appointed ones.

A second set of institutions includes fiscal decentralization arrangements. These are rules that define how fiscal revenue will be collected, distributed, and used at the subnational level. The literature on fiscal decentralization is discussed in more detail in Section 2.2.4.

Local Demand Shock

A resource boom can represent an increase in demand for local goods and inputs (Aragón and Rud 2013). A positive demand shock is plausible in contexts in which extractive industries use locally supplied inputs, such as labor or intermediate materials. Note that a similar effect could occur if rents of extractive industries are transferred directly to the local

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[31] However, booms associated with dispersed agricultural resources, such as coffee, banana, and tobacco, may have a greater effect on local wages, and thus increase the opportunity cost for conflict participants (Dube and Vargas 2013).

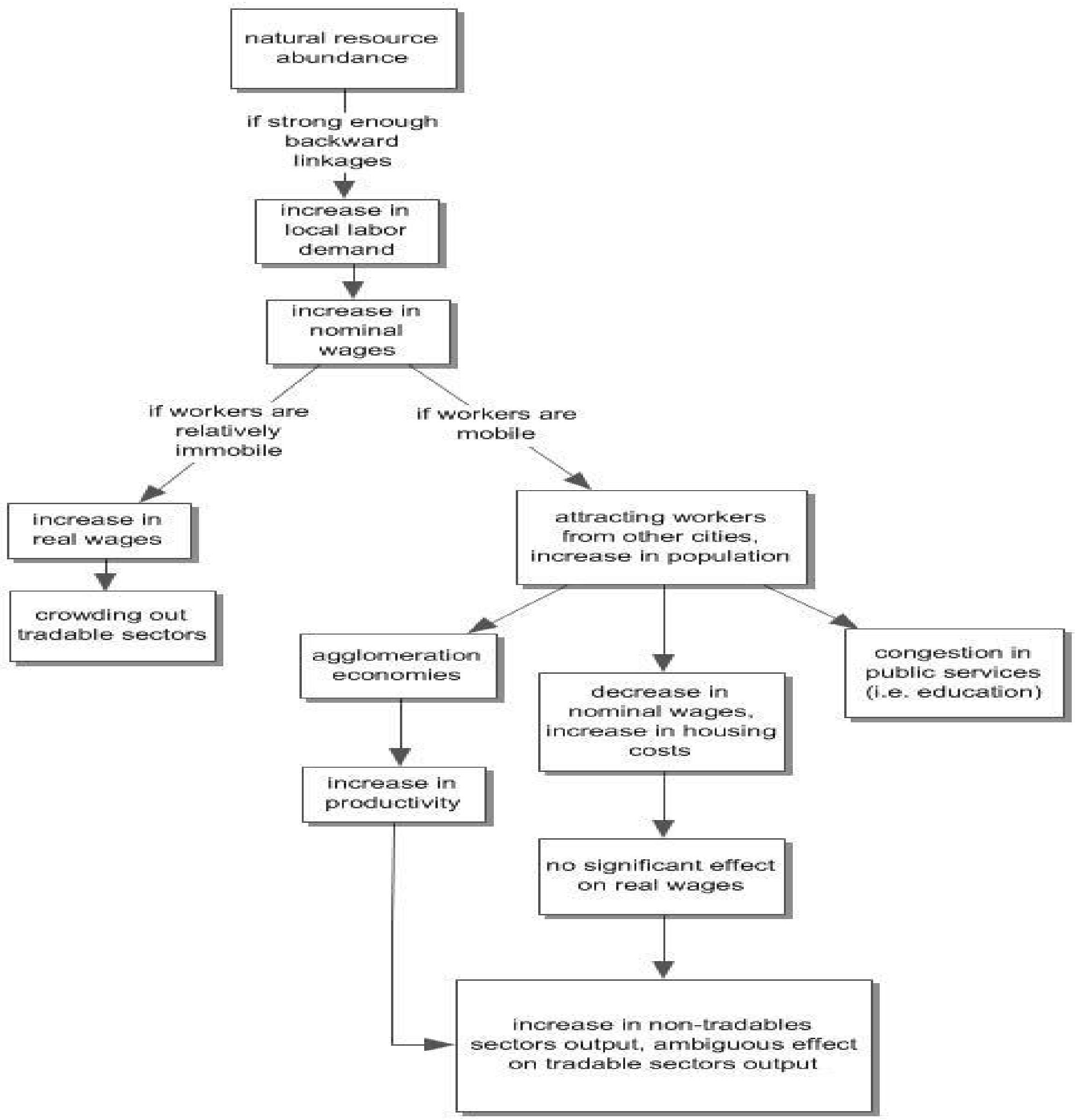
population. Think of this as a direct dividend. Examples of this are the impact benefit agreements in Canada and the permanent fund dividend in Alaska. The extent of the economic linkages of extractive activities would determine the size of the local demand shock. It should be noted, however, that strong backward linkages cannot be assumed in all contexts. A useful framework to examine the general equilibrium effect of such localized demand shocks is provided by models of spatial equilibrium (these models are increasingly used to analyze local housing and labor markets). One commonly used model is the Rosen-Roback framework, where a country is comprised of several cities or local economies and every local economy produces a single internationally traded good using labor, land, and a local amenity. Labor is homogenous and in infinite supply, while land is in fixed supply and immobile. A resource boom would mostly benefit owners of immobile factors, and real wages are equalized across locations. Figure 2.2 depicts the framework for understanding how this positive demand shock would impact local outcomes.

Extending this framework to incorporate an upward sloping supply curve for both labor and land or housing (Greenstone et al. 2010; Moretti 2011), yields more nuanced effects of a local demand shock. A positive shock in the local demand for labor would initially increase nominal wages. This, in turn, would attract workers from other cities, pushing down wages and increasing housing costs. The net effect, however, depends on the elasticity of supply of both labor and housing. Thus, the demand shock can lead to an increase in real wages, and welfare, of workers. Under certain conditions, for example if workers in different industries are substitutable, there could also be wider positive spillovers.

Spatial equilibrium models suggest that local demand shocks would attract workers and increase the local population. This may well increase congestion and create additional pressure on local services, such as education and health. Yet, the growth in population could also generate positive effects in the form of agglomeration economies: gains in productivity associated with the clustering of economic activity. A growing body of evidence, mostly from the United States, suggests that the magnitude of agglomeration economies in manufacturing and high-tech industries is not trivial.[32] There is little evidence, so far, on the magnitude of agglomeration economies generated by extractive industries. Agglomeration effects are explored in a recent paper by Fafchamps et al. (2015) on the contribution of gold mining to proto-urbanization in Ghana, which draws on central place theory.

[32] See Moretti (2011, section 4.1) for a review of the evidence.

Figure 2.2 Local demand shock



Moretti (2011) also points to heterogeneous effects across tradable and nontradable sectors. In particular, the model predicts that the demand shock would benefit mostly the nontradable sector, such as services. The effect on tradable sectors is ambiguous. This effect may be negative due to the increase in wages and land rents. Although, there may be a beneficial effect from increasing agglomeration economies associated with the larger population. Thus, it is not clear whether a resource boom would encourage or crowd out manufacturing. This prediction contrasts with the standard Dutch disease argument, which would predict deindustrialization.

This framework predicts several impacts of a resource boom, if there are strong backward linkages:

- Resource booms would have a positive effect on nominal wages and labor outcomes, such as participation rate, number of hours worked, or employment rates.

- Resource booms could increase real wages, and real income, of local populations, and lower the incidence of poverty.

- There may be positive spillovers working in several industries not directly linked to the extractive activity, and surrounding localities.

- Resource booms would be associated with the migration of workers and an increase in the price of nontraded goods, such as housing.

These predictions have some important implications for empirical analysis. One is that migration induced by the resource boom may change the spatial distribution of a population's productivity. This could happen, for instance, if high-productivity workers are more able to benefit from the boom or face lower migration costs, or if low-productivity workers are displaced away from resource-rich areas. The worry is that an increase in local real income would just reflect the change in population composition, not real improvements in economic well-being. The importance of these compositional effects is case specific.[33]

While this framework predicts a possible positive impact of resource booms on real income, it is less clear what would be the effect on other measures of human well-being, such as education and health. On the one hand, education and health outcomes could improve due to an income effect. In addition, if the resource boom is biased toward high-skilled workers it could increase the returns to education. On the other hand, the increase in wages could increase the opportunity cost of education and discourage it (Atkin 2012). A similar effect can occur if the extractive industry demands low-skilled workers and, thus, reduces the skill premium. In terms of health, an added consideration is that environmental pollution can reduce, or offset, the benefits from higher income.

[33] Some empirical strategies to address this concern include using individual panel data, focusing on subpopulations that reside in the locality before and after the resource boom, and examining observable population characteristics (such as measures of human capital) that may be indicative of the importance of compositional changes.

However, the literature on country case studies amply highlights that extractive industries in less developed and remote settings are associated with limited local hiring, procurement, product sales, and distribution of profit, especially if large-scale and foreign owned. In the policy arena, the Africa Mining Vision of 2009 has as its central pillar the aspiration to move mining on the continent out of the enclave and into a more locally integrated form of socioeconomic development.

Negative Externalities

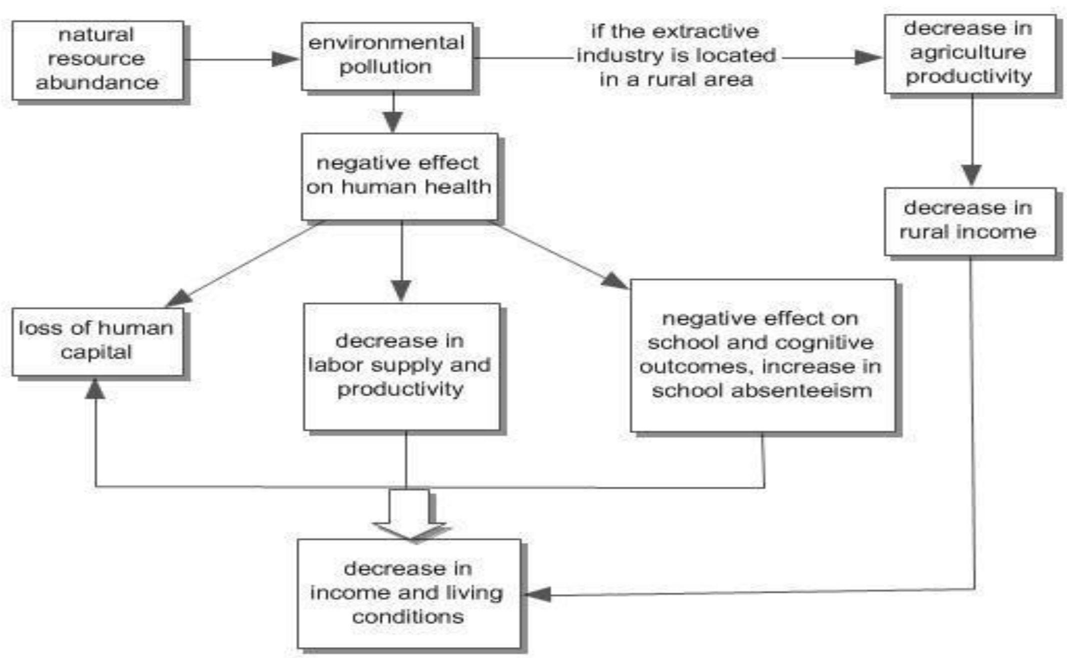
Mining and mineral processing can generate several types of negative externalities impacting local community welfare. For instance, these activities can generate significant amounts of air pollutants from dust from blasting and earth-moving operations, fumes from smelters and refineries, and exhaust of gasoline engines of heavy machinery. If toxic emissions are relatively large, they can deposit on the ground as acid rain, which contributes to soil degradation and can have cumulative negative effects (Menz and Seip 2004). Mining activities can also release industry-specific pollutants, such as cyanide, sulfuric acid, mercury, heavy metals, and acidic drainages (Dudka and Adriano 1997; Salomons 1995). These pollutants can have negative, cumulative effects, on quality of soil and water sources. Similarly, small-scale and artisanal mining operations can pollute air and water. The most notorious example is pollution from mercury used in gold amalgamation.

Environmental pollution can adversely impact health (Currie et al. 2013; Graff-Zivin and Neidell 2013) and, more broadly, labor supply and labor productivity (Graff-Zivin and Neidell 2012; Hanna and Oliva 2011). There is evidence that pollution can adversely affect cognitive outcomes and educational attainment (Almond et al. 2009; Lavy et al. 2012) and increase school absenteeism (Currie et al. 2009; Gilliland et al. 2001; Park et al. 2002; Ransom and Pope III 1992).

Another possible important pollution externality is the loss of agricultural productivity (Aragón and Rud 2015). The mechanisms through which this may take place have been examined in recent literature. One is through directly affecting crop health and growth (Heck et al. 1982; Miller 1988; Marshall et al. 1997), which translates into lower yields. Another is through degrading the quality of key agricultural inputs, such as soil and water (Menz and Seip 2004; U.S. Environmental Protection Agency 2012). For instance, deposition of air pollutants in the form of acid rain can lead to soil degradation. The increased acidity leaches nutrients from the soil, reduces plants' ability to absorb remaining nutrients, and releases toxic metals, like aluminum. Finally, air pollution can reduce labor productivity (Chang et al. 2014; Graff-Zivin and Neidell 2012). The loss of agricultural productivity can have a negative impact on agricultural output, and, through that channel, affect income of farmers and rural populations. This externality can be particularly relevant when extractive industries are located in the vicinity of rural areas, in which agriculture remains an important source of livelihood.

This framework has several implications for empirical analysis. First, it suggests examining the effect of resource booms on nonincome measures of well-being such as indicators of human health: mortality rate and incidence of illness. Second, it points to other possible outcomes such as worker productivity, labor supply, and agricultural output. Finally, it emphasizes the loss of agricultural productivity, through which resource booms could negatively affect local income, especially in rural areas.

Figure 2.3 Environmental pollution



2.2.2 Empirical evidence on local impact

In contrast to the country-level literature, the empirical literature exploiting within-country variation is more recent and less developed. There are, however, a growing number of studies already expanding this literature that are reviewed by Aragón et al. (2015). Broadly, the literature has focused on the impact of resource abundance on growth, employment and local living standards, corruption and conflict, and pollution.

Impact on growth. Using a cross section of subnational data from the United States, several studies have replicated the growth regressions used in the cross-country literature (Douglas and Walker 2013; James and Aadland 2011; Papyrakis and Gerlagh 2007). A more recent study (Zuo and Jack 2014), examined the impact on growth using data from

Chinese provinces. For the most part, these studies detect a local resource curse (table 2.1). However, it is difficult to interpret these results in a causal way because these studies suffer the same limitations of omitted variable bias, reverse causality, and measurement error as the country-level resource curse empirics.

Table 2.1 Empirical evidence of the impact of resource abundance on local growth

Paper	Explanatory variable	Outcome variable	Sign	Country, data level	Identification strategy
Douglas and Walker (2013)	Share of coal revenue in total county personal income	Income growth rate	–	U.S., county level	Cross-sectional OLS
James and Aadland (2011)	Share of earnings in resource-extraction industries			U.S., county level	Cross-sectional OLS
Papyrakis and Gerlagh (2007)	Share of primary sector in local GDP			U.S., state level	Cross-sectional OLS
Zuo and Jack (2014)	Provincial annual energy production per capita, or provincial annual energy production, or ratio of the regional energy production over GDP			China, province level	Fixed effect panel model

Source: Aragón, Chuhan-Pole, and Land 2015.
Note: + = positive relation; - = a negative relation; 0 = statistically insignificant; OLS = ordinary least squares.

Impact on employment and local living standards. In a shift away from the cross-country growth regressions, several studies have treated resource booms and busts in developed resource-rich countries (United States, Canada, and Australia) as shocks to the local demand of labor and examined the resulting economic spillovers (table 2.2).[34] These studies show that booms in coal mining, oil, and gas generate positive employment

[34] Black et al. (2005) use county-level data from the coal-rich areas in U.S. Appalachia to examine the short-term economic impact of the coal boom in the 1970s and subsequent bust in the early 1980s. Marchand (2012) uses data from Western Canada to examine the effects on local labor markets associated with the 1970s energy boom and bust. Fleming and Measham (2014) study the employment spillovers associated with the recent boom of coal seam gas in Australia. Michaels (2011) examines the long-term economic impact of oil discoveries in the Southern United States. He uses county-level data covering 1940 to 1990 and exploits geological variation in oil abundance. Allcott and Keniston (2013) extend Michaels' (2011) study to rural counties in the entire United States. More recently, Jacobsen and Parker (forthcoming) extend Black et al.'s (2005) study to the Western United States. They focus on oil and gas boomtowns created during the 1970s increase in energy prices. They also use county-level data but observe a longer time span, that is, 1969 to 1998. This allows them to explore the effect of a bust after a longer period.

spillovers in the short term—that is, increase in jobs and nominal wages in other industries. But these studies provide less clarity about the crowding-out of local manufacturing, with some studies documenting a reduction in the relative size of manufacturing, and others finding evidence of an increase in manufacturing activity. This points to booms generating possible agglomeration effects (increase in size of local markets) that benefit local manufacturing. Another limitation of these studies is that they do not examine the effects on real income and other measures of well-being.

Whether these local effects of resource booms carry over to less developed countries is being addressed by a limited, but growing, literature. From the analytical framework on local demand shocks, it follows that the economic effects at the local level depend on several context-specific factors, such as the degree of economic linkages of extractive activities (which determine the size of the local demand shock), substitutability of labor among industries, and labor mobility.

Caselli and Michaels (2013) use municipality-level data to examine the local economic effect of oil-based fiscal windfalls in Brazil. They find that oil production is associated with an increase in oil royalties paid to local governments and in public spending. However, the impact on provision of local public services is minimal. There is no significant improvement in housing quality or quantity, supply of educational or health inputs, or welfare receipts.[35] There is also a negligible effect on household income and population size.

These findings suggest that oil production has not been particularly beneficial to the local population, because the extent of economic linkages between oil companies and local economies is limited in Brazil. Instead, circumstantial evidence suggests that the oil revenues were used to fund patronage and extract rents, and were embezzled by officials. Using data from all municipalities (not only the recipients of oil royalties), Brollo et al. (2013) find that fiscal windfalls are indeed associated with an increase in political corruption.

Two studies have examined the impact of mining on local economies in Peru. Aragón and Rud (2013) examine the importance of economic linkages in the case of Yanacocha, a large gold mine in the Peruvian highlands. Using household-level microdata and a difference-in-differences approach, they find that backward linkages had a positive economic impact on real income and poverty reduction. The benefit of the local demand shock extends to local population not directly linked to mining, such as farmers and service workers. Similar to the findings of Caselli and Michaels (2013), they find that increased local revenue and public spending associated with the resource boom do not translate into higher household

[35] Using the same case but a different methodology, Monteiro and Ferraz (2010) also document that the oil windfall is associated to reported increases in expenses and size of the public sector, but no improvement in public services to the local population.

income. Using a rich dataset at the district level, Loayza et al. (2013) find a positive relation between measures of living standards (such as poverty, consumption, and literacy) and mining production, but not with government transfers associated to mining tax revenue.[36] Findings from Brazil and Peru cast some doubt on the usefulness of revenue-sharing schemes as a policy instrument for local communities to benefit from resource booms.

The more recent, though limited, literature on developing countries suggests that the presence of backward economic linkages from mining might play an important role in determining local economic outcomes. It also suggests that more research is needed to understand how revenue-sharing schemes can be an effective policy instrument for local communities to benefit from resource booms.

In one of the few studies focusing on Africa, Kotsadam and Tolonen (2015) examine the effect of mining on local employment. They use a rich dataset at the individual level for several Sub-Saharan African countries, and implement a difference-in-differences approach exploiting the opening and closure of mines. This study finds that mine openings seem to create new employment opportunities outside agriculture, and significant structural shifts. Interestingly, these effects are differentiated by gender. Women switch toward service sectors, while men move toward skilled manual jobs. Moreover, women's participation rate decreases with mine openings, while men's participation rate increases. These structural changes seem to persist after mine closures, at least for women. After a mine closure, men return to agricultural jobs, but women do not shift back to agricultural production. Instead, they leave the labor force. The authors interpret these findings as evidence that mining works as a boom-bust economy on the local level in Africa, but with permanent (negative) effects on women's labor market participation.

[36] Moreover, they find suggestive evidence that mining is associated with an increase in inequality. The authors highlight that this increase in inequality, among other factors, may explain the opposition of local communities to mining projects. A similar relationship among resource booms, income, and inequality has been reported in the case of Australia (Reeson et al. 2012). Interestingly, this study suggests that the relation between mining and inequality may have an inverted U-shape.

Table 2.2 Empirical evidence of the impact of resource abundance on local living standards

Paper	Explanatory variable	Outcome variable	Sign	Country, data level	Identification strategy
Allcott and Keniston (2013)	Whether the county produces any oil or gas in any year after 1969	Income growth rate, wages	+	U.S., county level	Difference-in-differences
		Manufacturing employment and output	+		
		Factor productivity	0		
Aragón and Rud (2015)	Gold mine production	Household income	+	Peru, household level	Difference-in-differences
	Mining transfer	Municipality revenue and expenditure	+		
		Household income	0		
Black et al. (2005)	Whether the county is the coal boom county	Employment and wages	+	U.S., county level	Instrumental variables
Caselli and Michaels (2013)	Oil output	Local government revenues	+	Brazil, municipality level	Instrumental variables
		Local government spending	+		
		Local public service	0		
		Household income	0		
Fleming and Measham (2014)	Indicator of having a coal seam gas operation	Income growth, employment	+	Australia, individual level	Cross-sectional OLS
Jacobsen (2013)	Whether the county is the oil and gas boom county	Nominal income, wages, employment and population	+	U.S., county level	Fixed effect panel model
		Manufacturing employment	0		
Kotsadam and Tolonen (2015)	Mine openings	Service sector employment	+	Sub-Saharan Africa, individual level	Difference-in-differences
		Agriculture employment	-		
		Women - service sector employment	+		
		Men - skilled manual jobs employment	+		
	Mine closings	Women - agriculture employment	0		
		Men - agriculture employment	+		
Loayza et al.	Mining production	Household consumption, literacy	+	Peru, district	Matching and
		Poverty rate	-		

(2013)		Consumption inequality	+	level	propensity
Marchand (2012)	Indicator of having 10% or more of their total earnings from the energy extraction sector	Employment and earnings	+	Canada, province level	Difference-in-differences
Michaels (2011)	Indicator of whether the county is located above an oil field or part of an oil field (or multiple oil fields) that contains at least 100 million barrels of oil before any oil was extracted	Employment share of mining	+	U.S., county level	Fixed effect panel model
		Employment share of agriculture	-		
		Employment share of manufacturing	0		
		Stock of educated workers	+		
		Nominal income	+		

Source: Aragón, Chuhan-Pole, and Land 2015.
Note: + = positive relation; - = negative relation; 0 = statistically insignificant; OLS = ordinary least squares.

Impact on corruption and conflict. There is a small but growing literature on within-country evidence linking resource booms to corruption and conflict (table 2.3). As discussed earlier, evidence from Brazil (Brollo et al. 2013; Caselli and Michaels 2013) suggests that the fiscal revenue windfall associated with oil royalties has increased corruption and rent-seeking at the local level. A fiscal revenue windfall is also associated with changes in political outcomes. For example, Brollo et al. (2013) argue that an increase in revenues allows bad politicians to increase public spending, while diverting rents. This translates into higher reelection rates of incumbents. Monteiro and Ferraz (2010) also document a similar increase in incumbency advantage, but only in the short term.

Anticipation of a windfall could change political behavior even before resources are actually extracted. This could happen because anticipated rents (from future resource extraction) increase the value of political positions, and politicians may start competing for office now in order to capture future rents. Vicente (2010) examines this issue in the context of São Tomé and Principe's announcement of oil discoveries. He uses microdata at the individual level with retrospective information on perceived corruption. He finds that oil discovery announcements are associated with an increase in perceived vote buying and corruption across a range of public services, such as customs, public procurement, state jobs, health care, and police.

The empirical study of resource abundance on local conflict has focused on exploring two possible mechanisms: the opportunity cost effect and the rapacity effect. As previously discussed, these mechanisms have different implications for the effect of resource booms on conflict, depending on the type of resource being exploited. Resources that increase local wages, such as agricultural products, decrease conflict by affecting the opportunity cost of conflict. By contrast, resources that create appropriable rents, such as oil, diamond, and minerals, may encourage conflict through a rapacity effect. Dube and Vargas (2013) provide convincing evidence of the importance of both the opportunity and rapacity effects. Using municipality-level data from Colombia, they find that increases in oil, coal, and gold prices are associated with an intensification of conflict, while the opposite is true for increases in the international prices of agricultural products, such as coffee, banana, sugar, palm, and tobacco.

Table 2.3 Empirical evidence of the impact of resource abundance on corruption and conflict

Paper	Explanatory variable	Outcome variable	Sign	Country, data Level	Identification strategy
Angrist and Kugler (2008)	Coca prices	Violent conflict	+	Colombia, individual level	Difference-in-differences
Brollo et al. (2013)	Oil royalty revenue	Political corruption	+	Brazil, municipality level	Regression discontinuity
		Quality of political candidates	-		
Dube and Vargas (2013)	Oil, coal, and gold prices	Conflict	+	Colombia, municipality level	Difference-in-differences
	International prices of agricultural products		-		
Monteiro and Ferraz (2010)	Oil royalty revenue	Incumbency advantage	+	Brazil, municipality level	Instrumental variables
		Public employment	+		
		Educational and health supply	0		
Vicente (2010)	Oil discovery announcements	Perceived vote buying and corruption on public services	+	Africa, individual level	Difference-in-differences

Source: Aragón, Chuhan-Pole, and Land 2015.
Note: + = positive relation; - = negative relation; 0 = statistically insignificant.

Impact on pollution. There is a vast literature highlighting the potential for mining and other extractive industries to pollute the environment. The negative effect of pollution on human health and, through that channel, on labor supply and labor productivity has also been documented in several studies (see references above). Despite these findings, empirical work directly examining the socioeconomic impacts of mining-related pollution is limited.

Some recent work examining mining pollution points to localized impacts on health and education. For example, Rau et al. (2013) examine the impact on educational achievement of children living in proximity to a deposit of mineral waste, which had hazardous levels of lead and other heavy metals, in northern Chile.[37] These children were found to have higher concentrations of lead in their blood, and worse academic performance. The study estimates that this translates into a significant loss of earnings in adulthood.[38] van der Goltz and Barnwal (2013) examine the effect of mining on human health outcomes using a rich microdataset from 44 countries and a difference-in-differences approach. They find suggestive evidence that mining is associated with an increase in stunting and anemia among children and young women, respectively. The effects are localized in the vicinity of mines (that is, within 5 kilometers [km]). Interestingly, these effects occur despite an increase in household wealth, spotlighting the trade-off between economic benefits and health costs that mining communities may face.

The importance of a pollution externality (that is, loss of agricultural productivity) that may occur when potentially polluting industries are located in the vicinity of rural areas is well highlighted by Aragón and Rud (2015). The study focuses on the effect of pollution on agriculture in the context of large-scale gold mining in Ghana. The authors find robust evidence that cumulative gold production (a measure of the stock of pollution) is associated with a significant reduction in agricultural productivity, with the effects concentrated closer to mines sites, that is, within a 20-km radius of mine sites, and declining with distance.[39] This loss of productivity is associated with an increase in rural poverty. They rule out alternative explanations, such as mines competing for local inputs (and increasing input prices), or changes in the composition of the local population, that may occur in the presence of selective migration (table 2.4).

[37] This is a case of environmental negligence in northern Chile in which hundreds of houses were built in the proximity of a deposit of mineral waste.
[38] The estimated figure is around US$60,000 for the average affected individual.
[39] Using satellite imagery, they also document an increase in the concentration of air pollutants in the proximity of mines.

Table 2.4 Empirical evidence of the impact of mining-related pollution

Paper	Explanatory variable	Outcome variable	Sign	Country, data level	Identification strategy
Aragón and Rud (2015)	Cumulative gold production	Agricultural productivity	-	Ghana, household level	Difference-in-differences
		Poverty	+		
		Respiratory diseases among children	+		
Rau et al. (2013)	Distance to the mineral waste site	Academic performance, earnings in adulthood	-	Chile, individual level	Two sample instrumental variables
von der Goltz and Barnwal (2013)	Indicator of whether the cluster is within 5 kilometers of the nearest mine	Stunting and anemia among children and young women	+	44 developing countries, individual level	Difference-in-differences

Source: Aragón, Chuhan-Pole, and Land, 2015.
Note: + = positive relation; - = negative relation; 0 = statistically insignificant.

2.2.3 Insights on impacts at the local level

Although the literature on the local impact of natural resource abundance is still emerging, it is already providing valuable insights. First, and in line with the country-level literature, it suggests that a local resource curse is not inevitable. On the contrary, there are some examples in which resource abundance has no detrimental effects. A provocative idea is that the channel through which resource rents reach a local economy might matter. When resource rents are distributed using public channels (such as a revenue windfall to local governments), resource booms do not seem to improve living standards, and may even foster negative side effects such as conflict, rent-seeking, and corruption. By contrast, when these rents are distributed through market channels (such as an increase in demand for local workers), resource booms may bring some economic benefits to the local population, at least in the near term. The failure of fiscal channels can reflect preexisting institutional factors that limit the responsiveness of local politicians and facilitate rent-seeking, as suggested by the country-level literature.

Second, there is no conclusive evidence that resource booms lead to deindustrialization, despite the increase in price of local inputs. On the contrary, in some cases, resource booms are even associated with an increase in manufacturing activity. This finding is the opposite of what we would expect from the standard Dutch disease arguments, and suggests that other effects, such as agglomeration economies, may also be relevant.

Finally, this literature highlights the importance of examining a broad range of outcomes, besides income and growth. Evidence linking resource booms to local demand shocks, employment shifts, and pollution suggests that natural abundance may also affect other measures of human well-being such as inequality, education, and health.

2.2.3 Input-output analysis

Analysis based on input-output models and Social Accountability Models are useful for economic planning and ex-ante impact evaluation. These tools construct mathematical models of an economy and then calculate the change on economic outcomes associated with changes in some variables, such as spending or output. Depending on data availability, these models can be built to describe regional and local economies, and thus inform about impacts at the subnational level. Their predictions are informative of what the economic effect of a mining project could be. Some countries, like Canada and the United States, routinely use I-O models to assess the ex-ante economic impact of extractive industries. But a main limitation of these models is that they do not tell what the effect actually is, for reasons that are well known (the Lucas critique).

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2.2.4 Role of institutions at the local level

As noted earlier, a second set of local institutions for effective use of fiscal revenues includes fiscal decentralization arrangements. These are rules that define how fiscal revenue will be collected, distributed and used at the subnational level. Aragón et al. (2015) find that the literature points to a limited scope for decentralization of mining-related taxes. The main sources of mining revenue, such as corporate tax and royalties, may be better managed by higher government tiers (national or regional) on grounds of efficiency, equity, and reduced administrative cost. There are, however, some tax tools that could be suitable to local governments, such as property taxes, surtaxes, and land use fees. Importantly, it also points to the importance of intergovernmental transfers to match increased local needs and to compensate local populations.

In practice, intergovernmental transfers are important tools to redistribute mining revenue among local populations. Transfers consist of nonmatching unconditional transfers, nonmatching conditional transfers, and selective matching transfers (cost-sharing programs). From an analytical perspective, nonmatching transfers create an income effect, while matching transfers change the relative price of public goods, thus also creating a substitution effect.

Another way to classify transfers is based on their source of funding. Some transfers are paid with funds from the national budget. Others are linked to a particular source of revenue or tax. This last type of transfer, also called a revenue-sharing or tax-sharing scheme, is commonly used to distribute mining revenues. Revenue-sharing schemes usually define the sharing rate and allocation procedure by law and thus are less subject to the uncertainties of annual budget negotiations. These schemes effectively give local recipients ownership over part of the stream of future fiscal revenue.

The main advantages of revenue-sharing schemes are their simplicity and transparency. They also give incentives to local politicians to support mining activities. But they have several disadvantages. First, if they are based only on certain taxes, they may bias national tax policy. In particular, they may discourage national fiscal efforts to collect those taxes. Second, if they share the revenue from origin-based production (as in the case of mining-related sharing schemes), they can break the link between revenue needs and revenue means at the local level; in other words, targeted localities may end up receiving too many resources. In turn, this can reduce the accountability of local politicians and their incentives to spend public funds efficiently. A similar phenomenon can occur if the sharing rate is applied uniformly, and thus revenue is unrelated to actual spending needs. Third, if revenue-sharing schemes depend on only a few taxes (such as mining firm corporate taxes), then their funding is exposed to industry shocks, such as changes in commodity prices. This can increase the volatility of local fiscal revenue. Finally, if tax collection is done locally and shared with the national government, then revenue-sharing schemes can create perverse incentives among local authorities to reduce fiscal effort or underreport tax revenues.

There is a lack of quantitative studies examining how different fiscal decentralization arrangements used to distribute mining revenues can shape the effect of this windfall. The current literature mostly focuses on examining how different degrees of decentralization affect income growth or corruption at the country or regional level. These studies use measures of expenditure or revenue decentralization, such as share of subnational governments in tax revenues or public spending. While not aimed at understanding how decentralization of mining revenues affects local communities, this literature might be informative of the overall impact of fiscal decentralization.

Related work examines the link between decentralization, corruption, and local capture. Evidence from less developed economies shows that decentralization can facilitate capture of local governments and collusion between local officers and local elites. For instance, Galasso and Ravallion (2005) find that the targeting performance of the Food for Education program in Bangladesh is worse in communities where land inequality is greater, and they interpret this as evidence of elite capture. In Ecuador, Araujo et al. (2008) find evidence that local capture of a social development fund was more likely in villages with greater inequality. Jia and Nie (2015) show how decentralization has facilitated collusion between coal mines and industry regulators in China, and that this has translated into poorer safety standards, and increased mortality rate of workers.

2.3 Conclusion

A review of the emerging research on the local impact of natural resource booms and sharing of resource rents is beginning to provide new insights on how the channels through which these shocks are transmitted matter. First, a number of empirical studies find that resource abundance may have negative effects by increasing corruption, deteriorating local political processes, and even increasing conflict. This evidence is similar to the cross-country literature, but is far from conclusive. Second, this work highlights the importance of studying other local phenomena such as the general equilibrium effects of local demand shocks, migration, and environmental pollution. These factors may also affect welfare and make the impact of natural resources more nuanced. Finally, there is a well-developed literature discussing several tools to distribute resource rents, and the principles that guide fiscal decentralization. There are, however, still several limitations and unsolved questions that merit further study.

A main limitation of the literature is that it is still emerging and, consequently, there is a paucity of robust empirical evidence on the effect of resource abundance on employment, local income, distribution of income, and poverty, especially in developing countries. The available evidence is sparse and focuses on a handful of countries—namely, the United States and Canada among developed countries and Brazil and Peru among developing countries. Research in other resource-rich contexts, particularly Sub-Saharan Africa, is needed to increase the external validity of these results and to better inform policy makers and practitioners.

A related issue is the limited number of quantitative studies exploring the effect of extractive industries on nonincome outcomes such as health, education, and pollution externalities. The few existing studies suggest that the impacts on health and agricultural productivity can be important and costly. Again, additional research is needed to gain a more complete view of the scope and magnitude of these negative spillovers, and to better understand the mitigation actions needed to ameliorate these potential negative effects.

Because the empirical literature on the local impacts of resource booms is still emerging, findings need to be interpreted carefully. For example, available research highlights the importance of market compared to fiscal mechanisms to create positive local impacts. It suggests that in the context of already weak institutions of governance, developing local supply chain linkages may be more effective in improving local living standards than sharing the revenue windfall with local governments. More empirical analyses are needed, however, to confirm these initial findings and to evaluate the effectiveness of different policies in developing these local linkages.

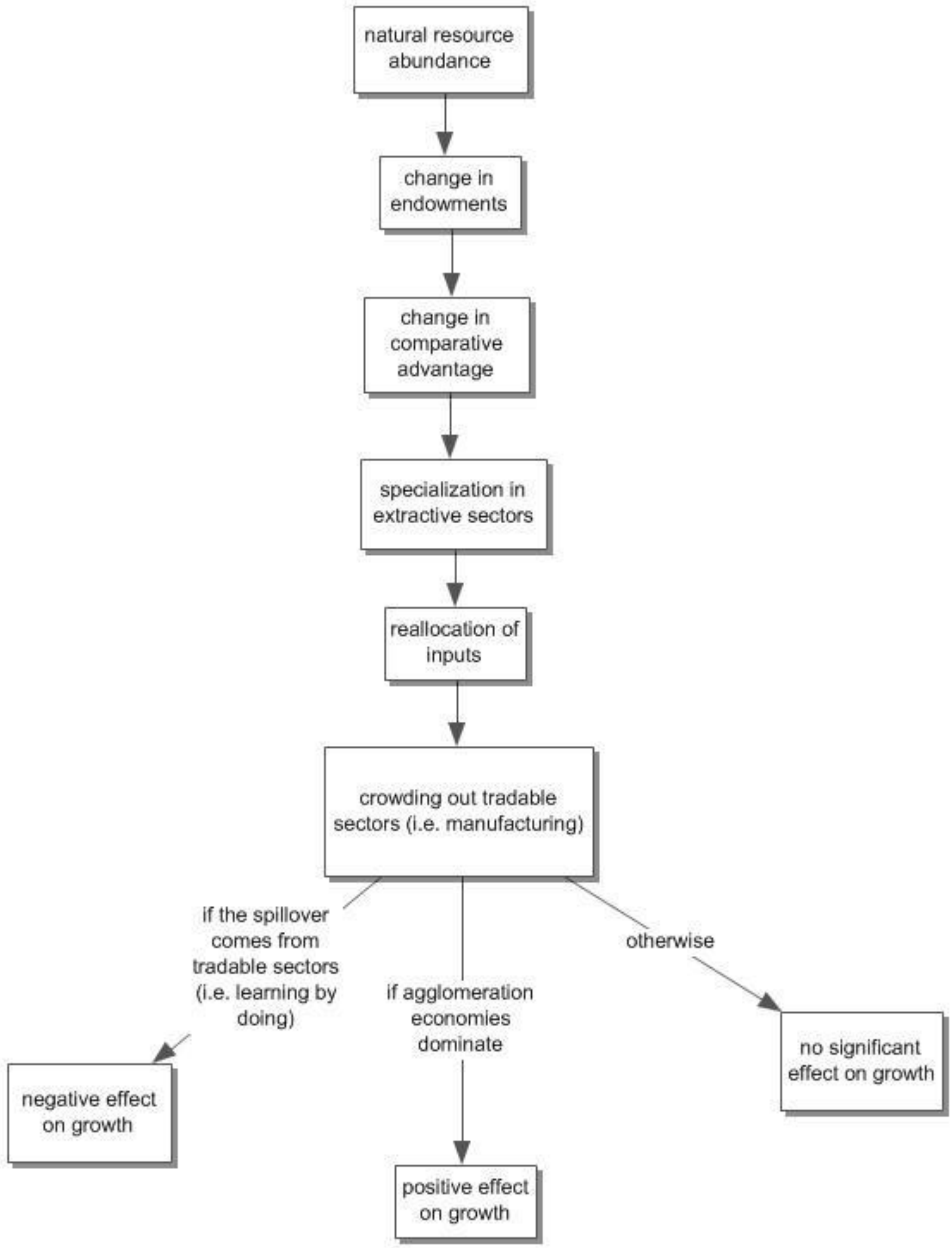
The findings of the review suggest that more quantitative research is needed to examine the effect of resource abundance on political outcomes. The existing evidence, mostly from Latin America (Brazil and Peru), already suggests that the revenue windfall associated with resource abundance may hinder political selection and increase corruption. There is a paucity of evidence, however, from other regions with different institutional contexts, such as Sub-Saharan Africa. Different institutional arrangements may attenuate, or exacerbate, these negative effects. As the delivery of public services and programs is increasingly shifted to local governments, including local politicians, local governance issues and institutions of accountability are of paramount importance. There is also a lack of evidence examining the effect of resource abundance on less violent forms of conflict, such as riots and civil unrest.

In addition, there is a paucity of empirical evidence assessing the political economic impact of different fiscal decentralization arrangements. The existing evidence examines the effect of the overall degree of decentralization, but it is not informative of the importance of the specific institutional arrangements, such as type of transfers, type of revenue-sharing schemes, or type of competences devolved. These features may affect the impact of resource revenues on local income, corruption, or local political responsiveness. Similarly, there is not much evidence on which institutional factors contribute to the success (or failure) of fiscal decentralization. Understanding these questions is crucial to inform the design of fiscal decentralization.

Finally, a related issue is the role of technical capacities of local bureaucrats and public officials. Even if local governments have the political will to use revenue windfalls to promote local development, they may lack the appropriate technical capacity to formulate and implement necessary public programs and projects. Some studies, using the Peruvian case, suggest that lack of capacity may be important and affect local governments' spending ability (Aragón 2013; Aragón and Casas 2009). More research is needed, however, to understand the main technical constraints faced by local governments, their effect on the ability of communities to benefit from a revenue windfall, and the best policies to alleviate them.

Annex

Figure A.2.1 Change in endowments



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Chapter 3: Insights from Three Country Case Studies

3.1. Introduction

Industrial gold mining is a natural choice for studying the socioeconomic impact of natural resources in Africa. As noted in Chapter 1, Ghana, Mali, and Tanzania are not new gold producers, but the advent of large-scale, industrial gold mining is recent and has been growing rapidly. Hence, it is possible to discern changes brought about by large-scale mining via "before- and-after" type studies, as well as by studying the outcomes and changes in mining areas as opposed to nonmining areas. However, each country is a special case, so the country studies constitute an integral part of the overall analysis by considering the specific country context.[40] This section summarizes elements of those studies, noting similarities and contrasts.

The point of departure in each of the studies comes from the tension between the national or macroeconomic gains from minerals and the local gains. This arises from the fact that, in all three countries, subsurface minerals belong to the national state, and the central government as guardian exercises ownership rights over those minerals. Local host communities have no property rights to the minerals. For the country as a whole, the benefits flow from exports and fiscal revenue.[41] For the mining areas themselves, these benefits may appear remote and their impact minor or imperceptible.

There are three mechanisms, or channels, through which the impacts are felt: (a) employment, income, and other positive spillovers such as improved infrastructure, worker training, and management; (b) government revenue: since government is the main recipient of the benefits from the minerals, the mechanism by which the revenues are distributed to the subnational authorities and, particularly, the mining ones, is a key determinant of the local impact; and (c) the negative externalities: the revenue benefits are national but the environmental and other costs such as congestion and population displacement will be local. As noted in the preceding chapters, while the national cost-benefit may have a positive balance, the mining areas themselves may not. The case studies therefore track the impact of mining through these three channels to gain insights into the country-specific institutions, practices, and outcomes. This chapter will examine these findings after a brief description of the role of large-scale mining in each country.

[40] This chapter draws on the three background papers, Sanoh and Coulibaly (2015) on Mali, Smith and Kinyondo (2015) on Tanzania, and Ayee and Dumisa (2014) on Ghana.

[41] As discussed in Chapter 2, there may also be costs in the form of Dutch disease and other elements of the so-called resource curse.

3.2. Country Background: Gold Mining in the three Countries

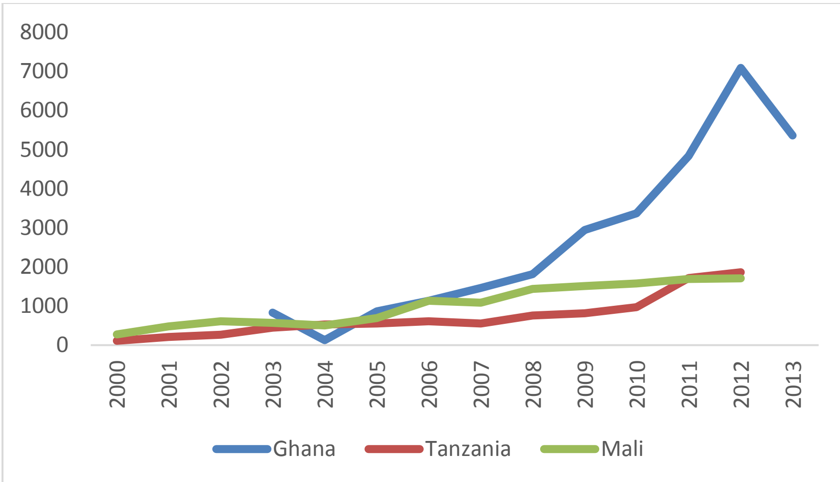
The role of gold: Important but not dominant

Large-scale gold mining and extractive industries in general are relatively capital-intensive industries. From a macro perspective, since foreign multinational companies own much of the capital, the returns to domestic factors of production, in particular labor, are relatively small. Thus, because mining is not a major employment generator, the national benefits from mining are mostly in the form of government revenue and net exports.

The contribution of gold mining to GDP in each of these countries is modest. In Mali, the poorest of the three countries, about 7 percent of GDP is due to mining and quarrying; in Ghana it is 5.5 percent (Bermudez-Lugo, 2012), and in Tanzania it is 4 percent.[42] However, in all three, the value of gold exports is substantial (figure 3.1) and gold is an important component of exports: for Mali, the annual average between 2000 and 2013 was 69 percent of exports; for Ghana, gold averaged 38 percent of exports over the same period; and in Tanzania, the figure was 31 percent (figure 3.2). Mali, in particular, with gold being such a large part of exports, is sensitive to the price of gold. The country study (Sanoh and Coulibaly 2015) notes the perception that the price of gold is the key determinant of business cycles in Mali. Although this dependence is not as strong in Ghana and Tanzania, it is nevertheless significant. Not surprisingly, the price of gold is a key determinant of the terms of trade, which is always a crucial factor in the macroeconomic fluctuations of developing countries. The contribution of gold mining to government revenue varies: in Mali, revenue from gold mining constitutes 25 percent of central government revenue; and in Ghana, the comparable figure is 4.9 percent; whereas in Tanzania, it was barely 2.5 percent. The contribution of gold mining to fiscal revenues is discussed in more detail below.

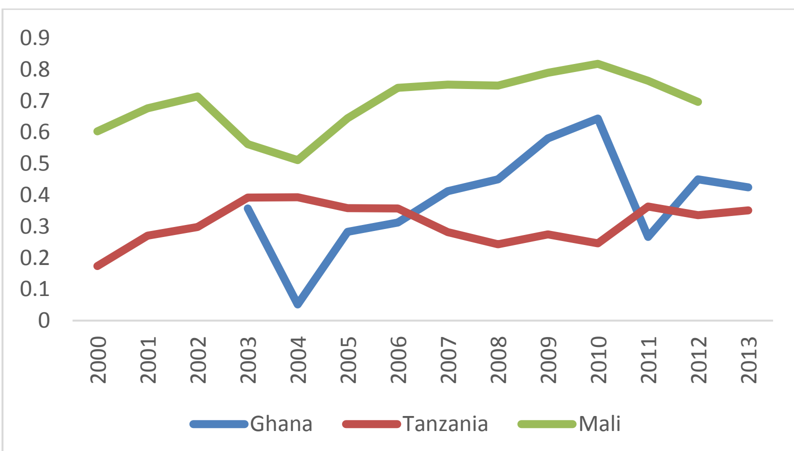
[42] GDP records the domestic value added of the gold exports—that is, the total value of exports minus the associated imports (though this will sometimes be recorded separately.) Disposable income, however, is the important variable with regard to national welfare. Thus, gross national income (GNI), which accounts for factor payments to and from abroad, will deduct the repatriation of profits by the gold-mining companies. Other things being equal, the contribution of mining to national income will therefore be less than its contribution to GDP. The repatriation of revenue will be reduced by the royalties and taxes paid by the companies. Hence, government revenue represents the domestic capture of the rents from mining.

Figure 3.1 Gold exports (in millions US$)



Source: World Integrated Trade Solution (WITS) database.

Figure 3.2 Gold exports as a share of total exports



Source: World Integrated Trade Solution (WITS) database.

Recent trends show that large-scale mining has contributed to the surge in exports and government revenue from mining. Gold mining, however, is not new to these countries, and has for the most part been done by artisanal and small-scale miners (ASM). The background papers explore this activity in more detail, and elements of these are summarized in box 3.1.

Box 3.1 Artisanal and small-scale mining

Sometimes known as "traditional" or informal mining, ASM combines mining activity with activities such as agriculture and livestock breeding, or even with informal activities such as services and production of craftwork. Also, the size of ASM activity fluctuates with the gold price and other employment opportunities and prospects. The scale of ASM varies considerably from cooperative ventures to individual miners. Some ASM operations are licensed, but others operate informally. For these reasons, it is also difficult to estimate the numbers involved in this activity at any given time.

For Ghana, the estimate of the number of people who were working at ASM in 1998 was 200,000, and it is estimated that now there could be as many as 1 million. The number is also difficult to accurately estimate in Tanzania, though Smith and Kinyondo (2015) report an estimated 550,000. The authors also estimate the output from ASM as being equivalent to that of a single large-scale mine. Their survey of a few ASM sights in Tanzania revealed that 50 percent of the miners regarded ASM as their sole source of income, and around 25 percent of them had been active for 5 to 10 years. This suggests that the activity is more stable than commonly thought.

For Mali, the exact number of artisanal mining sites is unknown, but was estimated by the government to be around 350 in 2009. In addition, the number of communes reporting artisanal gold mining as an important economic activity has been on the rise from 9 communes in 2006 to 17 in 2008 and 25 in 2013. Employment estimates in the artisanal gold-mining sector vary considerably—from 6,000 to 200,000 and up to 1 million according to different sources (Sanoh and Coulibaly 2015). However, the latest population census estimates the number of people involved in artisanal gold mining at 25,000.

Because of its informality, ASM is notoriously difficult to tax and regulate. In Ghana, it is estimated that 300,000 workers are involved in unlicensed (that is, illegal) mining. (These are known as galamseys.) Although the evidence is mostly anecdotal, the sector is thought to be one of lawlessness, occasional mayhem, and with hazardous working conditions. Accidents involving injury and death are frequent and often go unreported. Miners are also exposed to mercury and cyanide poisoning, and to environmental hazards including water pollution. In Mali, local authorities receive payment of duties and taxes in the allocation permit or title authorizing artisanal mining.

3.3. Channel 1: Employment, Linkages, and Positive Spillovers

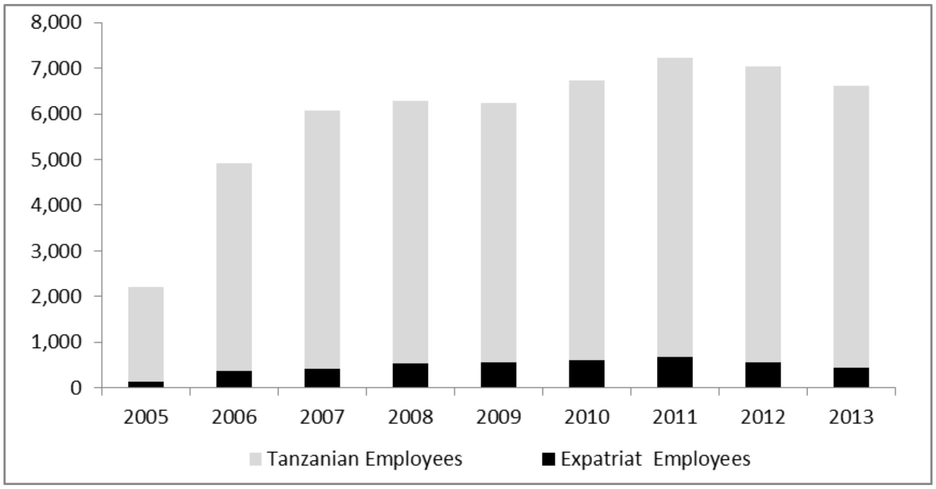
Modern large-scale mining does not employ many workers. It has historically been capital-intensive, and this feature has increased over time with technological progress. For the country as a whole, this magnifies the extent of the windfalls via exports and central government revenue, but may lower the amount of value added paid to indigenous factors, mainly labor. Thus, extractive industries have been characterized as "enclaves," cut off from the domestic economy except through royalties and taxes. The benefits to the economy as whole therefore depend crucially on how the central government uses the windfalls and, as is well known, that is often not well in developing countries.

Partly in answer to the criticism that employment in the mines is low, the companies and chambers of mines argue that although globally small, the number employed is locally significant and can raise average income and expenditure in the vicinity of the mine. Second, it is argued, mines are linked to local industry through the use of inputs of other goods and services. Employment and income is stimulated through these (backward) linkages. The country studies examine these claims complementing the empirical evidence of Chapter 4 on the employment and income effects of proximity to a mine. Third, analysts argue that industrial mining raises productivity in the area by improving infrastructure for its own needs and also through worker and management training. The companies also at times invest directly, through social responsibility endeavors, in improving infrastructure, health, and education.*Employment*

The country case studies report that the companies employed mostly nationals as opposed to expatriates, although managerial jobs went disproportionately to foreign nationals. In Mali, Sanoh and Coulibaly (2015) report a ratio of 14 national workers to each expatriate, and that on average, 78 percent of the jobs are held by people working in mines located in three communes, or local government entities (Gouandiaka, Sadiola, and Sitakily). Employees of the mining firms in Mali earn around US$1,200 per month on average. National labor survey data suggest that the mean income from mining activity is higher than the average income for all other activities, and considerably so when compared to the agricultural or industrial sectors.

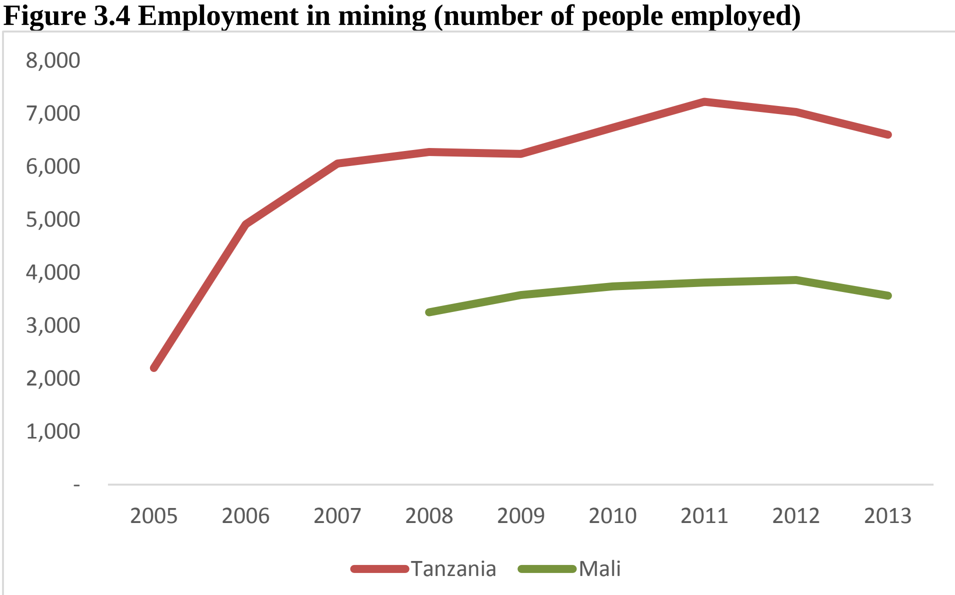
In Tanzania, employees of large-scale mining firms are typically based at the mine site, but also internationally and in regional offices, including in Mwanza (Tanzania's second city, on the southern shore of Lake Victoria) and Dar es Salaam (the country's commercial and administration hub). The total number of jobs, as expected, is relatively small, particularly when compared to a workforce of 22.1 million (2012 census) and the 70,000 Tanzanians entering the labor force each year. Nonetheless, employees of the large mining companies are typically well remunerated compared to national average income levels. The average monthly income from a manufacturing job is TSh 103,407, compared to TSh 76,277 in mining, TSh 49,693 in construction, TSh 31,301 in trade, and only TSh 15,234 in agriculture, currently the largest source of livelihood for Tanzanians (ESRF 2009). Further, it is clear that the vast majority of employees are Tanzanian and not foreign (figure 3.3), as is often argued, although the balance tilts further toward foreign workers when just management positions are considered.

Figure 3.3 Mining employment in Tanzania, 2005–13



In **Ghana**, the total number of people employed was 17,103 in 2014 (Government of Ghana 2014), of which only 289 were expatriates. In Tanzania, employment increased from around 2,000 in 2005 to around 7,000 during 2010–13 (figure 3.4), and in Mali, the total number of workers directly employed averaged 3,635 during 2008–13.

Figure 3.4 Employment in mining (number of people employed)



Linkages

It is difficult to estimate the linkages (or multipliers) because of data limitations. However, although the description "enclave" is not accurate, it is also fair to say that the backward linkages are not large. For example, for South Africa, where better data are available, gold mining is estimated to have a multiplier of around 1.8. In Mali, Sanoh and Coulibaly (2015) report that for every job in the mines, a further 1.67 jobs are "created" elsewhere through backward linkages and expenditure effects.

The multiplier effects are limited partly because of the capital intensity of the industry, but mostly because of the lack of local cost-effective procurement opportunities. This could change over time as the companies become better acquainted with local markets and suppliers, and also as local entrepreneurs learn to take advantage of the relatively new developments. In Tanzania, efforts have been made to improve the potential for local procurement, including in services such as catering, vehicle repair, machine shop services, welding, metal work, electrical work, and plumbing. However, the proportions of inputs sourced locally remain low, a situation mirrored in Ghana and Mali. While there is always a temptation to increase the linkages via local content laws, governments may be better advised to focus on developing the conditions for improved procurement than mandating it. McMahon and Moreira (2014) caution that: "the failed experience of many import-substitution plans suggests that linkages cannot be forced upon the mining sector without enabling business conditions." Instead, they advocate a focus on improving business conditions, such as better power and transport infrastructure, adequate human capital, access to finance, economies of scale, and outreach or technical assistance programs.

The studies note (and the empirical results confirm) that the mines do succeed in raising incomes in the near vicinity. The higher wages also attract migrant workers. This can have the effect of raising some prices such as rents and food prices, so that some local residents who may not be recipients of the higher mine wages may experience a loss of real income. The inflow of workers may also strain social services and crowd out some of the original residents.

Externalities

Direct development investment by the mining firms has traditionally been labeled corporate social responsibility (CSR), with examples of typical projects including secondary school construction, clinics, and water infrastructure. For example, Newmont Ghana Gold Limited has supported Ghana's Ahafo region via a partnership in the health sector that has supported health centers by constructing housing for resident nurses and three community health compounds in local villages, and equipped 60 local health "volunteers" with bicycles and medical equipment. However, there is a growing trend in the three countries for more sustainable projects that offer alternative livelihoods to mining (for example, brickmaking and fisheries) in the communities around the mines. This reflects greater interest in helping communities prosper after mine closures (World Bank 2002), and widespread recognition of the disappointing results (Campbell 2012).

Projects across the board have had mixed success and take a long time to implement. These are problems and afflictions similar to almost all foreign aid and government interventions, particularly where implementation capacity is limited. Challenges include ensuring that the investment has sufficient operational funding to provide an adequate level of the intended service. For example, in Tanzania, the mining firms have often promised to build a school or classrooms, with the government pledging to fund equipment and the recurrent costs of providing education. Many of the complementary commitments are not legally binding, however, and often do not happen in a timely manner, or at all.

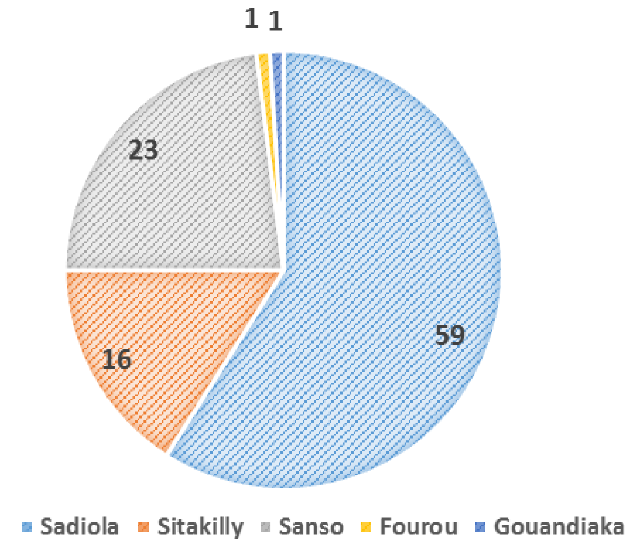
There are some instances where infrastructure has been improved by the multinational mining firms, but these remain rare. Gold mining differs from bulk mineral mining, and infrastructure benefits are expected to be limited. Roads must only be good enough to get inputs to the mine sites, since the mineral exports are typically flown out. When links cannot be made to national electricity grids, large-scale mines develop their own exclusive power supplies. Beyond some road improvement, infrastructure benefits are usually associated with CSR investment in the community (that is, not directly related to production needs).

Ayee and Dumisa (2014) note that, in Ghana, opinion surveys reveal unrealistically high expectations by the public from mining. These expectations often focus on the provision of public goods and services. Local governments often lack the capacity to provide these benefits even when additional revenues are present. Consequently, the public pressures the mining companies to step in for the government, for example, by building schools, health facilities, and, transportation infrastructure. While this may sometimes be the best available option, Ayee and Dumisa point out that there are also obvious risks in ceding responsibility for the provision of public goods to a foreign-based private corporation. In addition, mines inevitably are eventually exhausted. This is always a blow for the local economy but much more so when the departing company is also the provider of basic services.

In Mali, mining companies also contribute substantially to local development funds[43] that are not under the control of local authorities. During 1994–2010, the contribution of mining companies to the financing of local development amounted to more than 7 billion CFA francs resulting from license fees and nearly 20 billion CFA francs from special development funds. In general, the amount of license fees from each mine is lower than the amount of special development funds, except for the three mine sites of Yatéla, Loulou, and Morila, which represent 57 percent of the total license fees but only 17 percent of total special funds. Sadiola commune is by far the biggest contributor, at 59 percent of license fees and 71 percent of special development funds. This is because that mine has been operating for the longest time (figures 3.5 and 3.6).

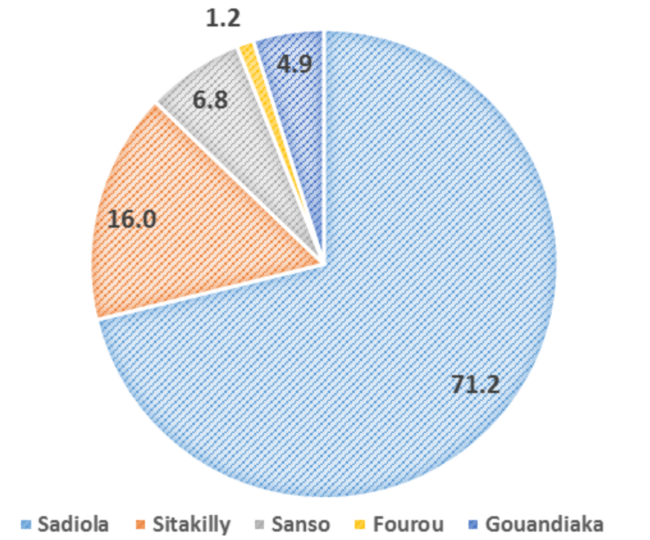
[43] The amounts contributed are not based on any standard formula but are decided mine by mine or specified in the mining convention. These funds should be seen as another direct form of compensation for some of the costs imposed by mining activities.

Figure 3.5 Communes' share of license fees in Mali, %, 1994–2010



Source: ODHD (Sustainable Development Observatory) 2011.

Figure 3.6 Communes' share of development funds in Mali, %, 1994–2010



Source: ODHD (Sustainable Development Observatory) 2011.

The sectoral distribution of the development fund within mining communes depends largely on their needs and the complementarity with their own budget spending. In Sadiola, more of the funds have been spent on agriculture (23 percent), while in Fourou, almost 83 percent of the fund has been spent on education. In Sanso and Gouandiaka, the focus has been on infrastructure spending (31 percent and 50 percent, respectively). The largest part of the development fund in Sitakilly was spent on relocating the local population (table 3.1). Because these funds are controlled by mining companies, they have more sway on how the funds are spent. The government considers these funds to mining communes as de-facto transfers, because they come as a deduction from equity returns to be paid to the governments (ODHD 2011).[44]

Table 3.1 Mali: Sectoral spending of the mining development fund, 1994-2010

	Sadiola	Sitakilly	Sanso	Fourou	Gouandiaka
Health	10.9	5.4	2.0	5.4	0.9
Education	13.9	4.6	26.9	82.7	33.4
Infrastructure	17.9	10.0	30.9	11.6	50.8
Agriculture	23.0	9.7	14.0	0.0	0.2
Others	34.4	70.4	26.3	0.3	14.7

Source: ODHD (Sustainable Development Observatory) 2011.

[44] The state of Mali owns 20 percent equity in all mines.

3.4. Channel 2: Government Revenue

The main sources of government revenue from gold mining are dividends accruing from state equity participation; property rates, ground rents, profit taxes, and excise and import duties; and royalties. Government revenues increased considerably in each of the three countries during 2001 to 2013, although levels reportedly dropped in 2014 following a decline in international gold prices. During 2005–13, gold mining provided the government with US$362 million per year (annual average) in Mali, compared to US$300 million per year in Ghana and US$137 million per year in Tanzania (figure 3.7). In Mali, it was primarily customs duties, and, later, taxes, which drove the increase in mining's contribution to government revenue (figure 3.8).

Figure 3.7 Government revenues from mining (US$ millions)

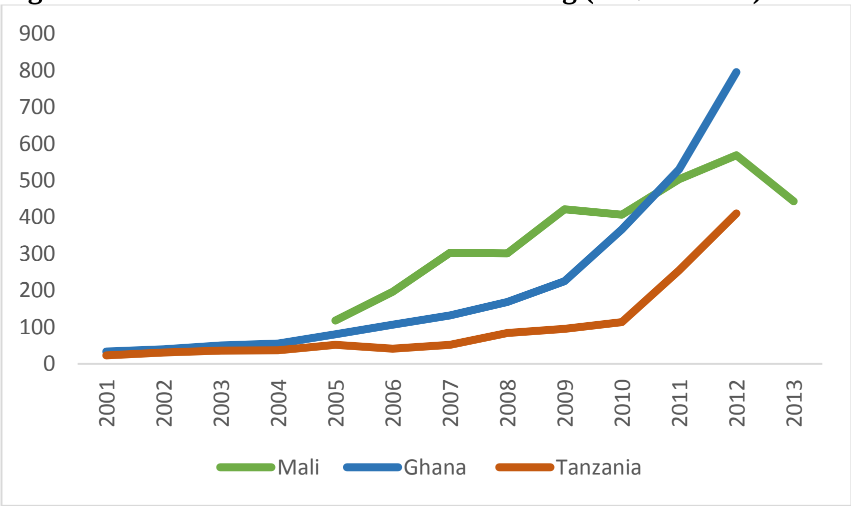
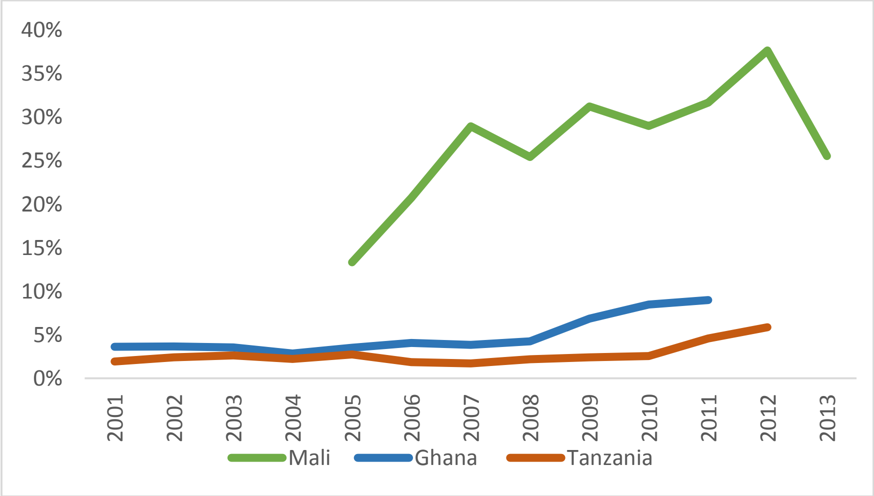


Figure 3.8 Government revenues from mining as a percent of total revenue



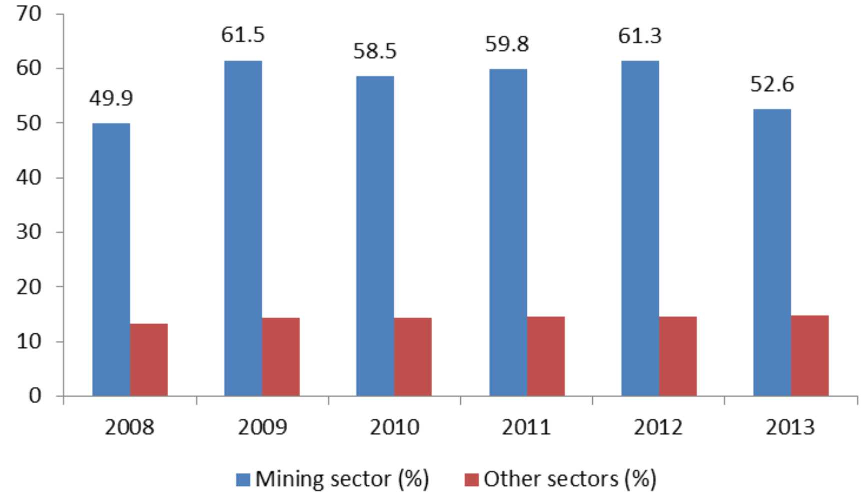
In Tanzania, tax and royalty payments to government were limited in the years following the opening of the first few large-scale mining projects, reportedly averaging only US$30 million per year between 1999 and 2006. This led to the claim that the incentives offered to the companies to attract the investment gave away too much in terms of tax exemptions and concessions. Despite an increase in the price of gold, tax holidays meant firms were making only partial payments of corporate taxes, and despite tightening the terms of the deals, most deals (Mineral Development Agreements) have stability agreements, locking in the original terms.[45] Nevertheless, taxes and royalties did improve to an average of US$77 million a year during 2007–09, and then to an average of US$260 million a year during 2010–13. However, a debate remains as to whether Tanzania has received a fair amount of tax and royalty payments, given the volume of mineral produced.

In Mali, tax revenues from the mining sector increased steadily as a percentage of total government resources, rising from 10 percent in 2005 to 25 percent in 2013, having peaked at 33 percent in 2012, a year that was particularly difficult with regard to the mobilization of resources because of the war in the north of the country. The strong growth of the mining sector's contribution to the national budget was due primarily to revenues from customs duties, and secondarily to domestic taxes.

All three countries are concerned about whether gold mining has been adequately taxed. Sanoh and Coulibaly (2015) report that in Mali, the tax burden on the mining sector (the ratio of the tax revenues of mining companies to the value-added of mining activity) is more significant than the tax burden on the whole economy (the ratio of the total tax revenues to the country's GDP), an average of 57 percent compared to 14 percent (figure 3.9). In 2012, the seven mining companies and their subcontractors represented 45 percent of all corporate taxes in Mali. However, this average tax burden on the mining sector is within the range of taxation on the mining sector observed in other countries like Canada (60 percent), South Africa (45 percent), and Papua New Guinea (55 percent) (Bhushan and Juneja 2012). While in developed countries the tax burden is a reflection of the high environmental costs of mining, in Mali that is not the case.

[45] This delayed the start of the payment of large-scale gold-mining company corporation tax. Added to this was the concession that mining firms could offset all equipment and machinery costs against revenues, and were exempt from the value-added tax on goods and services.

Figure 3.9 Fiscal burden in Mali (%)



Sources: CPS/SME (Mining and Energy Sector Planning and Statistics Unit) 2013; and authors' calculations.

Fiscal sharing

The central government owns the resources and therefore the revenues. The benefits from a natural resource will depend to a large extent on whether the revenues are put to good use. If history is a guide, there is ample reason to be cautious. In particular, the areas where mines are located have no property rights to the minerals and may feel deprived of the benefits while bearing the bulk of the costs. The fiscal arrangements between the central and local governments at various levels will therefore determine how much of the benefits from mining find their way back to the mining areas. In addition, the general competence, honesty, and, overall implementation capacity of the local-level government will be key to enhancing welfare and development.

The country studies show that Mali had the highest degree of fiscal decentralization and, therefore, the local authorities received a larger proportion of the revenues compared to the other two. Ghana is in the middle of the three in this regard, and its decentralization efforts are relatively new. Tanzania has a rather rigid centralized mechanism. All revenues are garnered by the central government. Transfers from the central budget fund 90 percent of local government. The funds are allocated according to criteria and priorities unrelated to the location of mines or the source of the funds.

Ghana

Ghana is an administratively centralized country with three local levels—districts, municipalities, and traditional "stools," presided over by traditional chiefs. Mineral resources in Ghana are owned nationally by the people, and their management (according to the constitution) is vested in the hands of the government. While the government is the caretaker of the minerals, corporations can apply for reconnaissance and prospecting licenses to search for specific minerals. The 1992 Constitution of Ghana recognizes a decentralized local government system to achieve this objective. Since 2007, the government has mandated that 7.5 percent of total government revenues are to be transferred to the Metropolitan, Municipal and District Assemblies (MMDAs) by way of a district transfer system. To supplement the transfers, MMDAs also collect internally generated funds from various sources, including rates, license fees, and fines that constitute between 1 and 20 percent of all MMDAs' revenues. For mining royalties' payment, the government takes the biggest share, 90 percent. For the remaining 10 percent, 4.95 percent is allocated to the MMDA where the mine is located and 2.25 percent to the traditional stool where the mine is located (Ayee and Dumisa 2014).

Mali

The local authorities in Mali are recognized as autonomous, with specific responsibilities related to the provision of public services. Despite some progress in the administrative and financial empowerment of local authorities, local authorities are still to a large extent under the authority of the central government with regard to resources, or even acts and decisions related to their respective territories. The government seems to be more concerned about national unity and the integrity of the territory than the enhancement of the transfers and public resources to communities.

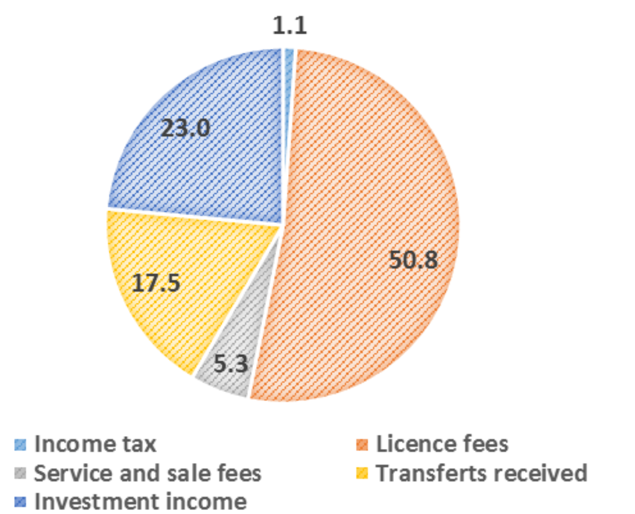
The local authorities in communes where gold production takes place are supposed to receive 60 percent of local taxes paid by commercial mining firms and 80 percent of license fees paid by small-scale miners. Producing Cercles are meant to receive 25 percent and 15 percent of these taxes, respectively, while producing regions retain 15 percent and 5 percent, respectively. Commercial mining companies are exempted from paying these taxes during the first three years of operation. Unfortunately, local authorities do not have the means to determine the actual level of the license fees that are supposed to be distributed among them. In fact, license fees from mining companies are not actually distributed, as required by the above-mentioned law. The share actually allocated to communes represents 73 percent of the total amounts collected instead of 60 percent according to the law. As a result, all the other levels of local authorities receive less than the percentages required by the law, 17 percent at the Cercle level (while the law requires 25 percent), and 1 percent at the regional level (while the law requires 15 percent).

In general, Malian local authorities have a low rate of revenue collection and therefore a low level of self-financing capacity. As a result, the transfers and subsidies from the government represent the main source of revenue to support current and especially investment expenditures. The analysis of the budgetary[46] accounts from 5 mining communes and 24 neighboring communes indeed reveal a low level of tax collection.

[46] These budgetary accounts do not include expenditures done by the state on behalf of the communes.

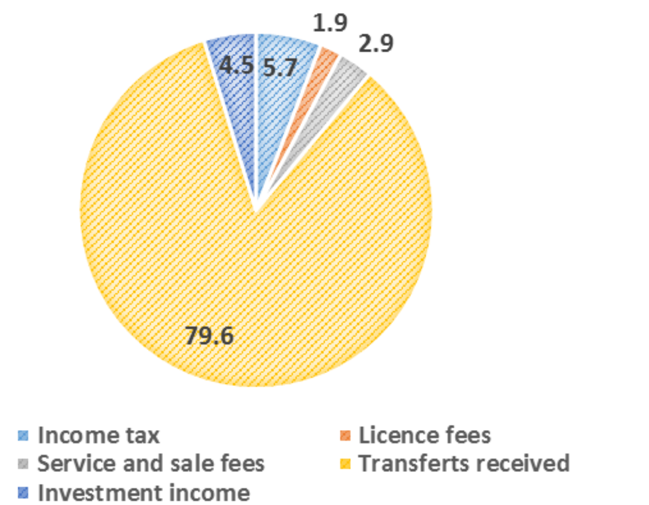
Because of the licensing fees paid by mining companies to local authorities, the mining communes generate more of their own revenues compared to nonmining ones. These license fees represented more than 50 percent of mining communes' revenues between 2011 and 2013 compared to just 2 percent for neighboring communes (figures 3.10 and 3.11). Although mining communes are less dependent on the transfers from the government, they still remain exposed to the risks related to the closing of mines or the drop of production in this sector because license fees payments are a function of turnover.

Figure 3.10 Source of budget revenues for mining communes, 2011–13



Source: DNTCP (National Directorate of Treasury and Public Sector Accounting).

Figure 3.11 Source of budget revenues for mining neighboring communes, 2011–13



Source: DNTCP (National Directorate of Treasury and Public Sector Accounting).

Tanzania

In Tanzania, all gold mining revenues accrue to the central government, with the exception of recent annual payments of US$200,000 per mine. There is no earmarking of revenues and little point in tracking how much of the gold mining taxes and royalties make it back to the respective districts. The gold in Tanzania belongs to the country and not the local population, and government expenditure in the gold mining local government authorities (LGAs) is largely unrelated to the revenues provided. In theory, expenditure is linked to a needs-based formula, but in practice, there are substantial inequities in the allocation across LGAs (ODI 2014). The formula is based on various measures of need, but because employment costs dominate the transfers, financial flows for the most part follow the number of public servants (mainly teachers and health workers), and this depends in turn on where public servants can be encouraged to locate. Five of the six LGAs hosting large-scale gold mining receive less in per capita terms than the national average (with the exception of Tarime District Council

3.5. Negative externalities: The costs borne by mining areas

As noted in Chapter 2, all types of mining can pollute and cause environmental damage unless carefully managed. But even when carefully managed, there are still substantial risks to local communities. Mercury is typically used in artisanal and small-scale mining, and not used in large-scale gold mining; instead, cyanide is used, and although highly toxic, its use is typically better controlled. Nonetheless, large-scale mines do produce toxic tailings, which can be spread by wind, and when tailings dams rupture, the results can be catastrophic.[47] People are often forced to relocate for environmental and other reasons upon the opening of a mine. If the costs of environmental damage and resettlement were treated with the same multipliers and subtracted from the overall impact, the declared benefits would be smaller. These external costs are an obvious source of tension between communities and local authorities, and also between local and national governments.

Arguments asserting the existence of a resource curse often point to the potential for natural resource windfalls to exacerbate rent-seeking, corruption, and conflict in society. Mining firms face challenges of securing their investments from theft and violence, some of which is fueled by community perceptions that they are not benefiting from the mine. In April 2009, armed thieves stole about 100 kilograms of gold worth US$4.2 million from the Golden Pride Mine in Tanzania, and the North Mara Mine has experienced regular raids. More commonplace is the intrusion of small-scale miners onto the mine site to access tailings and mining opportunities. However, despite the contestation and ongoing violence, the mines have continued to produce at a high level (Holeterman 2014).

In Tanzania, corruption is pervasive and a problem with roots wider than mining. However, there have been cases of grand corruption directly relating to large-scale gold mining. In 2008, the case of Alex Stewart Assayers become public. Following concern in the early 2000s that the mining firms were engaging in tax evasion or fraud, the government in 2003 hired Alex Stewart Assayers, a U.S.-based company, to audit gold production, with the aim of ensuring that Tanzania receives a fair deal. However, Alex Stewart Assayers also received tax-free status, and was contracted without a formal tender process, without any experience auditing mining companies, and on terms that would leave them with a fee of 1.9 percent of the marketed value of the audited gold exports, leaving only 1.1 percentage points of the 3 percent royalty for the government. The auditing carried out by Alex Stewart Assayers eventually cost the government US$70 million, without revealing any tax evasion or fraud by the large mining companies (Cooksey 2011).

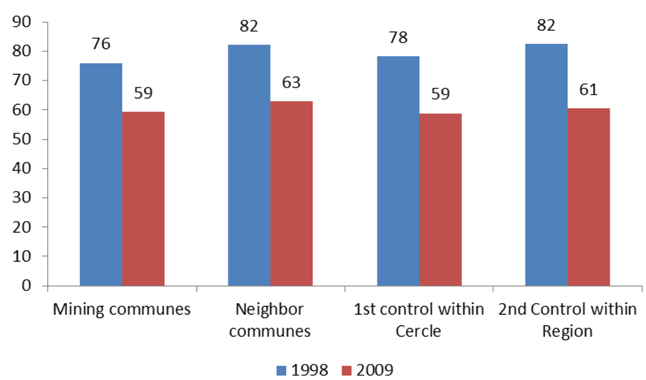
[47] For example, when the tailings dam at the Baia Mare gold mine in Romania failed in 2000, cyanide leaked into the Somes River killing 1,400 tons of fish and contaminating the water supply of 2.5 million people, at huge cost.

3.6. Outcomes

The studies overall show marginal improvements in welfare indicators in mining areas, though lack of data prevents drawing definitive conclusions. The study on Mali exploits a relatively rich data source on socioeconomic indicators, which unfortunately is not available for Ghana or Tanzania.

In Mali, for example, enrolment rates in primary schools clearly increase with proximity to the mine, and are higher in neighboring areas than in more distant ones. Not only are the rates higher, but they also increased faster from 1998 to 2009, these two years being the years of the last two General Population and Housing Censuses in Mali. Outcomes for poverty reduction are inconclusive, however: While poverty has declined across the whole country, the pace of poverty reduction in mining communes has not been faster compared to nonmining communes (figure 3.12).

Figure 3.12 Poverty headcount in mining and other areas in Mali (%)

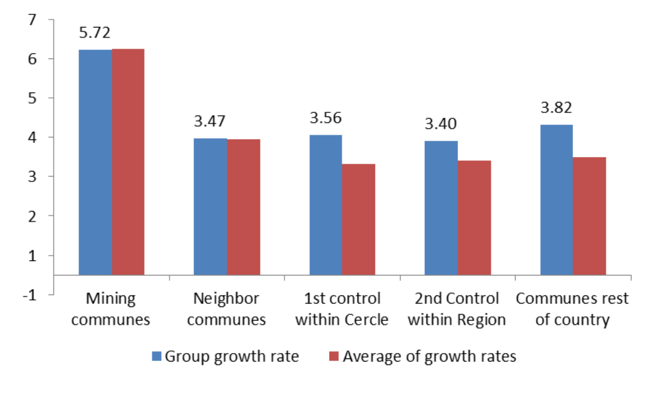


A further interesting outcome in Mali is the differential population growth in mining versus nonmining areas. The national population growth rate has averaged 3 percent annually between 1998 and 2009, but the population growth rate in mining communes is almost double the national rate.[48] Mining communes grew on average 5.7 percent annually compared with 3.5 percent for neighboring communes and other communes within the same Cercle (figure 3.13). The population growth rate is above 6 percent in all mining communes, except in Gouandiaka, where at 2.9 percent, it equals the national rate (figure 3.14). Since populations migrate from lower- to higher-income areas, the higher population growth in mining is itself indicative of an economic stimulus. However, other things being equal, the inward migration will tend to slow the rise of wages in the mining areas and raise average wages in the "donor" ones. This may explain why, despite the increase in economic

[48] There are many reasons why mining areas may experience higher population growth. It could be simple migration, or better health infrastructure in mining areas, or differential higher fertility rates.

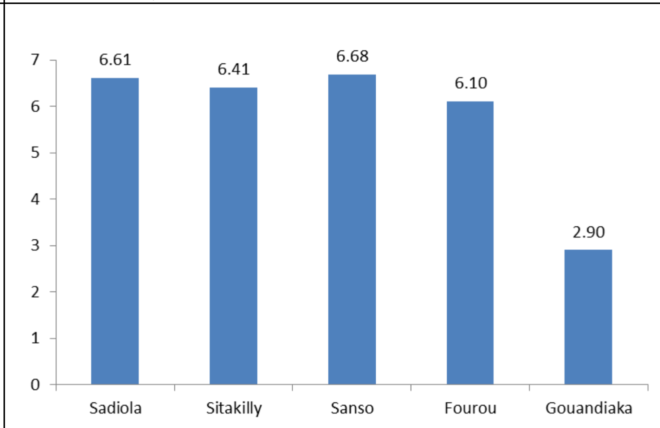
activity due to mining, the reduction in poverty in these areas has not significantly outstripped that of other areas. In other words, migration tends to be an equalizer.

Figure 3.13 Population growth rate by group of communes, 1998–2009



Source: RGPH (General Population and Housing Census) 1998 and 2009.

Figure 3.14 Population growth rate for mining communes, 1998–2009



Source: RGPH (General Population and Housing Census) 1998 and 2009.

Overall social outcomes in Mali are mixed. With regard to access to basic social services, mining communes had low levels of access to electricity and improved cooking fuels before the mining boom started in 1998. For example, less than 2 percent of the population used electricity for lighting or improved cooking fuels. However, 30 percent had access to an improved water source, and 50 percent to an improved sanitation facility (table 3.2). In terms of progress, between 1998 and 2009, mining communes had significant improvement with regard to those services where they started from a lower base. However, in 2009, only the share of the population using an improved water source is far greater in mining areas. This may explain the better children's health outcomes in the vicinity of mining activity (Polat et al. 2014 and Chapter 4). Beyond indicators of access, infrastructure outcomes in 2013 are not better in mining areas. For example, while paved road per capita is slightly higher in mining areas, irrigation per capita[49] is lower than in other areas. Mining areas also have fewer nurses and midwives per capita than other type of communes (table 3.3).

[49] However, this may reflect differences in rainfall or farming intensity.

Table 3.2 Use of infrastructure services, 1998 and 2009 (% of population)

	1998				2009			
	Electricity for lighting	Improved water source	Improved cooking fuel	Improved sanitation	Electricity for lighting	Improved water source	Improved cooking fuel	Improved sanitation
Mining communes	1.88	30.31	1.73	50.62	12.97	67.16	2.10	89.25
Neighbor communes	2.73	17.37	1.81	47.94	11.88	42.87	0.65	84.03
1st control within Cercle	7.71	23.45	2.48	48.97	13.31	42.08	0.61	83.20
2nd control within Region	2.62	19.38	2.11	52.35	10.54	29.06	0.47	82.08

Source: RGPH (General Population and Housing Census) 1998 and 2009.

Table 3.3 Infrastructure outcomes by group of communes, 2013

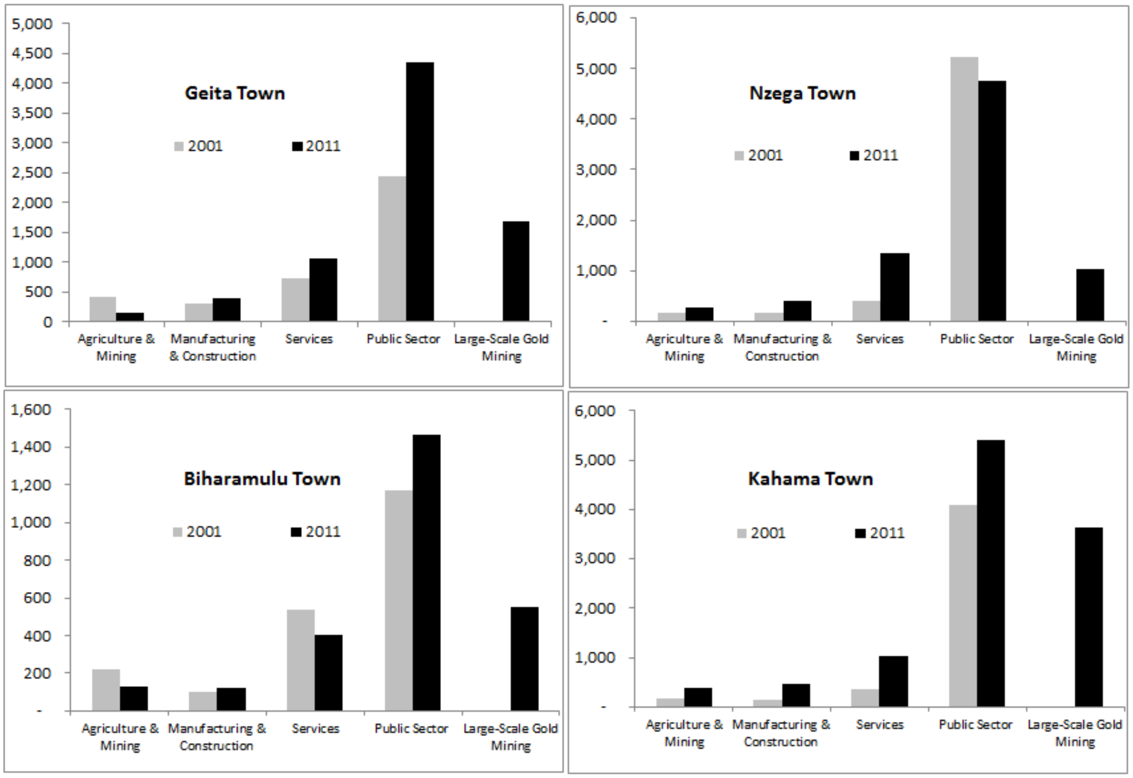
	Paved road per 1,000 inh.	Irrigated area per 1,000 inh.	Local health centers per 10,000 inh.	Health doctors per 10,000 inh.	Midwives per 5,000 inh.	Nurse per 5,000 inh.	primari school per 1000 inh.	Net primary enrollement (%)
Mining communes	6.80	0.73	0.74	0.52	0.06	0.38	0.88	73.00
Neighbor communes	6.56	4.84	1.17	0.41	0.14	0.82	0.90	63.75
1st control within Cercle	6.16	5.19	1.03	0.42	0.18	0.58	1.02	61.59
2nd control within Region	10.37	6.21	1.07	0.32	0.12	0.72	0.82	55.87

Source: ODHD (Sustainable Development Observatory) database 2013.

In the case of Tanzania, survey data from 2001 and 2011 are used to track changes in formal employment opportunities in areas around the large gold mines. The surveys suggest a considerable increase in employment opportunities, with additional jobs in 2011 relative to 2001 in the mining towns (figure 3.15). However, as shown in figure 3.15, most of the additional jobs were in the public sector.[50] Interestingly, there has been only a small increase in employment opportunities in manufacturing, suggesting linkages have been fairly limited, although a lack of decline in that sector supports an argument that there have not been local Dutch-disease-type effects from gold mining.

[50] In an export mineral boom, the booming sector is often the public sector, though in this case, the increase in public sector employment may be due to population growth, which in part could be due to the mining boom and the inward migration it attracts.

Figure 3.15 Change in employment opportunities around mines



3.7. Conclusions

All change in an economy brings both costs and benefits, and gainers and losers. So it is with gold mining. From the studies reviewed here, there is little evidence of economic decline at the national or local levels in the three countries. However, there is evidence of negative externalities impacting communities close to gold mines. The national benefits most likely outweigh these costs, but it is doubtful that compensation is made or effective.

Mining is not a major "employment generator." Studies of economic growth emphasize that higher productivity in general, and in extractive industries in particular, is a major source of growth and development. However, if the capital is mostly foreign owned and the industry is capital-intensive, then the main domestic recipient of the value generated by the gold mines is the government. Thus, in the final analysis, the welfare effects of gold mining (and generally mineral extraction in developing countries) depend on whether government collects its due and puts it to good use.

The conclusions from the case studies presented here are suggestive but need to be subjected to rigorous statistical analysis to yield more robust results. This analysis is the subject of chapter 4.

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Chapter 4 Socioeconomic Effects of Large-Scale Gold Mining: Evidence from Ghana, Mali, and Tanzania

4.1 Introduction

For more than a decade, starting around 2000, the minerals sector in Sub-Saharan Africa has witnessed a boom. This chapter provides an approach for understanding how the benefits from the minerals sector are captured by local communities, and it measures the size of the impact of mining on local welfare. Since the minerals sector in Sub-Saharan Africa is large and diverse, this chapter applies the framework developed in Chapter 2 to a single mineral—gold. Gold mining is now an important industry in several countries in Africa (see figure 4.1 for a map of gold mines). In 2013, Sub-Saharan Africa had four of the top 20 gold-producing countries in the world—South Africa, Ghana, Mali, and Tanzania. This chapter draws from studies trying to identify the local and district-level effects of large-scale gold mining in three of the top gold-mining countries in Africa: Ghana, Mali, and Tanzania.[51] Together, these countries accounted for about 35 percent of gold production in Sub-Saharan Africa in 2013.

Our focus on local impacts is motivated by the observation that, in general, the socioeconomic effects of large-scale mining are not well understood. In fact, to the extent that there is public opinion on impacts of gold mining on local communities, it is likely to be unfavorable. This is partly because, despite making an important contribution to country GDP and export revenue, total employment numbers generated country-wide by mines are generally modest (see chapter 3). Adding to the negative perceptions of the sector is the perception that the industry does not contribute enough to fiscal revenue, due to low royalty rates and tax holidays.

This research contributes to recent attempts to analyze the welfare impacts of mining. Evidence from Peru shows that mining districts have lower poverty rates, but also higher inequality (Loayza, Teran, and Rigolini 2013). An important finding of the Peruvian studies is that effects are found both around a mine (local impacts), and in mining districts. More generally, the results show that benefits decline with distance from the mine. The

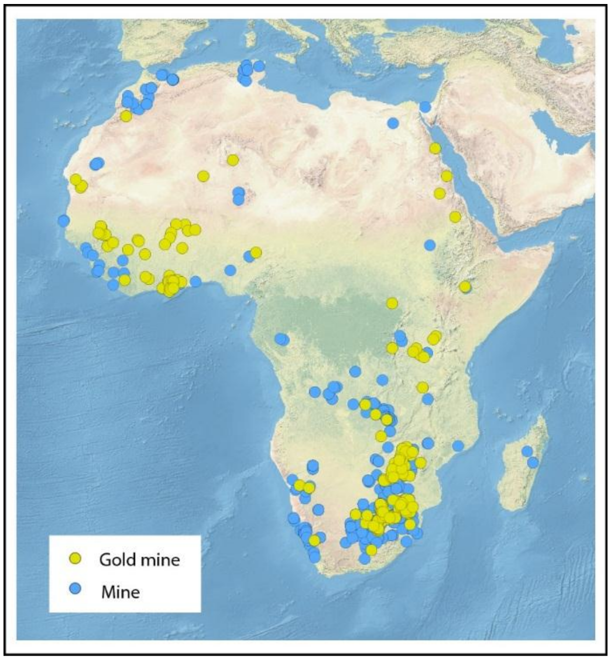
[51] This chapter is based on two papers that are also part of this study: "The Local Socioeconomic Effects of Gold Mining: Evidence from Ghana," by P. Chuhan-Pole, A. Dabalen, A Kotsadam, A. Sanoh, and A. Tolonen, World Bank Policy Research Paper 7250, World Bank, Washington, DC, 2015; and "Socioeconomic Impact of Mining Activity: Effects of Gold Mining on Local Communities in Tanzania and Mali," by B. Polat, N. Aktakke, M. A. Aran, A. Dabalen, P. Chuhan-Pole, and A. Sanoh, World Bank, Washington, DC, 2014.

largest positive impacts are found close to a mine, defined as areas within 20 kilometers (km) of the mine, but the impacts disappear altogether at distances that are more than 100 km away (Aragón and Rud 2013). The effects can be different at the vicinity of the mine and district levels. Locally, the mine can have a footprint by generating direct employment, while at the district level, welfare can additionally change because of the fiscal revenues mining activities can bring. The fiscal revenue channel will of course depend on the national fiscal sharing policies, which for Ghana is 10 percent of royalties. There is no redistribution of "mining royalties" in Mali and Tanzania, although the governments redistribute pooled funds according to criteria that have nothing to do with mining. In addition, in Mali, municipalities with mining production receive 60 percent of local taxes paid by commercial mining firms.

In Sub-Saharan Africa, while interest in these issues has been around longer, studies have been slow in coming. One recent study, however, looked at all large-scale mines across Africa, and using household data from 29 countries found that mining leads to a structural shift whereby agricultural labor participation decreases, which is partly offset by increases in other sectors such as services (Kotsadam and Tolonen 2015). In the case of gold, the decrease in agricultural participation can in part be caused by decreasing productivity within the sector because of pollution from the mines. This effect has been seen locally around Ghana's gold mines (Aragón and Rud 2015). Two recent studies explore the effects of gold mining on urbanization rates in Ghana (Fafchamps, Koelle, and Shilpi 2015), and women's empowerment and infant health in nine African countries (Tolonen 2015).

Using a similar approach, the studies underlying this report use variation in activity status and production volumes across gold mines to identify changes in welfare caused by the mining activities. The studies exploit the geographic identification of observations from existing household surveys, such as the Living Standard Measurement Surveys and the Demographic and Health Surveys, to link mines to a household in order to analyze how local- and district-level mining have affected the livelihoods of people residing there. First, we present evidence on the power of a mine to generate (a) structural transformation, by exploring effects on occupation and household expenditure; and (b) asset accumulation. Second, we turn to health indicators and explore child health and access to health care services. Finally, we examine access to infrastructure such as electricity and water. To complement the local-level analysis, we explore changes at the administrative district level. Overall, we try to determine whether both migrants and those permanently settled in the communities can benefit from the mining activities.

Figure 4.1 Map of large-scale mines in Africa



Source: The data are from IntierraRMG.
Note: The map shows all large-scale mines in Africa in production at any point between 1975 and 2012. Gold mines are highlighted in yellow.

Gold mining in Ghana, Mali, and Tanzania

Gold mining in Ghana and Mali has a rich historical tradition. Both the ancient kingdoms of Mali and the Gold Coast (Ghana) were renowned for their gold production, and remained major sources of gold trade between Europe and Africa in precolonial times. For the purposes of this study, it may seem that this historical tradition will pose a major problem for our empirical strategy, which relies on variation in activity status and intensity of production to identify the causal impacts at the local level. However, large-scale modern gold mining for Ghana and Mali began during the colonial era, and only 15 years ago in Tanzania.

To see why the historical production poses less concern for our study, it is worth noting that gold production in Ghana, which started earlier than in Mali and Tanzania, went into a prolonged and severe slump until the 1990s. But since the 1990s, several new large mines have started extracting gold in the three countries. In 2000, three mines opened in Mali, followed by an additional five mines over the next 10 years. In Tanzania, the oldest mine among existing mines that opened in 1999 was Golden Pride, while the last one to open within the study period was Buzwagi, which started extracting in 2009. From 1990 to 2012, there were 31 mines in production at one time or other. Table 4.1 shows the first and last year of activity of the gold mines included in the study, and figures 4.2 through 4.4 are maps of the gold mines in the three countries.

Table 4.1 List of mines, 1990–2011

Mine Name	Opening Year	Closing Year	Country
Ahafo	2006	Active	Ghana
Bibiani	1998	Active	Ghana
Bogoso Prestea	1990	Active	Ghana
Chirano	2005	Active	Ghana
Damang	1997	Active	Ghana
Edikan (Ayanfuri)	1994	Active	Ghana
Iduapriem	1992	Active	Ghana
Jeni (Bonte)	1998	2003	Ghana
Konongo	1990	Active	Ghana
Kwabeng	1990	1993	Ghana
Nzema	2011	Active	Ghana
Obotan	1997	2001	Ghana
Obuasi	1990	Active	Ghana
Prestea Sankofa	1990	2001	Ghana
Tarkwa	1990	Active	Ghana
Teberebie	1990	2005	Ghana
Wassa	1999	Active	Ghana
Gounkoto (Loulo Permit)	2011	Active	Mali
Loulo (Gara Mine)	2005	Active	Mali
Tabakoto/Segala	2006	Active	Mali
Sadiola Mine	2000	Active	Mali
Yatela	2001	Active	Mali
Morila	2000	Active	Mali
Syama	2000	Active	Mali
Kalana	2004	Active	Mali
Bulyanhulu	2001	Active	Tanzania
Buzwagi	2009	Active	Tanzania
Geita Gold Mine	2000	Active	Tanzania
North Mara	2002	Active	Tanzania
Golden Pride	1999	Active	Tanzania
Tulawaka	2005	Active	Tanzania

Figure 4.2 Gold mines and gold districts in Ghana

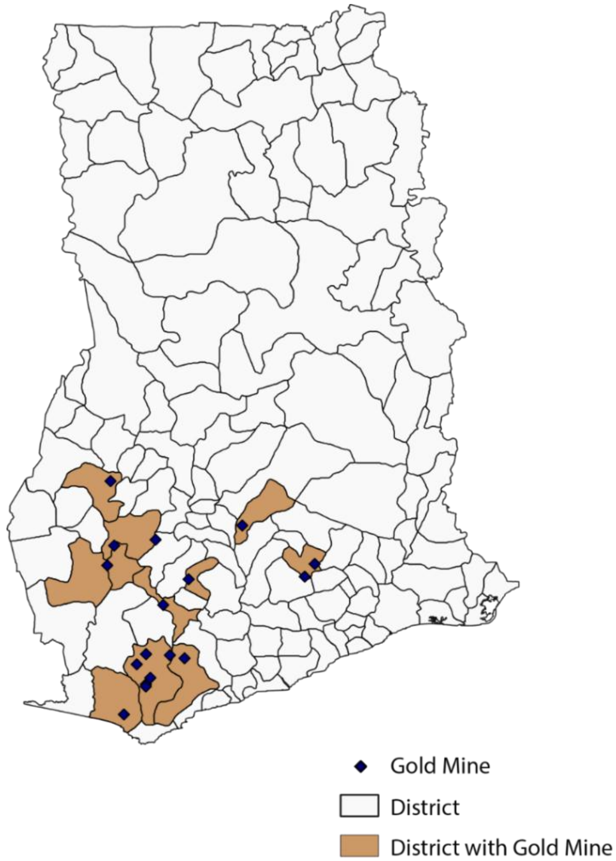


Figure 4.3 Gold mines and gold districts in Mali

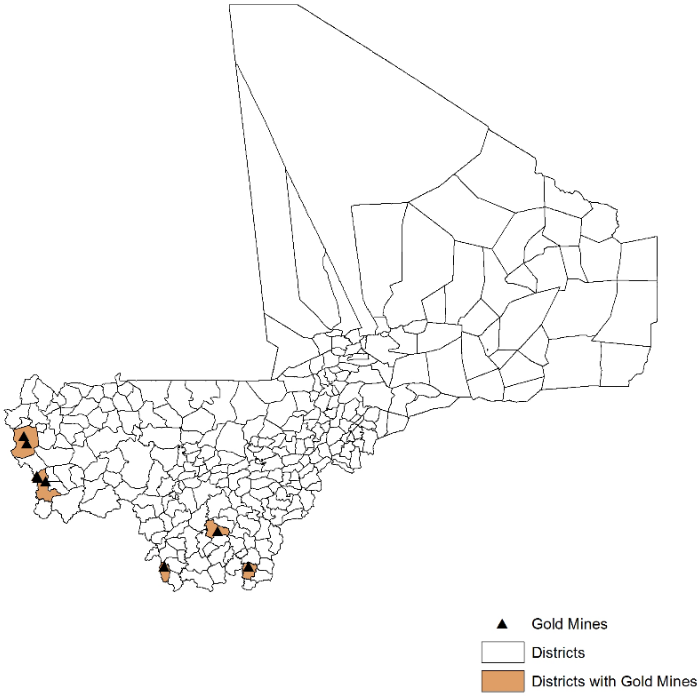


Figure 4.4 Gold mines and gold districts in Tanzania

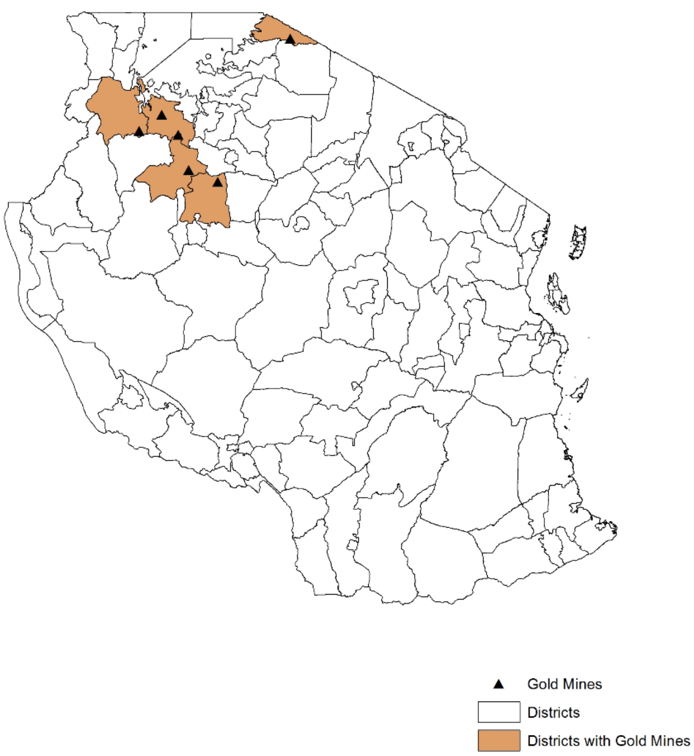
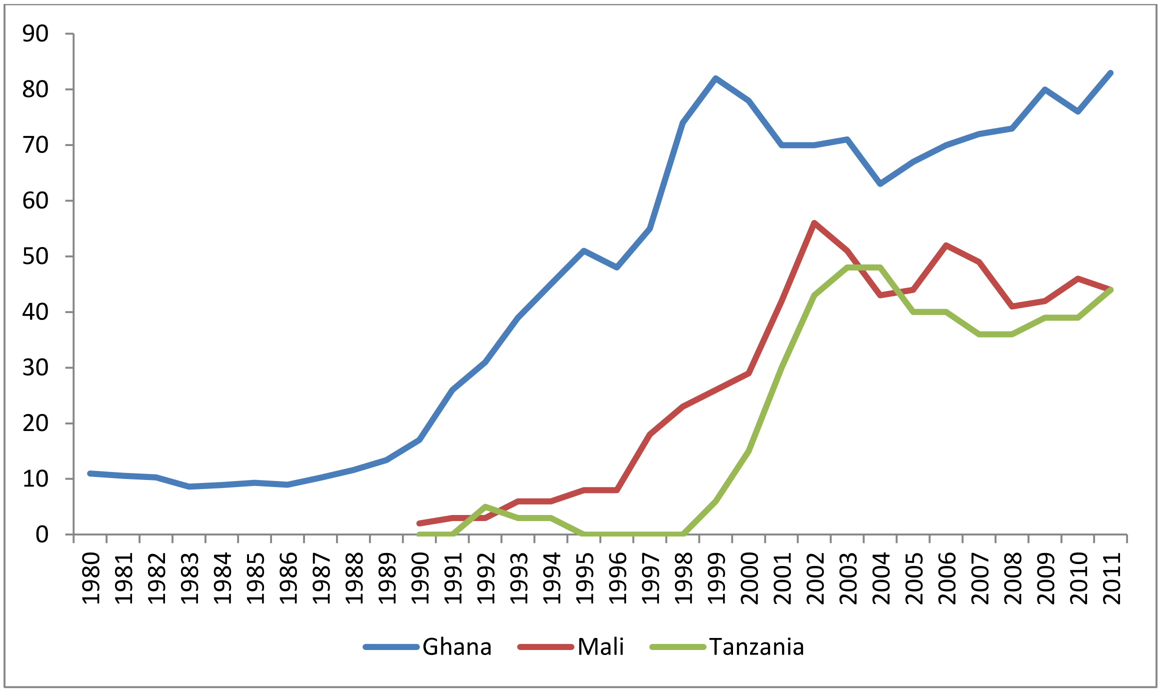


Figure 4.5 illustrates that annual gold production has risen in the three countries since 1990. Not surprisingly, Ghana has the highest annual production, but the evolution has been similar in Mali and Tanzania over the last decade.

Figure 4.5 Gold production (metric tons) over time in Ghana, Mali, and Tanzania



4.2 Empirical Methodology

Assessing the socioeconomic impact of gold mining

The discovery and exploitation of gold can introduce durable changes to an economy. The macroeconomic consequences of the revenue windfall from such mineral wealth have been the subject of a large literature in economics. In this report, we abstain from wading into that debate and instead focus our attention on local impacts as noted in Chapter 2. At the local level, the opening of a mine (or a cluster of mines) influences outcomes through two channels. In one, it can "draw in" resources to the local community and create a virtuous circle. For instance, it can increase the share of workers with higher wages. To meet the inevitable increase in the demand for goods and services by the pool of high-income earners, new local businesses might emerge or existing ones might expand, leading to more demand for workers and goods and services. This process could eventually lead to the concentration of economic activity in the local area—sometimes referred to as agglomeration—and be self-sustaining.

The second channel is through local (or central) government action via revenues generated from the mine(s). Imagine that the government sets aside a share of the mining revenues to be spent on local development. This could be implemented by the central government or by the local government. And suppose that the local government spends the money on productive public goods—roads, water, electricity, schools and clinics, and so on. Once again, these public investments and services can attract more people into the area, create new business, and eventually lead to local economic development. Thus far, these are the possible ways in which positive socioeconomic benefits can emerge. But gold mining can also bring zero or even negative benefits. It can poison the water and worsen health outcomes, pour pollutants into the soil and render agriculture unproductive. Government revenues may be spent on salaries and not on public goods. Even with no public goods, this boom in the government sector represents a rise in income. Therefore, the question of what impacts gold mining has on local socioeconomic development is, importantly, an empirical question.

The econometric studies that inform this report look at two definitions of local development. The first defines it as the district where the mine is located. The term district is used to refer to political or administrative units that have spending authority. For some of the countries, the latter may be due to a subnational fiscal arrangement in which the district has authority to raise revenue and spend it. In some, it has no taxing authority but instead implements projects on behalf of the central government as part of devolved functions. What they have in common is that one or more mines are available in the unit so described (for details of how districts are defined for the purposes of econometric estimation, see Chuhan-Pole et al. 2015 and Polat et al. 2014). The second defines it as an area within the vicinity of a mine. This section describes what this analysis looks like.

Measuring local effects of mining: District level

We begin with how to capture local impacts at the district level because conceptually it is perhaps the simplest since we identify the effects using an indicator variable capturing whether there are any active large gold mines in the district. Suppose that the outcome for individual *i* in district *d* in time period *t* (Y_{idt}) is regressed on an indicator for whether the individual lives in a district with an active mine (ActiveDistrict) at the time of the survey. The regression model also includes district (γ_d) and year fixed effects (g_t), which will control for cultural differences across districts, and contemporaneous changes that happen across the country. The estimated equation looks like this:

$$Y_{idt} = \beta_0 + \beta_1 ActiveDistrict_{dt} + \gamma_d + g_t + \lambda X_{idt} + \varepsilon_{idt} \qquad (1)$$

The above model is a difference-in-differences specification using a district panel. Quite simply, it compares districts with and without gold mines, before and after the mines started producing. The method allows for initial differences across districts. However, it makes a crucial assumption—called the parallel trends assumption—which is the idea that these initial differences will not affect estimates of outcomes that will be due to the presence of a mine, as long as the trends of the socioeconomic development in the districts were similar before the extraction from the mines began. Under this assumption, one can deduce that the change that happened in mining districts at the same time as the mine opening is in fact a result of the mine (assuming that no other confounding changes happened at the same time) (see box 4.1).

We can run this equation either using individuals as the level of observations and thus control for their characteristics (captured by X_{idt}), or we could estimate a similar model after collapsing the data to the district level and then controlling for the average population characteristics (in that case captured by (X_{dt}). The standard errors are clustered at level of treatment, the district level. Since the treatment variable is at the same level as our district fixed effects, β_1 is interpretable as the treatment effect. We refer to year fixed effect here, because the data structure is not always so simple as to allow for the temporal variation being defined as before and after the mine started producing.

Box 4.1 Artisanal and small-scale mining

The analytic intent of this report is to explore the impact of the large-scale, capital-intensive mining industry in Sub-Saharan Africa on the welfare of local communities. However, not all mining in Sub-Saharan Africa is large scale. In many Sub-Saharan Africa countries with substantial mining industries, including the three cases covered in this report—Ghana, Mali, and Tanzania—there is an artisanal and small-scale mining (ASM) sector, which provides employment (ILO 1999) and livelihood support for many families. It is estimated that around 1 million people in Ghana, 200,000 in Mali, and 550,000 in Tanzania support themselves with revenues from ASM activities. See box 3.1 for more details.

Unlike large-scale mining, ASM workers have low skills and low capital per worker. Moreover, the sector is associated with several hazardous labor conditions: child labor, mercury exposure, risk of mine collapse, and so forth.

Despite huge organizational and operational differences, these two sectors often exist side by side. In some instances, the competing interests lead to conflict between the two sectors, such as around the Prestea mine in Ghana, where domestic *galamsey* miners (informal small-scale miners) have been in conflict with the multinational concession owner (Hilson and Yakovleva 2007). This presents challenges to the exact identification of the impact of large-scale mining. Since we cannot always identify individuals who work in ASM in the data, we cannot account for their contribution to these impacts or ways in which the opening of a large-scale mine affects the ASM participants.

Measuring spillover effects at the district level

Looking for impacts in only the districts that have a mine, as equation (1) implies, could miss the potential spillovers that result from mining. There are two main reasons to consider spillover effects across districts. First, a natural economic impact area of a mine can be larger than a district, whose administratively or politically determined geographic boundaries can be too small for the mine's overall economic and social influence. Second, some mines will be placed on a district border, and the decision to consider the mine as belonging to one district rather than another can seem arbitrary. There is, in fact, a third important reason to consider spillover effects. Mining districts can receive additional fiscal revenue if the mine is within its administrative borders and the country has such fiscal sharing rules. This is one important reason to explore district-level effects. But mining district spending can spill over to the neighboring district—for instance, if they build a road to the border of the neighboring district. In order to compare outcomes in mining districts, neighboring districts, and nonmining districts, the following estimation is used:

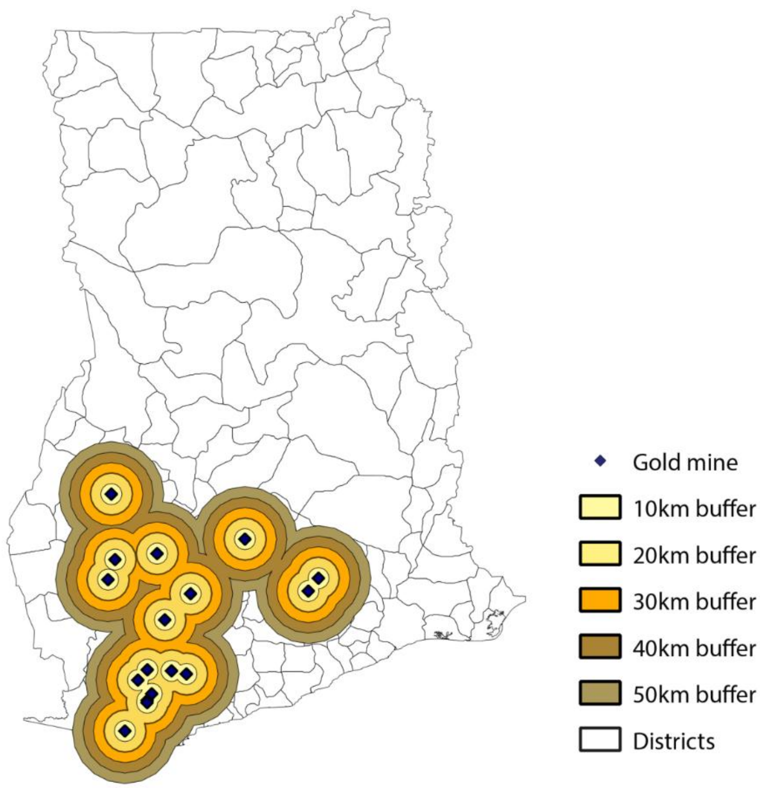
$$Y_{idt} = \beta_0 + \beta_1 ActiveDistrict_{dt} + \beta_2 NeighborDistrict_{dt} + \gamma_d + g_t + \lambda X_{idt} + \varepsilon_{idt}. \quad (2)$$

The interpretation of this model will be similar to the interpretation explained for Equation 1. However, now we are interested in both β_1 and β_2, which allows us to compare the difference in districts with mines, and districts that border these. Both of the methods outlined in Equation 1 and Equation 2 can be further nuanced by allowing for differential effects with intensity of mining, captured by the number of active mines or the annual and aggregated production volumes. In addition, when data permit, a synthetic control method can be used where instead of comparing mining districts to all other districts, we compare them to a specially created synthetic group (following Abadie et al. 2010). The control group is created to be as similar as possible to the treatment group. This method is beneficial when there are few treatment observations (that is, few mining districts), but has high demands on pretreatment data. For Tanzania and Mali, this strategy is tried, but for Ghana, it is not possible since the mines opened earlier and there are too few observations to ensure that we find the right control group.

Measuring local effects of mining: Vicinity of mines

Instead of the district-level effects—or in addition to them—one could look even more closely—that is, analyze the impacts of mining within the vicinity of the mine(s). In this case, it is important to determine how large this local area has to be. As noted, how broadly the mine's influence goes is an empirical exercise. Along with looking at the vicinity of a mine, where up to 20 km from a mine is identified as being close (baseline treatment area)—the focus is also on distance bins—concentric circles of varying distances from the mine. These bins can be within a district or they can span several districts depending on the location of the mine. The spatial lag model divides the plane into small concentric distances, such as 0–10 km, 10–20 km, 20–30 km, and so on, up to 100 km from a mine. In the regression specification, each distance bin can have its own coefficient. The model thus allows for nonlinear effects with distance. Moreover, it allows us to understand whether there are spillovers from large-scale gold mining further away than our baseline treatment distance. Figure 4.6 presents the distribution of mines in Ghana and illustrates how the impact area of the mine is captured in the estimation.

Figure 4.6 Gold mines in Ghana and spatial buffers



For the distance-level analysis, what matters is estimating the outcomes of individuals who live close to the mine regardless of the administrative jurisdiction they live in. The difference-in-differences model that is estimated is as follows:

$$Y_{ivt} = \beta_0 + \beta_1 MineXkm_v * After_t + \beta_3 MineXkm_v + \beta_2 After_t + \gamma_d + g_t + \lambda X_{idt} + \varepsilon_{ivt,} \quad (3)$$

where the outcome *Y* of an individual *i* who lives in village or neighborhood *v* in year *t* is a function of living close to a mine—say, *X* kilometers from a mine (*MineXkm*), after the mine has started producing (*After*). The estimate of interest is the magnitude and direction of the coefficient that is obtained from the interaction of the two, which captures whether the individual lives in the vicinity of a mine that is currently extracting gold. We can still control for individual characteristics, as well as the cross-sectional variation across districts, and the broad changes that happen over time. A similar method has been used by Aragón and Rud (2013, 2015), Kotsadam and Tolonen (2015), and Tolonen (2015).

It is possible that local procurement, to the extent it might not be captured by the businesses in the vicinity of the mine, will contaminate the control groups, and therefore bias the impact downward—toward zero. In addition, some mines have special programs to increase the amount of domestic procurement from suppliers that are not necessarily in the vicinity of mines. Lack of time series data on the level and composition of goods and services procured by each of the mines studied means that this factor cannot be fully controlled for in the estimation. One way to capture these spillover effects in the district-level regressions is by adding specific dummies for neighboring districts.

Combining Mining and Household Data

To estimate models 1–3, the report combines data on mines and from household surveys. The mining data are obtained from several sources. Information on the location of mines (GPS coordinates) for all three countries was obtained from online sources such as *mine-atlas.com* and *google.maps*, as well as from Raw Materials Database of IntierraRMG for Ghana. The mine information on the first year of production and production volume was from IntierraRMG.

Data on households/individuals come from four main sources: Demographic and Health Surveys (DHS), Household Budget Surveys (HBS), Living Standard Surveys (LSS), and Censuses of Population. The DHS are nationally representative household surveys that collect data on marriage, fertility, family planning, reproductive health, child health, and HIV/AIDS. Household Budget Surveys are nationally representative surveys that are used to track changes in consumption levels of households. They include information about household characteristics as well as yearly and monthly household expenditures, and in some cases income levels. The LSS also collects demographic and consumption data. In addition, they collect detailed information on access to services (education, health, water and sanitation), household enterprises and agricultural production, and labor market activity.

Censuses collect information about a range of household and individual characteristics but cover the whole population. Household characteristics include household size and access to electricity, water, and toilet facilities. Individual characteristics like occupation, education, age, and marital status are also included in the censuses. Most of the censuses like the ones used for this analysis do not contain information about individuals' income or consumption levels.

Some of the surveys, especially the DHS and the LSS, are geocoded. Since the mines are also georeferenced, it is easy to determine how far a household observed in such surveys is from the mine. The estimation strategy that uses individuals and households makes use of this information to identify the impacts of the mines. Table 4.2 shows the survey years that are used. Table A.4.1 lists the outcome variables.

Table 4.2 Household survey data

	DHS	LSMS	Census
Ghana	1993, 1998, 2003, 2008	1999, 2004, 2012	
Mali	1995, 2006, (2001)	1989, 2001, 2010	1987, 1998, 2009
Tanzania	1999, 2010, (2007, 2012)	1992, 2001	1988, 2002
Used for	Individual analysis District analysis	Individual analysis District analysis	Synthetic control Analysis

Note: Survey years in parentheses are used in some parts of the analysis.

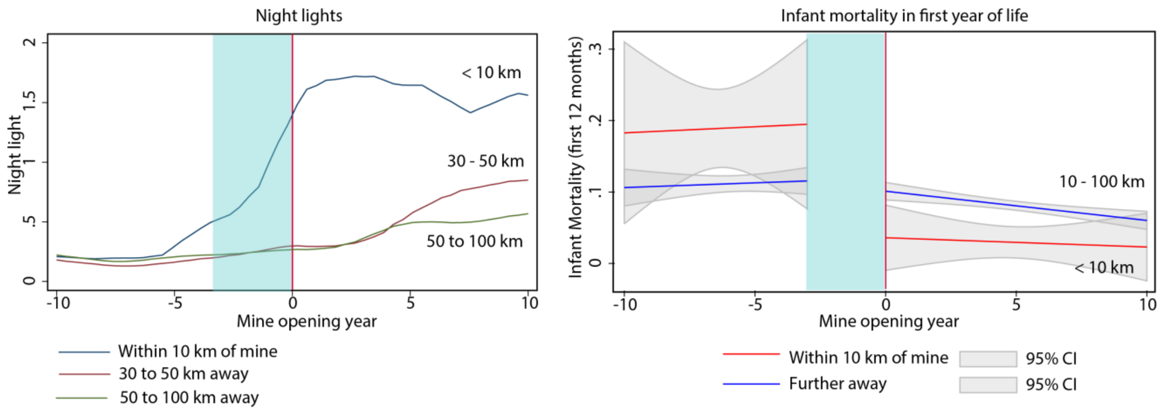
4.3 Results

The assumption of parallel trends is crucial for the difference-in-difference methodology. In the context of this study, the assumption can be interpreted as demanding that the socioeconomic outcomes of interest in mining areas and areas further away would follow the same trend in the absence of the mine becoming active. One way of asserting the validity of this assumption is to analyze pre-trends. The balancing table of outcome and control variables was one first attempt at understanding pre-trends. However, the assumption allows for differences in levels between the control and treatment group, as long as the evolution of the variables are on similar paths. We explore this using night lights and infant mortality. The reason for choosing these two variables is that they provide annual variation (in contrast to, say the labor data, which we only have for the survey years). Moreover, both night lights and infant mortality are two important welfare and development indicators.

Figure 4.7 indicates that night lights in mining areas (defined to within 10 km) are similar to areas further away (30–50 km or 50–100 km away) 10 to 5 years before the mine opens. Already starting from 5 years before, there is a small divergence in night lights and in the investment phase, commonly two years before production begins, the mining areas are already clearly having higher level of lights at night. If we do not exclude this pre-investment period from the control group, it will downward bias our results (a discussion regarding this follows in the result section where we try to exclude this phase). The night light estimates are local polynomial smooth, whereas the infant mortality estimates are linear predictions. In figure 4.7 we allow for a trend break around the pre-investment phase. To the left of the opening year, that is, before the mine started producing, the trends in infant mortality are negative and similar in mining areas and further away. However, the infant mortality rates are higher closer to the mines. After mine opening, that is, to the right on the red vertical line, the opposite is true: Mine areas have lower infant mortality rates. These results for Ghana, Mali, and Tanzania are confirmed in

Tolonen (2015), where the same patterns are found, and for additional mining countries such as Burkina Faso and Senegal.

Figure 4.7 Investigation of parallel trends in night lights and infant mortality



Occupation

Using the methods outlined above, we analyze how gold mining has changed the livelihoods of people in Ghana, Mali, and Tanzania. First, selected summary statistics show that the mine areas have developed differently from nonmining areas in terms of occupation (table 4.3). Mining communities, defined as villages and towns within 20 km of a mine, are on average more focused on agricultural production, with a larger share of men working in agriculture than further away. This is especially true before the mines start active operation.

Mines are land intensive. It is therefore not surprising that they open mostly in rural areas, where land is relatively cheaper and where we would expect agricultural participation to be higher before the mine opens. This is true for Mali, but not for Ghana and Tanzania. Women's participation in the service sector is quite low overall, but the summary statistics show that the sector has grown over time, suggesting that the growth rate in service sector employment might be higher in mining communities.

Table 4.3 Summary statistics for main outcomes from Demographic and Health Surveys sample

	Ghana		Mali		Tanzania	
	(1)	(2)	(3)	(4)	(5)	(6)
	Before	During	Before	During	Before	During
Woman's characteristics						
Age	30.15	30.01	28.59	30.68	29.24	27.68
Wealth	3.01	3.26	—	3.19	3.12	2.80
Nonmigrant	0.36	0.31	0.38	0.49	0.33	0.33
Urban	0.23	0.33	0.25	0.00	0.00	17.8
Woman's occupation						
Not working	0.22	0.21	0.16	0.22	0.14	0.11
Service and sales	0.19	0.25	0.11	0.23	0.01	0.5
Professional	0.06	0.07	0.01	0.00	0.06	0.02
Agriculture	0.41	0.32	0.33	0.06	0.69	0.71
Manual labor	0.12	0.15	0.39	0.06	0.10	0.11
Earning cash	0.88	0.90	0.45	0.60	0.59	0.36
Works all year	0.88	0.88	0.33	0.34	0.17	0.24
Woman's education						
3 years education	0.78	0.82	0.09	0.07	0.74	0.25
No education	0.17	0.13	0.88	0.88	0.22	0.73
Partner's occupation						
Service and sales	0.09	0.12	0.06	0.09	—	0.07
Professional	0.12	0.15	0.04	0.10	—	0.05
Agriculture	0.57	0.42	0.70	0.10	—	0.74
Manual labor	0.21	0.28	0.15	0.15	—	0.13
Child health						
Diarrhea	0.13	0.17	0.22	0.19	0.10	0.12
Cough	0.22	0.18	0.30	0.21	0.29	0.21
Fever	0.24	0.20	0.33	0.22	0.38	0.29

Note: Columns (1), (3), and (5) show summary statistics for a sample within 20 km of a nonactive mine. Columns (2), (4), and (6) show summary statistics for a sample within 20 km of an active mine.
— = not available.

Table 4.4 shows the econometric results for all three countries, across different occupations and for men and women separately. Among women, the likelihood of being a manual worker declined in populations living around the mines. This is stronger for Mali and Tanzania and less so for Ghana, where this is observed more for men than for women. For Ghana, there is a shift from agriculture to services for women, but it is not statistically significant. In Mali, in addition to a large decrease in manual work, there was also a large (insignificant) increase—by about 16 percentage points—in service sector employment for women. Finally, for Tanzania, there was an increase in agricultural participation for women, and a small increase in professional work.

Table 4.4. Occupation for men and women

	Ghana	**Mali**	**Tanzania**	**Ghana**	**Mali**	**Tanzania**
Sample	*Men*	*Men*	*Men*	*Women*	*Women*	*Women*
Treatment distance	*20 km*	*20 km*	*20 km*	*20 km*	*20 km*	*20 km*
Worked last 12 months	0.006	-0.023	0.049	0.006	-0.141	0.124**
	(0.023)	(0.069)	(0.063)	(0.023)	(0.113)	(0.053)
Agriculture	0.05	-0.125	0.103	-0.025	-0.137	0.172***
	(0.051)	(0.164)	(0.117)	(0.039)	(0.232)	(0.062)
Service sector	0.02	0.111	-0.015	0.024	0.160	-0.017
	(0.02)	(0.074)	(0.021)	(0.031)	(0.127)	(0.013)
Professional	0.027	-0.004	-0.011	-0.017*	-0.010	0.023***
	(0.026)	(0.011)	(0.01)	(0.009)	(0.007)	(0.008)
Manual worker	-0.069*	-0.117	-0.029	0.012	-0.227***	-0.071**
	(0.036)	(0.091)	(0.061)	(0.021)	(0.086)	(0.03)

Note: Each line is a new regression estimated using the baseline model. Reported coefficients are for *active*mine*. All regressions control for year and district fixed effects, urban dummy, age, and years of education. *** p<0.01, ** p<0.05, * p<0.1.

The data used for this estimation comes from DHS, which has a prime focus on women's welfare. This means that fewer men were sampled. This can cause problems in our statistical model for men, since a small number of observations means that we can have a problem estimating effects precisely. Not surprisingly, for men, few statistically significant effects are observed, with only a marginally significant drop in manual worker occupation of 6.9 percentage point in Ghana.

Furthermore, these results were obtained by using a 20-km cutoff distance for the treatment area; that is, it is assumed the mine influences outcomes within a 20-km radius. But, in fact, there is no strong reason to assume that 20 km is the true radius of the mine caption area. This cutoff was selected based on guidance from previous studies using similar methodologies: Aragón and Rud 2015 and Kotsadam and Tolonen 2015 use 20-km distances when they explored effects of mining on local agricultural and labor markets in Ghana and Africa. However, Tolonen (2015) shows that most health and labor effects are concentrated within 10 km and 15 km in gold-producing countries in Africa. By contrast, Aragón and Rud's (2013) study on one large gold mine in Peru showed that effects can be found as far afield as 100 km.

The geography of mining

Instead of using a binary variable—comparing those within 20 km of a mine with everyone else outside that distance—in order to capture the impacts, a spatial lag model is used, which allows for nonlinear effects with distance. The results from this model are presented in figure 4.8. The focus is on women's access to occupations, since the DHS data these results are based on are more suitable for women subsamples.

Figure 4.8 shows that service sector employment for women is significantly higher close to active mines. In fact, the effects are stronger within 0 to 10 km of a mine than within 10 to 20 km of a mine. In Mali, the probability that a woman works in service and sales increases by 30 percentage points, and in Ghana by 17 percentage points, in the very closest distance. For Ghana and Mali, agricultural participation drops close to mines, by roughly 20 to 10 percentage points. In Tanzania, no clear change is noticed, either in service and sales or in agricultural employment. The occupation pattern is similar across the three countries between women migrants and never-movers (figure 4.9).

A similar analysis using DHS data can be done for men, since women answer what occupation their partner has. Figure 4.10 shows that men are less likely to work in agriculture if they live within 10 km of a mine (this is statistically significant in Mali). There is a pattern in the data that indicated that there might be a geographic displacement of farming activities from very close to a mine to slightly further away (20 to 30 km), especially in Ghana. Men are not more likely to work in manual labor in Ghana or in Mali. For Ghana, data on mining employment from the Ghana Living Standards Survey dataset confirms that there is a 10-percentage-point increase in the likelihood that a man living close to a mine works in mining.

Figure 4.8 Spatial lag model illustrating geographic distribution of effects on service sector employment

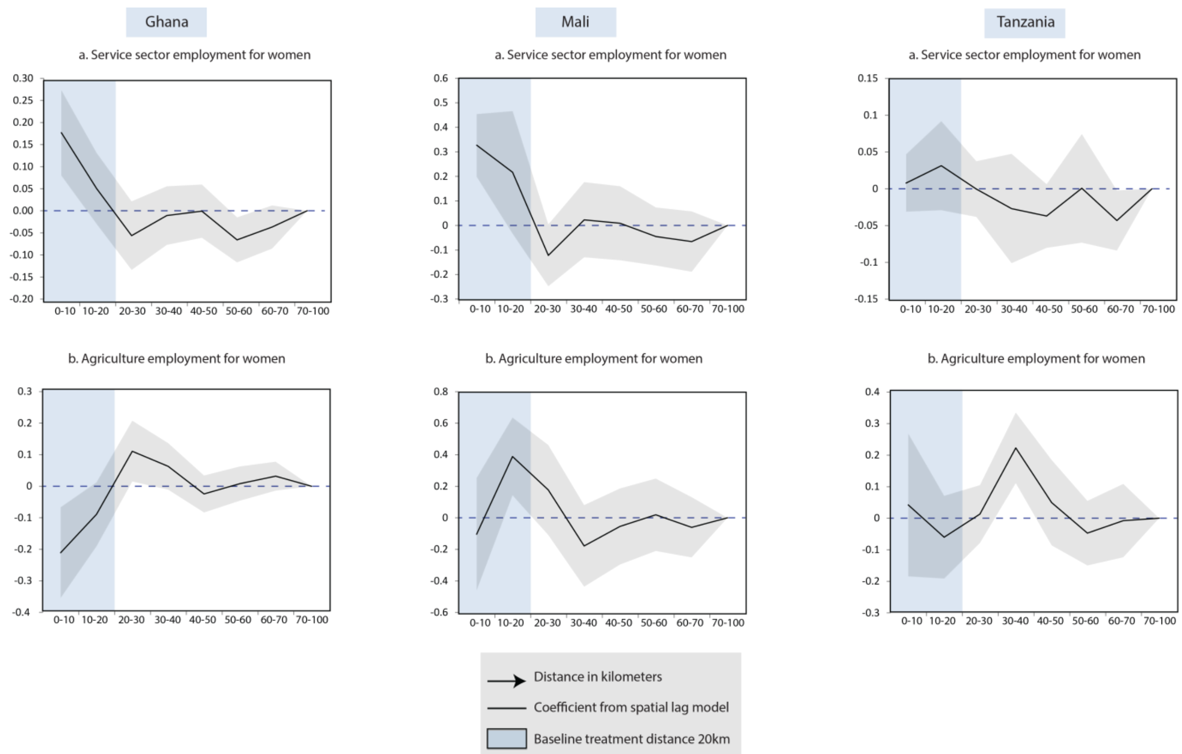


Figure 4.9 Migrants and never-movers: Occupation

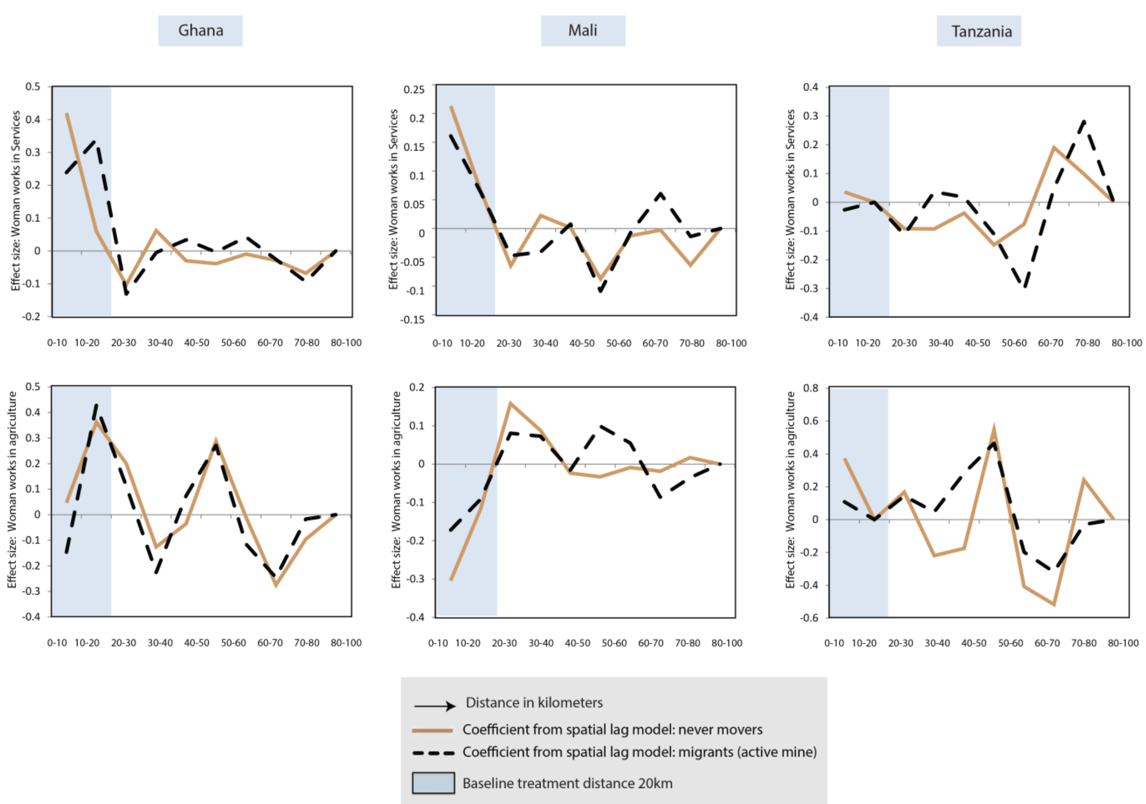
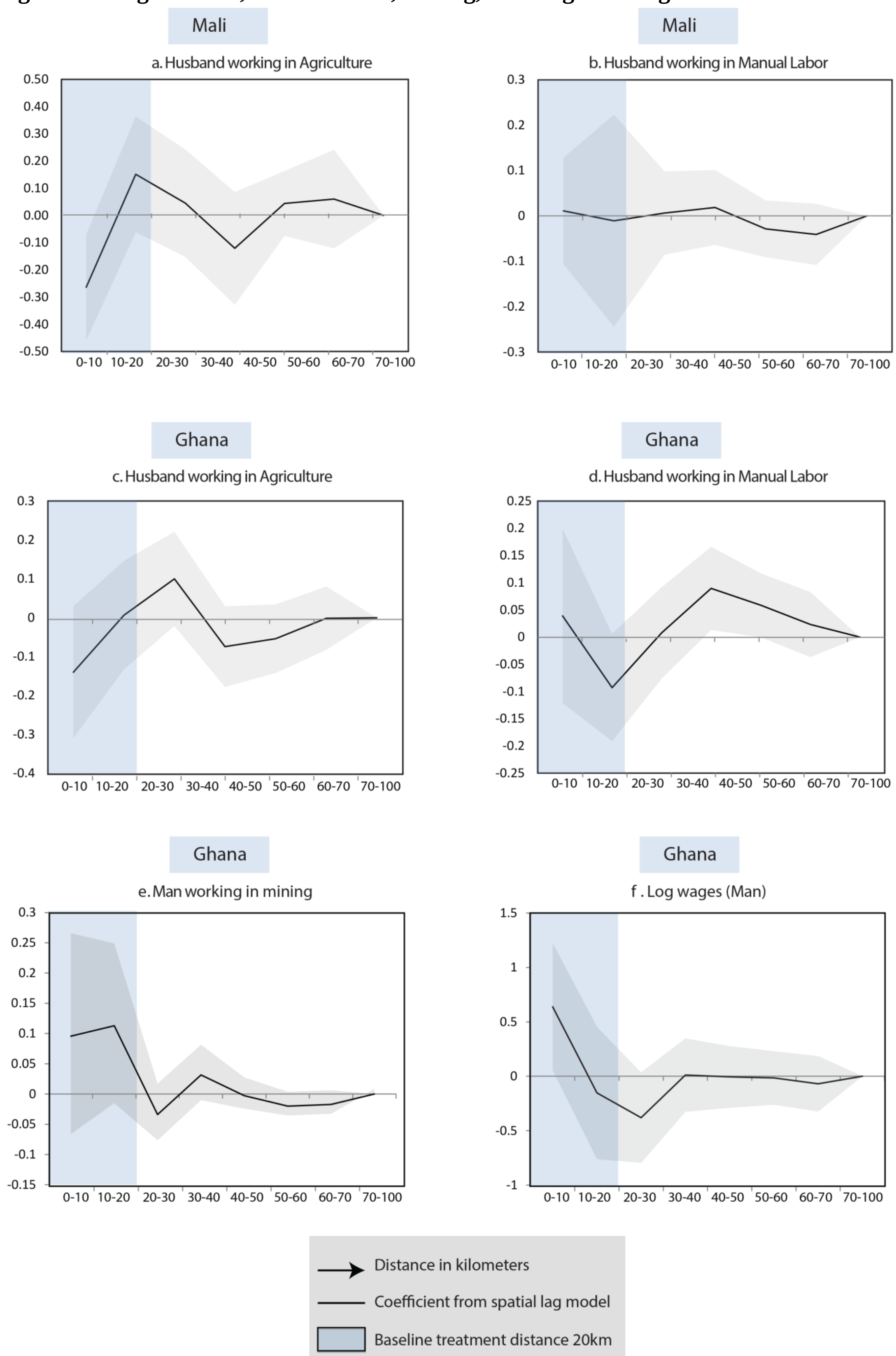


Figure 4.10 Agriculture, manual labor, mining, and wage earnings for men



The discussion in previous sections took a closer look at the impacts of mines on individuals' employment prospects and wages. This is one way of looking at local impacts of mining. But the costs and benefits within the neighborhood of a mine that have been discussed thus far are not exhaustive. As we argued at the beginning of this chapter, mining can have additional impacts beyond the neighborhood of the mine if mining royalties and revenues are spent on populations living in districts where the mine is located. Injection of additional expenditures into the district could increase spending on welfare-enhancing services, such as schooling or health care. The likelihood of identifying these channels depends on a host of factors, including whether in fact there is a rule-based formula for sharing of mining revenues, and the quality and performance of local politicians and bureaucracy.

Unfortunately, while information is available on whether or not there is a revenue-sharing rule in the three countries, time series data on the actual revenue flows or a measure of bureaucratic performance are lacking. Absent data on these crucial drivers of outcomes, we present in this chapter a first approximation of additional impacts by simply comparing outcomes between mining and nonmining districts. As in the previous results, the district-level analysis makes use of data from DHSs, HBSs, and censuses. In Mali and Tanzania, we mapped (through well-known imputation methods) the outcome variables that do not exist in the censuses (see table 2 of Polat et al. [2014] for the list of variables used in mapping), which are malnutrition outcomes of children and per capita expenditure. The averages of all the outcome variables for each district are calculated. Then, a simple difference-in-differences analysis and a synthetic control group analysis using district-level averages is undertaken. For Tanzania, the district-level analysis includes the districts that are on the mainland; it excludes the districts of Pemba and Zanzibar.

In the synthetic control analysis, an average of the outcomes of the mining districts and average of the outcomes of neighboring districts are used to compute one representative mining district and one representative neighboring district. The synthetic control method gives weights to the remaining districts to come up with the most representative control district (see Polat et al. [2014] for details of how this was constructed). Following Abadie, Diamond, and Hainmueller (2010), placebo tests are used to find out whether the significance of the results could be found by chance. That is, we try to determine whether a district that is randomly assigned to be the treatment district differs significantly from its synthetic control district in the post-treatment period. This will show us how often the difference between the outcomes of the real treatment district and its synthetic counterpart stands out. In the ideal case, it must be that the outcome of the real treatment district should be significantly different from the outcome of its synthetic control district, while for other districts that are randomly assigned to be the treatment district, the difference should not be as high.

Overall, the district-level analysis of changes in women's and men's employment confirms the findings of the distance-level analysis. Table 4.5 reports the simple difference-in-differences at the district level for Ghana. The results indicate that agricultural employment decreases in mining districts by 8.5 percentage points relative to nonmining districts for women (panel A). Moreover, there is a negative relationship between tons of gold produced and agricultural employment (panel B). In addition, the probability of a woman working all year increases by 5.4 percentage points, as does the probability of working in manual work (panel A). The same is not observed in adjacent districts (panel B). For men, there is a 5.2-percentage-point decrease in agricultural participation, but no significant increases in other sectors. However, the insignificant point estimates indicate that men might be shifting toward service sector employment and manual work. Previously, results from the Ghana Living Standards Survey had shown that men in Ghana might shift into mining employment. For DHS, similar information on whether men work in mining employment is not available, so this finding cannot be confirmed here.

Table 4.5 District-level effects on occupation in Ghanaian gold districts and neighboring districts[a]

	(1) Not Work-ing	(2) Agri- Culture	(3) Service or sales	(4) Profes- Sional	(5) Manual work	(6) Earns cash	(7) Works All Year
Panel A. Mine districts: Women							
active district	0.019	-0.085**	0.034	-0.018**	0.050**	-0.021	0.054*
	(0.027)[b]	(0.042)	(0.03)	(0.008)	(0.02)	(0.049)	(0.032)
Panel B. Spillovers: Women							
gold period	0.004	-0.009**	0.003*	0.004***	-0.002	0.001	0.006
district	(0.004)	(0.004)	(0.002)	(0.002)	(0.004)	(0.003)	(0.004)
neighbor	-0.004	0.005	-0.001	-0.002***	0.001	0.008*	-0.002
gold production	(0.004)	(0.004)	(0.004)	(0.001)	(0.003)	(0.004)	(0.004)
Panel C. Mine district: Men							
active district	0.008	-0.052**	0.020	-0.009	0.024		
	(0.009)	(0.023)	(0.030)	(0.026)	(0.027)		

Note: a. Women's (Panel A and B) and Men's (Paned C) labor market opportunities according to DHS.
b. Robust standard errors clustered at the district level in parentheses. All regressions control for year and district fixed effects, urban dummy, age, and years of education. Active is active status of mine in the survey year. *** p<0.01, ** p<0.05, * p<0.1. *gold_period_district*, is equal to total production for the years before the survey.

Table 4.6 shows the results from a district analysis for Tanzania and Mali. For Tanzania, the data come from HBSs and compare across districts in the Tanzanian mainland. For each of the 103 districts in the analysis, 4 are mining districts (Geita, Kahama, Nzega, and

Tarime). For Mali, there are 257 districts and 5 of these are mining districts (Fourou, Kalana, Kenieba Central, Sadiola, and Sanso). The difference-in-differences district analysis shows that there are significant increases in the likelihood of mining employment. In Mali, men are almost 10 percentage points more likely to work as miners, and women 2.3 percentage points more likely to work as miners than before. Note, however, that these changes can also be due to increases in small-scale mining in these districts over the same period. Overall, men's and women's agricultural employment decreases, but these results are not statistically significant. For Tanzania (panel B), there is no recorded information on mining employment. Similar to Mali, there is an economically significant decrease in agricultural employment (8 percentage points for men and 11 percentage points for women), but these estimates are not statistically significant.

Table 4.6 District-level effects on employment in gold districts in Mali and Tanzania

	(1)	(2)	(3)	(4)	(5)	(6)
	Agriculture (men)	**Agri-culture (women)**	**Service empl. (men)**	**Service empl. (women)**	**Mining empl. (men)**	**Mining empl. (women)**
Panel A. Mine districts in Mali						
active district	-0.12	-0.35	0.02	-0.01	0.097***	0.023**
	(0.342)	(0.035)	(0.454)	(0.552)	(0.000)	(0.002)
R-squared	0.10	0.02	0.12	0.01	0.14	0.05
Observations	514	514	514	514	514	514
Panel B. Mine districts in Tanzania						
active district	-0.08	-0.11	-0.0003	-0.006		
	(0.5456)	(0.4428)	(0.9875)	(0.7083)		
R-squared	0.02	0.133	0.01	0.012		
Observations	206	206	206	206		

Note: Standard errors in parentheses. Unit of observation is district level. Mining districts have at least one active gold mine. The regressions control for year fixed effects and initial conditions in mining districts. No information is available on mining employment for Tanzania. ***p<0.01, **p<0.05, *p<0.1.

For both Mali and Tanzania, a district-level analysis that compares mining districts to control districts using the synthetic control method is undertaken. While the findings do not indicate large positive impacts of mines on overall employment rates of men or women in mining districts compared to nonmining districts, there is some evidence of significant changes in the composition of employment. For example, in Mali, employment rates of men and women working in the manufacturing sector increased, while agricultural employment for women decreased considerably (table A.4.2). In Tanzania, by contrast, there are no significant differences between mining and nonmining districts on overall employment changes or in the composition of employment for both men and women (table A.4.3). Overall, these district-level results are consistent with the finding using individual-level estimates that were reported in the previous section.

Is local structural transformation occurring?

Recall that one mechanism through which mining can have large impacts is through agglomeration economies—that is, gains in productivity that are unleashed with clustering of economic activities around the mine(s). The first sign of such a change would be the movement of labor and other factors away from traditional sectors to new sectors. In our country cases, that would mean a change in the structure of the local economy from being dominated by "traditional" farming—defined by low inputs and low capital per worker—to a more balanced local economy. Therefore, an important question is whether the results presented in the previous section lead us to believe that gold extraction in these countries has helped shift workers from agriculture to other sectors with higher productivity, higher wages, and greater opportunities for economic growth. In other words, are there signs of local structural transformation?

The empirical results thus far show that, in some countries, women shift from agriculture to service sector employment in the close vicinity of mines. There is also an increase in employment in mining for men. The shift into mining or into services is away from subsistence farming, which is the dominant occupation before mine operation. Summary statistics show that participation in the agricultural sector is between 33 and 70 percent in mining communities at the start of our period (table 4.3) for men and women. After mining begins, the participation rates for both men and women drop sharply in Ghana and Mali. It is possible that this is caused by pull factors, where higher productivity and wages in mines encourages community members to change occupations. A competing hypothesis is considered by Aragón and Rud (2015), who show that pollution from the mine decreased agricultural productivity around Ghana's gold mines. This effect could be reinforced by the land-intensive nature of mining, which increases competition over limited land resources, and leads to a decrease in available arable land if the mines are located in the agricultural hinterland.

The increase in service sector employment and in other sectors can be understood as "local multipliers" (Moretti 2010), where for each job created directly in mining, there are additional jobs created in the tradable or nontradable sector. The size of the multiplier will depend on total mine employment, miners' wages and spending habits, and how the mining company sources inputs (such as food, electricity, and housing for its workers). Companies can try to boost the multiplier by, for example, ensuring that it sources inputs from local suppliers. In addition, there are local fiscal multipliers. A mine may result in local tax contributions that when spent by the local government can help stimulate the local economy. Unfortunately, there are insufficient data to calculate these multipliers, but the results support this hypothesis.

Findings from the Ghana Living Standards Survey show that women are not benefiting as much from direct employment in mining, which highlights that the structural change that happens with mining is gender specific. Gender segregation in labor markets has previously been found to be important in determining how extractive industries can generate employment for men and women. This argument was first made by Ross (2008) regarding oil industries, and this hypothesis was later tested for African mining using microdata (Kotsadam and Tolonen 2015).

Income, wages, and expenditure in mining communities in Ghana

One sign of structural transformation is the shift toward wage or nonfarm activities. The findings so far have shown that there are signs that the latter is happening in local communities around the mines in the three countries. Is similar evidence available for wages? The available household surveys listed above have two drawbacks for understanding wages and mining. First, they are not geocoded, so the workers cannot be linked to a mine. Second, most have no wage data. The exception is Ghana, where geocoordinates for the surveyed households are available in the Ghana Living Standards Survey. This allows a mapping of wages, income, and expenditure change in the mining communities. The analysis shows that in mining communities, household total wages increase, as do women's wages (table 4.7). Men's wages increase too, but the increase is not precisely estimated. In general, men's wages are higher, so despite a larger increase in women's wages, these estimates do not indicate that women's wages are higher than men's wages. While household total wages increase, there is a decrease in household expenditure (column 4). Note that wage earnings are only recorded for those who are engaging in wage labor—in fact, only 13.3 percent of people in the Ghana Living Standards Survey sample have recorded wage earnings. So while there is an increase in the wage rate for those who earn wages, what happens to total earnings in households without any wage labor is not clear.

Table 4.7 Using LSMS for Ghana for mapping changes in income, wages, and expenditure

	(1) Ln wages All	(2) Ln wages Men	(3) Ln wages Women	(4) Ln pc exp.	(5) Total household exp.
active*mine	0.520**	0.391	0.694***	-0.178*	-0.126
	(0.226)	(0.238)	(0.241)	(0.093)	(0.089)
Controls					
individual	Y	Y	Y		
hh head				Y	Y
hh size					Y
district fe	Y	Y	Y	Y	Y
year fe	Y	Y	Y	Y	Y
deflated	N	N	N	Y	Y
mean (ln)	15.3	15.31	15.29	13.04	14.19

Note: (1) Annual wages and salaries for individuals in all ages (nondeflated).
(2) Annual wages and salaries for women in all ages (nondeflated).
(3) Annual wages and salaries for men in all ages (nondeflated).
(4) Real per capita annual food and nonfood expenditure (regionally deflated).
(5) Total annual regionally adjusted household expenditure (local currency).
*** p<0.01, ** p<0.05, * p<0.1. All regressions control for year and district fixed effects, urban dummy, age, and years of education.

Findings on changes in expenditure in Ghana are presented in table 4.8. The evidence shows that regional food prices are higher in mining areas (column 1), which is similar to the findings in Peru (Aragón and Rud 2013). But unlike the Peru study, the regionally deflated food expenditure does not increase (column 2), nor does the share of food in total deflated household expenditure (column 6 or 7) rise. However, total household expenditure on housing increases by 31.6 percent with the mining onset, all else being equal (column 4, not regionally deflated prices), along with the share of this component in total expenditure. The same is true for energy costs, such as electricity and gas, which rise 29.7 percent with the onset of mining, all else being equal. This might be due to a rise in electrification that is observed in the DHS data (results are presented later in the chapter).

Table 4.8 Using LSMS for Ghana for mapping changes in expenditure composition

	(1)	(2)	(3)	(4)	(5)
	Food price index	**Food expenditure**	**Education health**	**Housing**	**Electricity and gas**
Panel A: Household Expenditure					
active mine	0.035***	-0.069	-0.168	0.316**	0.297**
	(0.012)	(0.095)	(0.199)	(0.139)	(0.119)
mean (ln)	—	13.42	10.88	10.74	9.52
Observations	7,557	7,396	6,541	7,420	4,752
R-squared	0.582	0.963	0.837	0.933	0.950
Deflated	—	Y	N	N	N
	(6) food share	(7) food share	(8) education and health share	(9) housing share	(10) electricity and gas share
active mine	-0.017	-0.022	-0.097	0.404***	0.267**
	(0.054)	(0.053)	(0.186)	(0.121)	(0.129)
Observations	7,396	7,396	6,541	7,420	4,752
R-squared	0.196	0.245	0.145	0.225	0.171
per capita expenditure	No	Y	N	N	N
deflated	Y	Y	N	N	N

Note: All expenditure and food share variables are used in natural logarithms. All regressions control for household head, household size, district fixed effects, and year fixed effects.

Similar analysis for Mali andTanzania, using the district-level analysis that compares mining districts to control districts using the synthetic control method, shows an increase in income inequality in mining and neighboring districts compared to control districts in Mali, while the opposite happens in Tanzania (tables 4.9 and 4.10). In Tanzania, average real per capita expenditure decreases when the mining districts and neighboring districts are taken together as treated units in the difference-in-differences analysis; however, the decrease turns out to be significant for mining districts only in the synthetic control analysis.

Table 4.9 Outcomes for variables from synthetic control analysis, Tanzania

	Mining districts	Synthetic control group – Mining districts	Neighboring districts	Synthetic control group – Neighboring districts	Control group
Real per capita expenditures					
1988	4,867.5	4,868.3	5,062.9	5,052.7	4,747.1
2002	2,231.4	3,058.6	2,201.6	3,172.2	2,982.7
Gini					
1988	0.329	0.328	0.332	0.331	0.344
2002	0.371	0.362	0.323	0.362	0.364
Income share of bottom 40%					
1988	0.189	0.188	0.198	0.198	0.184
2002	0.154	0.161	0.153	0.161	0.162
Income share of upper 5%					
1988	0.178	0.178	0.184	0.182	0.182
2002	0.202	0.199	0.186	0.198	0.199

Note: Reported outcomes for mining district is the average outcome of the mining districts, and for neighboring district it is the average outcome of the neighboring districts. Control group is the average outcome of the districts except neighboring districts and mining districts.

Table 4.10 Outcomes for variables from synthetic control analysis, Mali

	Mining districts	Synthetic control group – Mining districts	Neighbor-ing districts	Synthetic control group – Neighboring districts	Control group
Real per capita expenditures					
1987	174,626	165,184	154,242	151,096	137,099
1998	133,798	137,750	121,767	125,681	122,919
2009	142,779	115,028	120,288	117,702	115,153
Gini					
1987	0.319	0.327	0.276	0.277	0.288
1998	0.382	0.371	0.333	0.333	0.348
2009	0.366	0.313	0.300	0.287	0.285
Income share of bottom 40%					
1987	0.218	0.208	0.231	0.229	0.205
1998	0.184	0.195	0.205	0.208	0.185
2009	0.194	0.223	0.219	0.233	0.229
Income share of upper 5%					
1987	0.182	0.173	0.147	0.150	0.149
1998	0.207	0.208	0.175	0.172	0.176
2009	0.201	0.176	0.164	0.161	0.156

Note: Reported outcomes for mining district is the average outcome of the mining districts, and for neighboring district it is the average outcome of the neighboring districts. Control group is the average outcome of the districts except neighboring districts and mining districts.

Asset accumulation

How does the opening of a mine close to a community affect the household's probability of ownership of assets such as cement floor, radios, and cars? The regression results using the baseline specification in table 4.11a show that households (close to a mine) in Mali are 30 percentage points more likely to have floors made of cement, tile, wood, or materials other than earth, sand, or dung. Households in Mali are also 5 percentage points more likely to own a car (but 11 percentage points less likely to own a bicycle, at a 90 percent confidence level). Elsewhere, households in Ghana are 14 percentage points more likely to own a radio. Table 4.11b decomposes the effects by migration status of the surveyed women. Radio ownership increases for both migrant women and nonmigrant women in Ghana, but for Mali it seems like the positive effects on household assets are driven by migrant households. In Tanzania, we found no significant changes in assets according to table 4.11a, but we learn from the decomposition that radio ownership in fact increased among nonmigrant households. These effects are also illustrated with figures 4.11 and 4.12.

Table 4.11a Household asset accumulation

	(1) Floor (cement)	(2) Bicycle	(3) Car	(4) Radio
Ghana				
active*mine	-0.000	0.036	0.010	0.137***
	(0.044)	(0.026)	(0.011)	(0.038)
Observations	14,099	14,114	14,112	14,102
R-squared	0.235	0.280	0.093	0.146
Mali				
active*mine	0.299***	-0.113*	0.049**	0.003
	(0.091)	(0.068)	(0.023)	(0.081)
Observations	6,861	6,884	6,847	6,881
R-squared	0.311	0.204	0.087	0.049
Tanzania				
active*mine	0.048	0.011	-0.003	0.024
	(0.054)	(0.107)	(0.007)	(0.049)
Observations	6,942	6,945	6,938	6,942
R-squared	0.363	0.175	0.082	0.054

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy, and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. See table A.4.1 for variable definitions. All outcome variables are indicator variables that take the value 1 or 0. *Shared toilet* is if the household shares toilet facilities with other households rather than having a private toilet facility; *Water>10min*, indicates if it takes more than 10 minutes to fetch drinking water from the home; *Floor (cement)* captures whether flooring is made of cement, tile, wood, or materials other than earth, sand, or dung; *Bicycle*, *Car*, and *Radio* captures whether the household has these assets. *p<0.05; **p<0.01; ***p<0.001.

Table 4.11b Household asset accumulation by migration status

	(1) Floor (cement)	(2) Bicycle	(3) Car	(4) Radio
Ghana: Migrants				
active*mine	-0.045	0.067**	0.010	0.113***
	(0.046)	(0.029)	(0.013)	(0.042)
Ghana: Nonmigrants				
active*mine	0.055	0.001	0.022	0.212***
	(0.058)	(0.035)	(0.015)	(0.057)
Mali: Migrants				
active*mine	0.449***	-0.147*	0.062**	0.132***
	(0.107)	(0.087)	(0.026)	(0.050)
Mali: Nonmigrants				
active*mine	0.116	-0.053	0.038	-0.141
	(0.075)	(0.101)	(0.030)	(0.121)
Tanzania: Migrants				
active*mine	-0.099	0.076	0.001	-0.082
	(0.088)	(0.193)	(0.012)	(0.083)
Tanzania: Nonmigrants	-0.184	-0.191*	0.005	0.248**
active*mine	(0.111)	(0.103)	(0.008)	(0.095)

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy, and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. See table A.4.1 for variable definitions. All outcome variables are indicator variables that take the value 1 or 0. *Shared toilet* is if the household shares toilet facilities with other households rather than having a private toilet facility; *Water>10min*, indicates if it takes more than 10 minutes to fetch drinking water from the home; *Floor (cement)* captures whether flooring is made of cement, tile, wood, or materials other than earth, sand, or dung; *Bicycle*, *Car*, and *Radio* captures whether the household has these assets. Migrants are women who have ever moved in their life, and nonmigrants are women who have never moved in their life. *p<0.05; **p<0.01; ***p<0.001.

Figure 4.11 Spatial lag model illustrating geographic distribution of effects on radio ownership

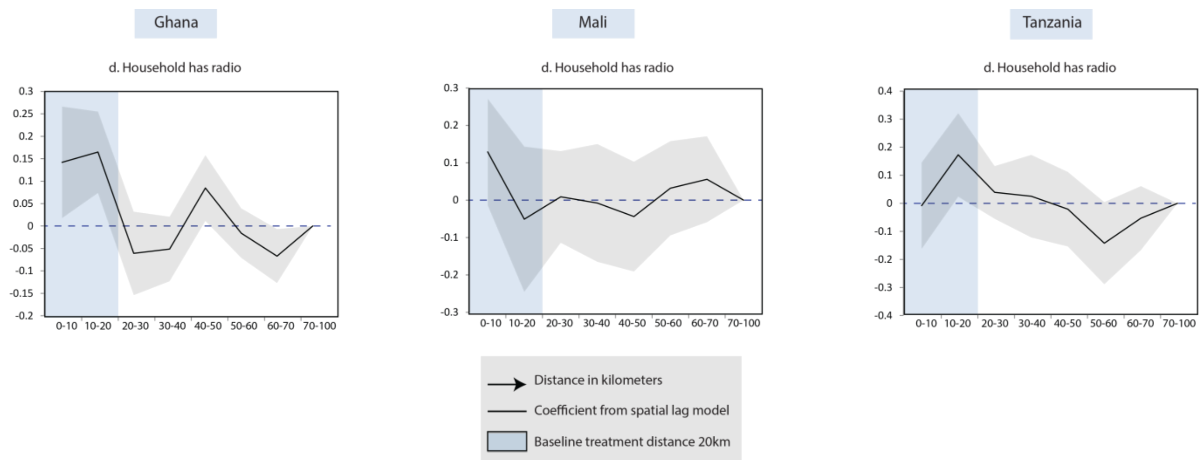
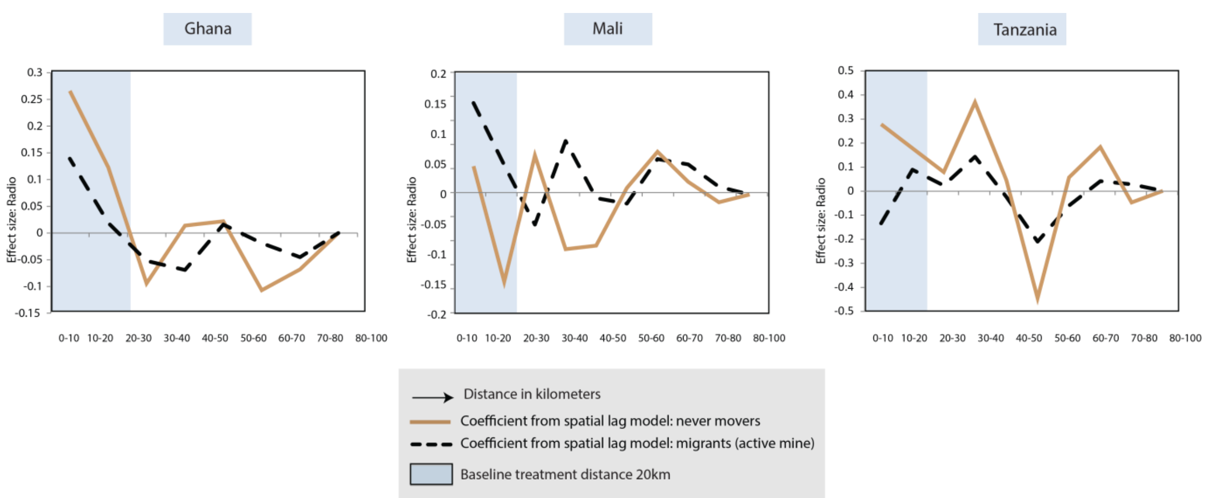


Figure 4.12 Spatial lag model illustrating geographic distribution of effects on radio ownership for migrants and nonmigrants



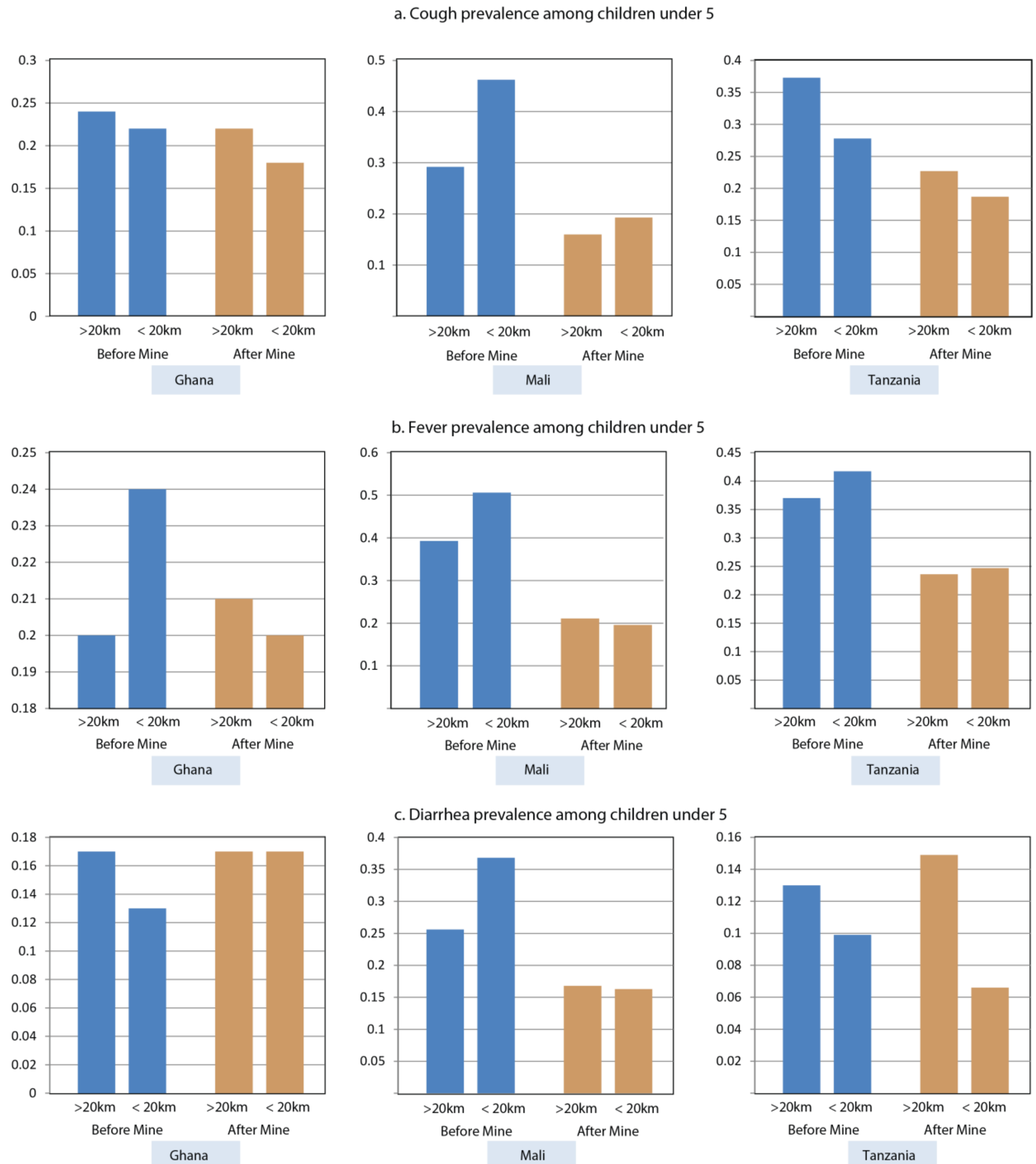
Child Health

Large-scale gold mining can affect child health in different ways. First, it could change household income. Higher income enables the household to buy better or more nutritious food. Second, it could affect child health through changing the environment where the children live. Higher income could improve child (and household) health by reducing the disease environment through making it possible for the household to buy better-quality housing—with proper sanitation and clean water. Higher incomes can also directly buy better health care. However, if large-scale gold mining decreases local agriculture, it could increase food insecurity among households in the vicinity, and if it leads to environmental degradation and pollution that is harmful for humans, the effects on child health could be negative. Thus, how a mine affects child health remains theoretically ambiguous.

Previous literature, however, does provide some clues. Using a dataset from nine African countries and more than 60 gold mines, Tolonen (2015) shows that infant mortality decreases sharply in gold mining communities in Africa with the onset of large-scale mining. She argues for an income story explaining the huge drops. Another econometric study (von der Goltz and Barnwal 2014) focusing on different types of mineral mines across developing countries finds that mines associated with lead pollution lead to increased rates of anemia in women and stunting in children in very close proximity to large mines (<5 km).

Summary statistics show mixed trends across a range of child (under 5 years of age) health outcomes across countries and between mining and nonmining areas (figure 4.13). With a few exceptions, the broad trend is lower incidence of diseases: declines in prevalence of cough and fever, but mixed trends in prevalence of diarrhea.

Figure 4.13 Summary statistics of child health in Ghana, Mali, and Tanzania



Child health improves in Mali

The empirical analysis finds positive effects on access to health care and health outcomes in Mali (table 4.12, column 2). Pregnant mothers receive many more prenatal health visits. Infant mortality decreases by 5.3 percentage points (although it is not significantly estimated), and stunting decreases by 27 percentage points, which is equivalent to a 45 percent decrease in the prevalence from the pre-mine average rate of stunting. Stunting is an indicator of chronic malnutrition, which affects children's growth patterns and thus makes them short for their age. By contrast, wasting measures acute malnutrition. Wasting can be a life-threatening condition, if the child rapidly loses weight and becomes severely malnourished. For Mali, the estimated effect is negative but insignificant for wasting, but negative and significant for underweight, which is a composite measure of acute and chronic malnourishment.

The results also show that the prevalence of cough, fever, and diarrhea decrease, although all but fever are only marginally statistically significant. The significant drop in diarrheal incidence of children in mining communities in Mali is a welcome development, since diarrhea remains a serious threat to children in developing countries, even though it is a disease that is easy to cure and prevent. Access to safe water and sanitation are important in fighting diarrheal diseases, and this could be a way in which a mine affects diarrheal incidence in Mali. Table 4.17 shows that households in Mali are 6.5 percentage points less likely to spend more than 10 minutes fetching water (insignificant), although this suggests little about the quality of that water. There is some evidence (box 4.3) that access to a private toilet facility, which might be important to stop the spread of diarrheal diseases, and access to flush toilets, increase in mining communities (although this is insignificant).

Table 4.12 Child health outcomes in infancy and for children under age 5

	(1)	(2)	(3)
Country	**Ghana**	**Mali**	**Tanzania**
Treatment Distance	**20 km**	**20 km**	**20 km**
Outcomes in infancy			
Prenatal care	-0.151	0.398***	0.007
	(0.331)	(0.086)	(0.018)
Infant mortality	-0.041*	-0.053	0.027
	(0.022)	(0.035)	(0.017)
Anthropometrics (under 5)			
Stunted	0.148	-0.274***	0.123*
	(0.120)	(0.066)	(0.067)
Wasted	0.095	-0.063	0.004
	(0.119)	(0.056)	(0.022)
Underweight	0.065*	-0.160***	0.113***
	(0.037)	(0.06)	(0.032)
Health outcomes last 2 weeks (under 5)			
Cough (last 2 weeks)	-0.061*	-0.195*	0.103
	(0.033)	(0.104)	(0.075)
Fever (last 2 weeks)	-0.035	-0.154	0.074
	(0.037)	(0.102)	(0.074)
Diarrhea (last 2 weeks)	0.042	-0.164**	-0.002
	(0.027)	(0.065)	(0.023)
Household access to sanitation			
Flush toilet	-0.008	-0.001	-0.014
	(0.022)	(0.012)	(0.035)
Pit toilet	0.046	0.177	-0.170
	(0.038)	(0.187)	(0.107)
No toilet	-0.038	-0.176	0.184*
	(0.033)	(0.186)	(0.111)

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy, and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. See table A.4.1 for variable definitions. *p<0.05, **p<0.01, ***p<0.001.

Box 4.3 Does access to sanitary facilities change in Mali?

Table 4.12 shows that the opening of a mine does not significantly change access to sanitation; there are no significant shifts between having no toilet facility, to having a pit latrine, to having a flush toilet.[a] For Tanzania, there is a marginally significant increase in the likelihood that the household does not have a toilet facility in the compound. In Mali, the results indicate (although note that they are not statistically significant) that there is a shift in likelihood from having no toilet (a 17.6-percentage-point decrease) to having access to a pit toilet (a 17.7-percentage-point increase).

To understand the effect of a mine opening on household access to sanitation, we explore whether households are more likely to not share their toilet facility and whether they are more likely to have access to a flush toilet, the closer the household is to an open mine. Figure 4.14.a shows that the likelihood of a household sharing their toilet facility with another household decreases close to active mines, and that the likelihood of the household having a flush toilet increases (figure 4.14.b), although these results are not significant, as indicated by the 95 percent confidence intervals, in grey. Figure 4.15 shows that no clear change in access to any toilet or pit toilet is found in households where the woman is a never-mover. However, for the migrant population, it seems like migrants who live very close to the mine (within 10 km) have better sanitation facilities than migrants who live a little farther away. Note that no confidence intervals are presented here, and that these effects are not significantly estimated.

Figure 4.14 Household access to toilet facilities in Mali

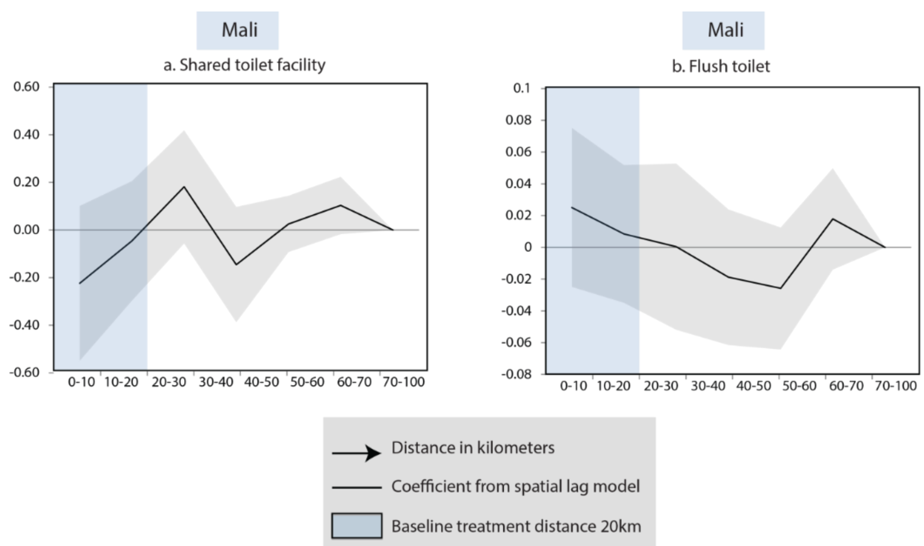
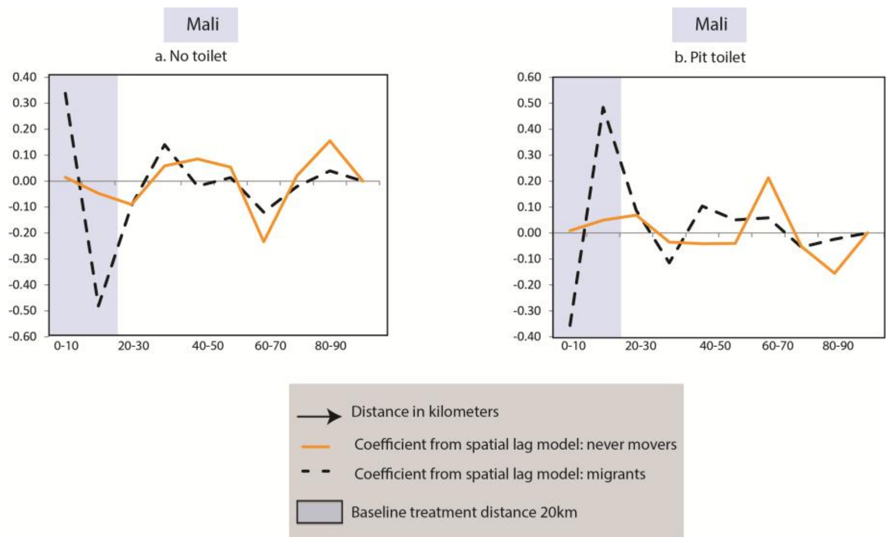


Figure 4.15 No toilet or pit toilet among migrants and never-movers in Mali



Note: a. Decomposing these effects by migration status shows no significant differences across migrants and never-movers.

In contrast with Mali, the evidence on child health effects of the onset of mining in Ghana and Tanzania is ambiguous. The likelihood that a child is stunted increases 12.3 percentage points in Tanzania, and underweight increases in mining communities in both Ghana and Tanzania. However, there are some positive effects of the mine. Importantly, infant mortality decreases in Ghana, and there is also a marginally significant decrease in cough prevalence. The effect of the mine on diarrheal incidence in Ghana is positive but insignificant. Disaggregating this effect by groups shows that, in Ghana, migrants experience higher rates of diarrhea and never-movers lower rates.

The district-level analysis confirms some of the above child health findings. Table 4.13 shows five measures of child health care access. In Ghana, mothers in gold-mining districts have 0.759 more prenatal visits per child, and they are 12.5 percentage points more likely attended by a trained midwife (column 3). Moreover, infant mortality is 8.5 percentage points lower in active mining communities (column 5). No changes are noticed for district-level access to water (measured in time) and household electrification.

Table 4.13 District-level effects on access to health services for children in Ghanaian gold districts

	(1)	(2)	(3)	(4)	(5)
	Prenatal visits	**Prenatal: physician**	**Prenatal: midwife**	**Health card**	**Infant mortality**
Panel A. Mine districts					
active district	0.759***	0.055	0.125***	0.039	-0.085***
	(0.244)	(0.115)	(0.033)	(0.059)	(0.031)
Observations	9,245	9,462	9,462	11,047	9,270
R-squared	0.242	0.160	0.154	1.161	0.138

Note: Robust standard errors clustered at the district level in parentheses. All regressions control for year and district fixed effects, urban dummy, mother's age, and mother's years of education. Active is active status of mine in the birth year, except has health card, which is a measure of contemporary health care access. ***p<0.01, **p<0.05, *p<0.1.

Findings from the district-level analysis (which compares mining districts to control districts using the synthetic control method) for Mali and Tanzania indicate some positive outcomes (tables 4.14 and 4.15). For example, the results show improvements in children's nutrition status in mining and neighboring districts compared to control districts.

Table 4.14 Outcomes for variables from synthetic control analysis, Tanzania

	Mining districts	**Synthetic control group – Mining districts**	**Neighboring districts**	**Synthetic control group – Neighboring districts**	**Control group**
Stunted					
1988	0.415	0.417	0.405	0.406	0.397
2002	0.465	0.512	0.428	0.51	0.509
Severely stunted					.
1988	0.316	0.316	0.305	0.305	0.279
2002	0.112	0.26	0.093	0.267	0.272
Wasted					.
1988	0.231	0.229	0.21	0.208	0.209
2002	0.016	0.141	0.019	0.144	0.145
Underweight					
1988	0.328	0.326	0.315	0.315	0.292
2002	0.101	0.273	0.067	0.277	0.283

Note: Reported outcomes for mining district is the average outcome of the mining districts, and for neighboring district it is the average outcome of the neighboring districts. Control group is the average outcome of the districts except neighboring districts and mining districts.

Table 4.15 Outcomes for variables from synthetic control analysis, Mali

	Mining districts	Synthetic control group – Mining districts	Neighbor-ing districts	Synthetic control group – Neighboring districts	Control group
Stunted					
1987	0.222	0.234	0.199	0.204	0.180
1998	0.396	0.385	0.390	0.384	0.328
2009	0.296	0.319	0.297	0.297	0.352
Severely stunted					
1987	0.156	0.123	0.116	0.119	0.042
1998	0.229	0.258	0.234	0.231	0.209
2009	0.028	0.068	0.035	0.038	0.060
Wasted					
1987	0.166	0.083	0.115	0.120	0.051
1998	0.165	0.248	0.166	0.162	0.192
2009	0.002	0.021	0.002	0.003	0.010
Underweight					
1987	0.209	0.169	0.177	0.177	0.142
1998	0.303	0.332	0.303	0.302	0.278
2009	0.056	0.114	0.065	0.072	0.110

Note: Reported outcomes for mining district is the average outcome of the mining districts, and for neighboring district it is the average outcome of the neighboring districts. Control group is the average outcome of the districts except neighboring districts and mining districts.

Is diarrheal incidence different among migrants and never-movers in Ghana?

Diarrheal diseases are major killers of young children in developing countries despite the existence of simple and inexpensive solutions, such as oral rehydration solutions. The main result in table 4.12 indicates that diarrheal incidence among children under age five increased in mining communities in Ghana. This is surprising given the expectation that local industrial developments, such as mines, could increase infrastructure investment in access to sanitation and water systems (including to electricity and road networks) in mining communities, and this improved access is important in preventing diarrheal disease. Perhaps, the results stem from the possibility that the same industrial developments could also increase competition over available resources, such as clean water, or by increasing the population pressure on limited resources through inward migration. Migrants may be a particularly vulnerable group if they are less settled in the community and live in more informal dwellings. If so, diarrheal disease could increase particularly in this group.

Figure 4.16 illustrates this. Diarrheal disease increases significantly up to 30 km from a mine among children born to women who have migrated compared to children born to women who have migrated but live farther away. The largest treatment coefficient is for the baseline distance, within 20 km of a mine, where the mine is associated with a 6.9-percentage-point increase in diarrheal incidence. Interestingly, children who are born to women who have never moved experience (insignificantly) less diarrheal disease. Within the first 10 km, the effect is a 9.1-percentage-point decrease in incidence. This shows that in Ghana, child health—measured in diarrheal incidence—is very different among those who have migrated compared to those who have been settled for a longer time. Migrants living in mining areas seem particularly vulnerable. Since the reason for the migration is not known (it could be relocation/displacement due to the mine, or that the household moved to take an employment or income opportunity offered by the mine, or irrespective of the mine), it is difficult to draw any strong conclusions as to why this population is doing less well. Migration is discussed in more detail later in the chapter.

Table 4.16 shows that the strongest differences in child health across migrants and never-movers are in Ghana. In Mali, there are no significant effects of mining across the two groups. In Ghana, there is a decrease in prevalence of cough in the last two weeks among both children born to migrants and children born to never-movers. However, as noted, children born to migrants in Ghana see an increase in diarrheal incidence. The results for Tanzania are not presented due to too-small sample sizes once controlling for migration status.

Figure 4.16 Incidence of diarrhea in Ghana by migration status

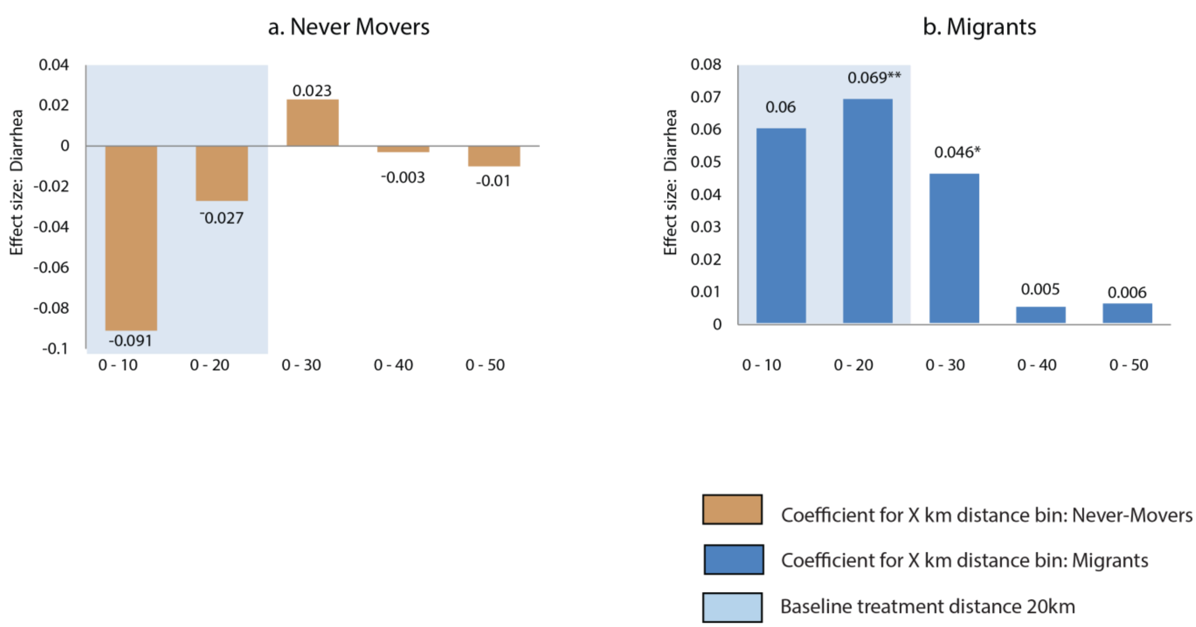


Table 4.16 Child health among migrants and never-movers

	(1)	(2)	(3)	(4)	(5)	(6)
	Fever (last 2 weeks)		**Cough (last 2 weeks)**		**Diarrhea (last 2 weeks)**	
Country	**Ghana**	**Mali**	**Ghana**	**Mali**	**Ghana**	**Mali**
Migrants						
active*mine	0.034	-0.033	-0.081**	0.027	0.068*	-0.046
	(0.043)	(0.084)	(0.031)	(0.079)	(0.040)	(0.063)
Observations	4,723	3,075	4,633	3,076	4,672	3,077
R-squared	0.043	0.064	0.066	0.061	0.043	0.050
Never-Movers						
active*mine	-0.006	0.114	-0.118*	-0.083	-0.063	0.083
	(0.066)	(0.119)	(0.060)	(0.112)	(0.048)	(0.074)
Observations	2,451	2,547	2,405	2,545	2,420	2,546
R-squared	0.073	0.075	0.093	0.082	0.059	0.065

Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy, and the control variables, including child's age, mother's age and education, survey month, and urban area dummy. No results are presented for Tanzania because the sample size is too small when controlling for migration status. Error terms are clustered at the sample cluster level. *p<0.05, **p<0.01, ***p<0.001.

Access to Infrastructure

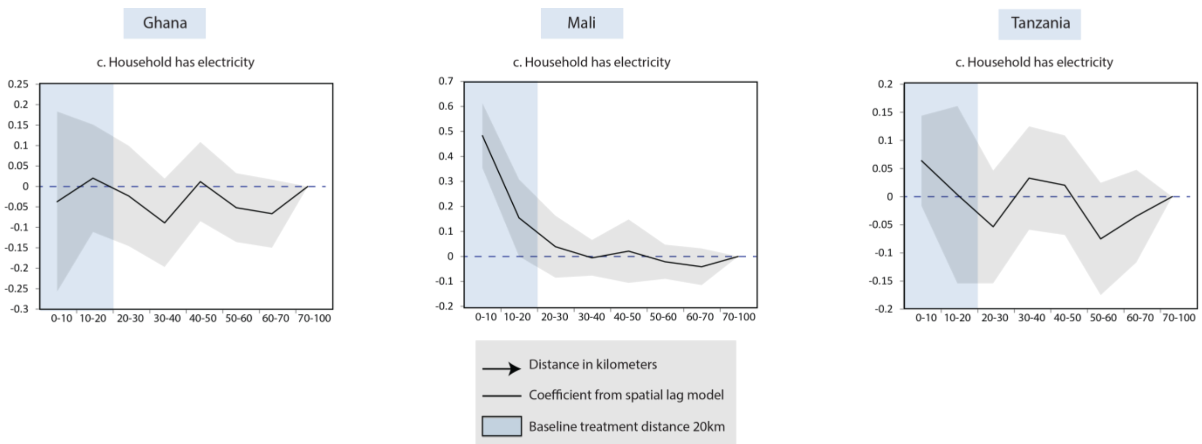
Access to adequate infrastructure contributes to improvements in welfare. How is this access impacted by the opening of a mine? Table 4.17 shows how the opening of a mine close to a community affects the household's probability of having access to infrastructure, such as electricity and a private toilet facility. The regression results using the baseline specification in table 4.17 show that those households close to a mine are generally more likely to have access to a private toilet facility. The results are especially strong for Tanzania, where households in mining communities are 24 percentage points less likely to share the toilet facility with other households. Turning to the spatial lag model, figure 4.17 shows that access to electricity increases in Mali but with no discernable effect for either Ghana or Tanzania.

Table 4.17 Household access to infrastructure

	(1) Electricity	(2) Shared toilet	(3) Water >10min
Ghana			
active*mine	-0.046	-0.050	-0.001
	(0.052)	(0.044)	(0.054)
Observations	14,112	6,059	11,552
R-squared	0.494	0.127	0.162
Mali			
active*mine	0.134	-0.046	-0.065
	(0.086)	(0.110)	(0.094)
Observations	6,876	4,230	6,009
R-squared	0.169	0.064	0.173
Tanzania			
active*mine	0.007	-0.235***	0.048
	(0.033)	(0.070)	(0.070)
Observations	6,941	4,681	6,862
R-squared	0.415	0.113	0.192

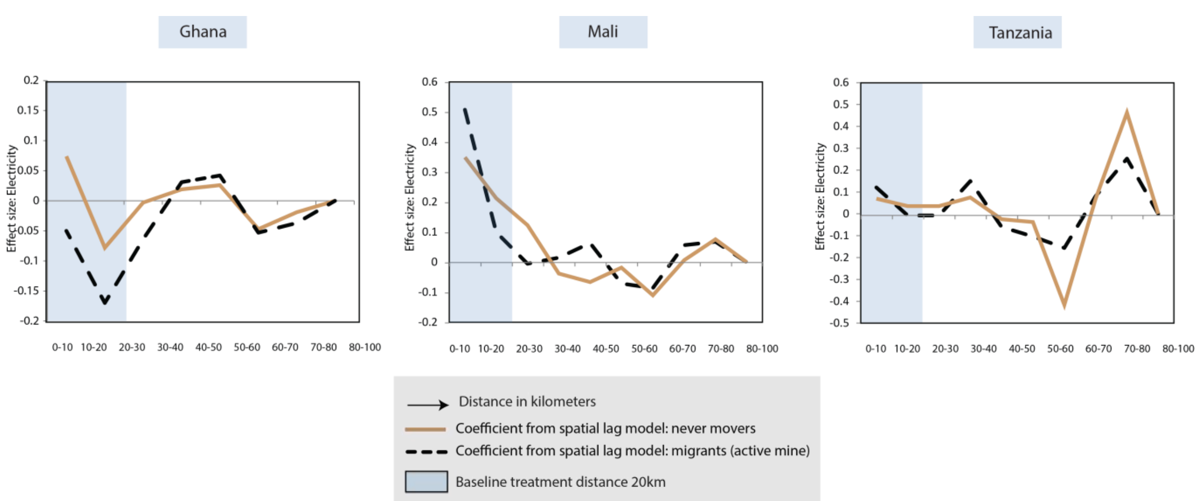
Note: Reported coefficients are the coefficients of the interaction variable for being close to a mine that was active in the survey year. Unreported coefficients include coefficients of the treatment dummy, year dummy, and the control variables. Standard errors are in parentheses. Error terms are clustered at the sample cluster level. See table A.4.1 for variable definitions. All outcome variables are indicator variables that take the value 1 or 0. *Shared toilet* is if the household shares toilet facilities with other households rather than having a private toilet facility; *Water>10min*, indicates if it takes more than 10 minutes to fetch drinking water from the home; *Floor (cement)* captures whether flooring is made of cement, tile, wood, or materials other than earth, sand, or dung; *Bicycle*, *Car*, and *Radio* captures whether the household has these assets. *p<0.05; **p<0.01; ***p<0.001.

Figure 4.17 Spatial lag model illustrating geographic distribution of effects on electricity



The above analysis is complementary to figure 4.18, which shows differences for migrants and never-movers in the same communities. The migration analysis shows differences in infrastructure access across the study countries: migrants in Ghana are seemingly less well off than never-movers. In Mali, the relationship is reversed, with migrants having better access to electricity. In Tanzania, there is no difference in access rate among the two groups.

Figure 4.18 Migrants and never-movers: Access to infrastructure (electricity)



Controlling for mine-induced migration

Thus far, the discussion has been on how mining affects the composition of local employment, women's economic opportunities, accumulation of assets, and children's health outcomes. The underlying assumption is that these impacts apply to people who lived in the vicinity of the mine before the mine opened. However, such a result rests on the assumption that either there is no migration, or if there is, that it had no influence on the estimated impacts. But as shown below, the first assumption does not hold. The opening of a mine in a local area is a magnet for workers from near and far as they seek opportunities to improve their incomes and employment status. What about the second assumption?

If migrants and local populations have exactly the same characteristics—that is, identical in all dimensions that matter for being successful at taking advantage of the opportunities offered by the mine—then the estimated impacts will remain valid. However, if people who move to the mining area from afar are different—say, with regard to skills, ability, motivation, health status, and so forth—from the people who lived in the mining area before the mine opened, then there would be selection bias. Imagine if men who are more interested in and trained for mining jobs move into these communities, and women who have a particular interest or aptitude for work in the service sector do the same. Then the results reported above on the composition of occupations and the changing employment opportunities for women, is identifying the change in composition of the labor force in the mining communities that is not due to the mine alone.

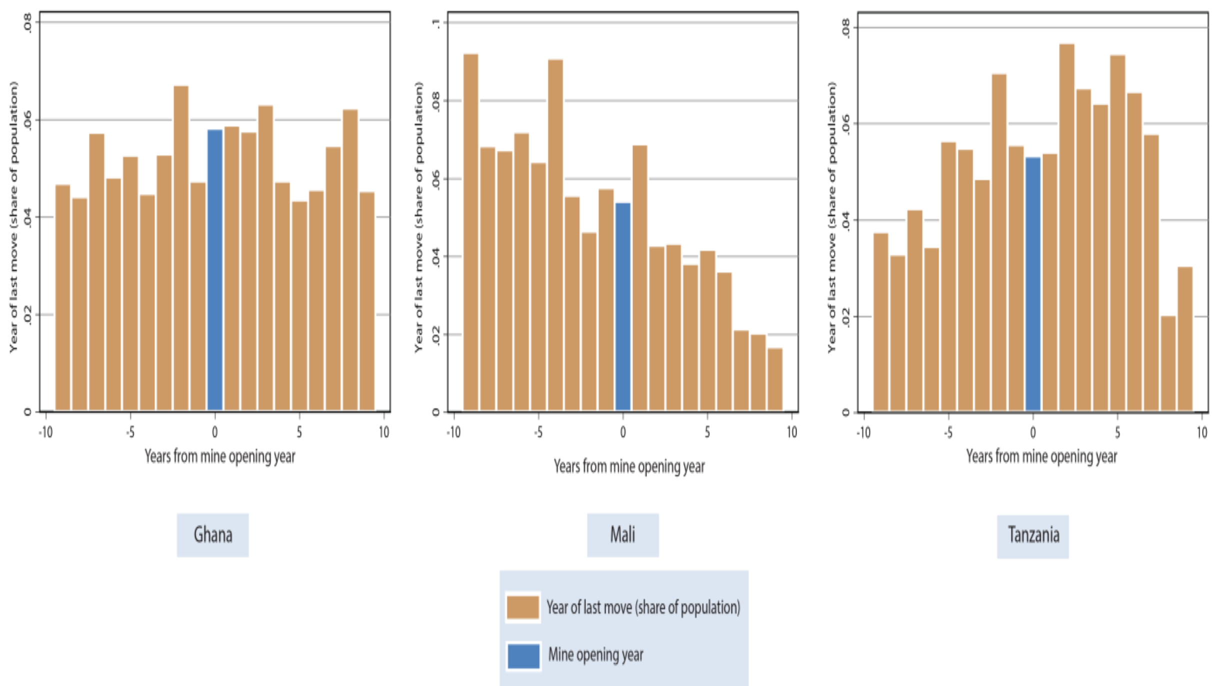
It should be noted that the study is interested in identifying the impact of the mine(s) on local populations who lived there before the mine(s) opened, as well as exploring how the local economy is changing even if the population changes with it. This is why isolating the role of migration on the estimated effects is important and not trivial. Because the data are repeated cross-section, the analysis cannot follow an individual over time. Thus, the analysis of migrants compares people who have moved to their current place of residence (migrants) with those who have never moved (never-movers). In this sense, the analysis compares migrants in mining communities with migrants who live elsewhere. Any difference that is noted between these groups could stem from selection into migration to mining communities, and so the results should not be interpreted causally. For example, if only poorer households with children with worse health move to mining communities, the results will indicate that migrants in mining communities are worse off. But this is not due to the mine. With this important caveat in mind, the analysis is conducted to shed light on the welfare of migrants in mining communities.

Most of the data available for the countries analyzed here do track migratory history in detail. For most individuals, it is known whether they have ever moved in their life and in what year they moved to the current location. In the following section, migration rates in mining communities are presented, and the outcomes between migrants and never-movers are compared.

Migratory patterns in the three countries

Figure 4.19 shows the share of the population that moved in a given year and living within 100 km of a mine. The figure does not use calendar year but rather "mine year," defined as counting down to mine opening, with the mine opening year indicated as time zero. Thus, the figure presents the fraction of the population that migrated prior to the opening of a mine over a 20-year time span—10 years prior to the opening of the mine and 10 years after the mine opens. As suspected, there is indeed plenty of in-migration, but the migratory patterns are different across all three countries.

Figure 4.19 Timing and share of migration in Ghana, Mali, and Tanzania



In Ghana, 4 to 6 percent of the population can be considered migrants, but there is no clear evidence that the opening of the mine has affected migration patterns in any particular way. Migration before and after the mine opened remained relatively stable. In Mali, migration rates appear to have been decreasing over time. It appears that migration to the mining area was relatively high 4 to 10 years prior to the opening of the mine. Then it slowed and stabilized for the 3 years prior to the opening of the mine. There was a surge a year after the mine opened, but the trend reversed so that less than 2 percent of the population around 100 km of the mine was considered migrants 10 years after the mine opened. The opposite seemed to have happened in Tanzania. Migration rates increased leading to the opening date of the mine. They peaked two years after the mine opened, and remained relatively stable and high for the following 4 years, after which they declined.

There are two points to keep in mind about these migration patterns. First, the relatively higher rates in Mali and Tanzania could be explained by the relatively young nature of the sector in these countries relative to Ghana's. Second, it is important to bear in mind that, while mines are major attractions for those seeking employment, not all this migration is due to the opening of the mine. However, for our estimation of impacts, knowing whether people moved because of the mine or not is not going to help identify the impact of mines on the local community. Instead, what matters is the knowledge of whether or not migrants differ substantively from the local population who lived in that locality before the mine opened. The differences between migrants and never-movers are explored through women's occupation and household access to electricity and radio ownership.

Migrant women and nonmigrant women have the same opportunities in the labor market

Empirical analysis finds no difference in the labor market outcomes between migrant and nonmigrant women. Figure 4.9 shows the increase in the likelihood of a woman working in nonfarm employment, in this case proxied by service sector employment. The chances of working in the service sector are substantially higher for women who live near the mine compared to those who live further away, in both Ghana and Mali, although the effect size is larger in Ghana. However, women who were born in the local communities and did not move away and those who moved there plausibly because of the mine have equal chances of working in the service sector. In other words, migrants do not seem to have major advantages or disadvantages when it comes to success in finding new employment.

In Tanzania, women who live closer to the mines do not enjoy any better chances of working in nonfarm jobs than women farther away. It would seem that the pull of the nontraded sector is no greater closer to the mine than farther away. It is equally the case that nonmigrant women do not enjoy any advantages closer to the mines (20 km) compared to migrant women. The pattern for working in agriculture (figure 4.9 lower panel) is less clear. In Mali, women are less likely to work in agriculture than those farther away, a finding that in some ways reinforces the results on service sector jobs. The effect size is larger for women who never moved. But in Ghana and Tanzania, the prospect of working in agriculture for women closer to mines is not that different from women farther away. And closer to mines, the change in probability of working in agriculture between migrant and nonmigrant women is the same.

Access to infrastructure: A challenge for migrants?

Figure 4.18 shows whether migrants, in general, have access to better infrastructure (in this case, electricity) or lower assets. There are several hypotheses for why access to infrastructure could be different between migrants and never-movers. It could come from income differences: those with higher incomes can afford to pay for electricity and other services. It could also come from service delivery failures by local governments, which may not reach places where migrants settle. Similarly, if migrants have lower assets to begin with, then the impacts reported above would be underestimating the effect of mines on asset ownership.

There are three points to note regarding variation in access to electricity between migrants and never-movers from figure 4.18. First, the difference in access to infrastructure between migrants and never-movers is largest in Ghana, where the effect of the mine on local electrification for the nonmigrant population is positive at the closest distance (within 20 km of the mine). Second, access to electricity for both migrants and never-movers near the mine is highest in Mali, where household access to electricity increases sharply—by 30 to 50 percentage points—within the first 20 km.

Finally, these differences in access to electricity for both migrants and never-movers may be partially explained by looking at the differences in the migration patterns in some of these countries. For example, access to electricity might not be readily available to community members, and if it entails a household investment, one could expect people that have been settled in the communities for a longer time to do better. With that in mind, recall that in Mali, most migration movements happened a few years before a mine opened, so it can be assumed that many migrants may have already settled in the local community by the time the mine opened. By contrast, in Ghana, migration patterns continued to flow at the same pace from year to year. Given this migration pattern, it is expected that there would be lower access to electricity for migrants in Ghana and equal access in Mali, which is what is observed in figure 4.18.

Summary of Results

Although the mining industry is generally associated with weak direct employment generation compared with its contributions to GDP and export revenue at a national level, it nonetheless has the potential to have large local impacts through clustering of economic activities. This chapter looked at these local impacts for individuals who live in the neighborhood of the gold mines and districts that have a gold-mining sector. The results lead to four major conclusions.

First, there appear to be signs of structural transformation associated with the mining sector. Both the individual and district results find that employment in agriculture is declining, while employment in nonfarm occupations such as services, manufacturing, and mining is rising. In cases where wage data are available, such as Ghana, there is evidence that wages for those in mining are higher. These results are robust especially for countries where gold mining started earlier, such as Ghana and Mali.

Second, mining is associated with improvements in women's nonfarm employment opportunities. Employment in sales and services for women are substantially higher for women who live closer to mining sites than women who live farther away. In the same vein, their employment in agriculture declines. In addition, the probability of working throughout the year rises for women closer to mines and those who live in mining districts.

The finding that there is structural transformation in large-scale gold-mining communities is further supported by changes in expenditures. Overall, despite increasing food prices, neither total deflated food expenditure, nor food share of total household expenditure, increases. Instead, the results show that expenditure on housing and energy increases, which is in line with the higher electrification rates that are found in these mining communities.

Third, child health outcomes have mixed results. Overall, health outcomes such as child mortality have declined in mining communities and districts. But only in Mali do decreases in stunting (ratio of height to age) and wasting (ratio of weight to age) appear to improve for households in mining districts and for individuals who live closer to mines. In both Ghana and Tanzania, these outcomes appear worse for mining areas. Similarly, the incidence of diarrheal disease decreases in Mali but rises in Ghana and Tanzania, although in the case of Ghana this appears to be driven by poor outcomes among migrants who live near the mines. Diarrheal incidence is much higher among children born to migrants in mining communities than migrants living farther away, whereas other children are doing better. In addition, women of migrant households have less access to important infrastructure, such as electricity.

It is not clear why these child health outcomes differ across these countries at this local level. Stunting, which is a measure of long-term nutritional deficiency, may reflect a significant income effect. In other words, those who live closer to mines may have higher incomes and use it to buy better nutrition for their children. By contrast, wasting is a short-term measure of nutritional deficiency and can be explained strongly by access to health services.

Fourth, and finally, migration patterns may explain some of the differences in child health outcomes across countries. For instance, Mali, which shows the most positive changes, is also the country with the lowest level of migration around the time of mine opening, and migrants in mining areas in Mali seem less vulnerable than in Ghana or Tanzania. Tanzania, which shows evidence for structural transformation and few gains in child health, seemingly has the largest increase in migration flows after mine opening.

Annex

Table A.4.1 Variable definitions for Demographic and Health Survey

Women and household characteristics	
Age	Age of respondent
Wealth	Household wealth index score
Nonmigrant Migrant	Respondent was born in the location and has never moved Any respondent who has ever moved in their life
Urban	The household lives in urban area
Household characteristics	
Electricity	Household has access to electricity
Shared toilet	Toilet facilities shared
Flush toilet	Household has a flush toilet
Pit toilet	Household has pit toilet
No toilet	Household has no toilet facility
Water <10min	Less than 10 minutes to drinking water sources
Floor (cement)	House has cement, tile, or wood floor
Bicycle	Household has bicycle
Car	Household has car
Radio	Household has radio
Woman's occupation and education	
Not working	Was not working in last 12 months
Service and sales	Works in services or sales
Professional	Works as a professional
Agriculture	Works in agriculture
Manual labor	Works in manual labor
Earning cash	Earns cash for work (0 = not paid, in kind)
Works all year	Works all year (0 = seasonally, occasionally)
3 years of education	At least 3 years of education
No education	No education
Partner's occupation	
Service and sales	Partner of woman works in service or sales
Professional	Partner of woman works as professional
Agriculture	Partner of woman works in agriculture
Manual labor	Partner of woman works in manual labor
Child health	
Diarrhea	Child had diarrhea in last 2 weeks
Cough	Child had cough in last 2 weeks
Fever	Child had fever in last 2 weeks

Infant mortality	Died within first 12 months of life
Prenatal care	Mother had at least one prenatal care visit
Stunted	Child under 5 is stunted (below 2 standard deviations of height/age)
Wasted	Child under 5 is wasted (below 2 standard deviations of weight/age)
Underweight	Child is underweight (below 2 standard deviations of weight/height)

Table A.4.2 Outcomes for variables from synthetic control analysis – Mali

	Mining districts	Synthetic control group - Mining districts	Neighboring districts	Synthetic control group – Neighboring districts	Control group
Employment rate (men)					
1987	0.902	0.904	0.904	0.912	0.904
1998	0.888	0.886	0.877	0.871	0.887
2009	0.833	0.826	0.822	0.827	0.824
Employment rate (women)					
1987	0.721	0.666	0.672	0.703	0.491
1998	0.422	0.480	0.515	0.484	0.409
2009	0.325	0.389	0.413	0.504	0.424
Working as a Professional (men)					
1987	0.019	0.019	0.016	0.014	0.016
1998	0.022	0.022	0.016	0.019	0.018
2009	0.041	0.039	0.027	0.027	0.031
Working as a Professional (women)					
1987	0.007	0.004	0.003	0.004	0.004
1998	0.001	0.005	0.003	0.002	0.004
2009	0.009	0.012	0.008	0.007	0.009
Working as a services worker (men)					
1987	0.015	0.021	0.014	0.015	0.018
1998	0.033	0.027	0.026	0.025	0.031
2009	0.066	0.049	0.053	0.047	0.048
Working as a services worker (women)					
1987	0.018	0.021	0.026	0.018	0.021
1998	0.008	0.014	0.017	0.024	0.034
2009	0.013	0.028	0.020	0.017	0.030
Working as skilled agriculture or fishery worker (men)					

1987	0.779	0.772	0.812	0.818	0.801
1998	0.755	0.762	0.790	0.780	0.783
2009	0.524	0.664	0.635	0.673	0.673
Working as skilled agriculture or fishery worker (women)					
1987	0.659	0.585	0.616	0.647	0.377
1998	0.391	0.464	0.487	0.456	0.339
2009	0.246	0.419	0.340	0.463	0.338
Working as a craftsmen (men)					
1987	0.083	0.088	0.050	0.051	0.056
1998	0.036	0.029	0.027	0.025	0.030
2009	0.183	0.051	0.085	0.049	0.051
Working as a craftsmen (women)					
1987	0.013	0.016	0.011	0.010	0.066
1998	0.004	0.005	0.002	0.003	0.014
2009	0.030	0.004	0.017	0.004	0.016
Working in elementary jobs (men)					
1987	0.002	0.005	0.003	0.003	0.006
1998	0.010	0.008	0.008	0.008	0.012
2009	0.009	0.006	0.006	0.015	0.008
Working in elementary jobs (women)					
1987	0.019	0.014	0.013	0.012	0.020
1998	0.000	0.005	0.000	0.002	0.004
2009	0.009	0.006	0.004	0.003	0.006
Working as an employer (men)					
1987	0.001	0.001	0.003	0.002	0.002
1998	0.003	0.004	0.005	0.006	0.005
2009	0.007	0.006	0.005	0.006	0.006
Working as an employer (women)					
1987	0.002	0.001	0.000	0.001	0.001
1998	0.001	0.002	0.001	0.001	0.001

2009	0.002	0.002	0.002	0.002	0.002
Working as own-account worker (men)					
1987	0.491	0.542	0.483	0.513	0.541
1998	0.606	0.550	0.566	0.540	0.572
2009	0.568	0.592	0.599	0.574	0.594
Working as own-account worker (women)					
1987	0.074	0.073	0.063	0.075	0.083
1998	0.150	0.160	0.198	0.187	0.153
2009	0.061	0.142	0.066	0.075	0.080
Working as wage worker (men)					
1987	0.071	0.075	0.041	0.040	0.043
1998	0.053	0.045	0.027	0.029	0.031
2009	0.083	0.026	0.021	0.018	0.018
Working as wage worker (women)					
1987	0.007	0.007	0.005	0.005	0.008
1998	0.003	0.005	0.005	0.004	0.007
2009	0.010	0.003	0.003	0.004	0.006
Working as unpaid worker (men)					
1987	0.332	0.282	0.357	0.339	0.312
1998	0.219	0.275	0.272	0.291	0.271
2009	0.133	0.176	0.171	0.177	0.183
Working as unpaid worker (women)					
1987	0.636	0.512	0.596	0.639	0.397
1998	0.262	0.386	0.305	0.263	0.243
2009	0.237	0.300	0.324	0.479	0.314
Working in agriculture sector (men)					
1987	0.775	0.773	0.813	0.816	0.800
1998	0.754	0.755	0.784	0.781	0.779
2009	0.525	0.658	0.636	0.688	0.674

Working in agriculture sector (women)					
1987	0.658	0.594	0.617	0.647	0.378
1998	0.388	0.452	0.484	0.453	0.339
2009	0.246	0.392	0.340	0.460	0.339
Working in manufacturing sector (men)					
1987	0.041	0.050	0.019	0.019	0.027
1998	0.053	0.031	0.016	0.016	0.021
2009	0.145	0.037	0.057	0.028	0.026
Working in manufacturing sector (women)					
1987	0.010	0.016	0.007	0.006	0.066
1998	0.013	0.008	0.003	0.004	0.023
2009	0.030	0.003	0.016	0.004	0.016
Working in mining sector (men)					
1987	0.015	0.031	0.000	0.001	0.001
1998	0.037	0.020	0.001	0.001	0.001
2009	0.117	0.007	0.034	0.004	0.002
Working in mining sector (women)					
1987	0.004	0.007	0.000	0.000	0.000
1998	0.007	0.004	0.000	0.000	0.000
2009	0.028	0.001	0.014	0.001	0.001
Working in construction sector (men)					
1987	0.016	0.016	0.005	0.007	0.004
1998	0.006	0.007	0.010	0.008	0.006
2009	0.015	0.016	0.017	0.015	0.015
Working in construction sector (women)					
1987	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000

Working in services sector (men)					
1987	0.067	0.077	0.060	0.064	0.069
1998	0.067	0.059	0.063	0.060	0.075
2009	0.159	0.134	0.123	0.108	0.123
Working in services sector (women)					
1987	0.048	0.040	0.045	0.038	0.045
1998	0.015	0.023	0.024	0.031	0.041
2009	0.044	0.061	0.046	0.039	0.058

Note: Reported outcomes for mining district is the average outcome of the mining districts, and for neighboring district it is the average outcome of the neighboring districts. Control group is the average outcome of the districts except neighboring districts and mining districts.

Table A.4.3 Outcomes for variables from synthetic control analysis – Tanzania

	Mining districts	Synthetic control group - Mining districts	Neighboring districts	Synthetic control group - Neighboring districts	Contro l group
Employment rate (men)					
1988	0.881	0.878	0.877	0.874	0.866
2002	0.758	0.827	0.81	0.821	0.816
Employment rate (women)					
1988	0.833	0.831	0.864	0.862	0.817
2002	0.612	0.734	0.721	0.768	0.719
Working as a Professional (men)					
1988	0.05	0.05	0.062	0.063	0.073
2002	0.053	0.043	0.044	0.052	0.060
Working as a Professional (women)					
1988	0.022	0.022	0.025	0.025	0.030
2002	0.028	0.028	0.022	0.031	0.035
Working as a services worker (men)					
1988	0.023	0.023	0.03	0.03	0.034
2002	0.024	0.026	0.024	0.032	0.035
Working as a services worker (women)					
1988	0.019	0.02	0.015	0.015	0.021
2002	0.015	0.021	0.015	0.017	0.023
Working as agricultural worker (men)					
1988	0.691	0.688	0.691	0.689	0.636
2002	0.544	0.624	0.621	0.625	0.571
Working as agricultural worker (women)					
1988	0.751	0.749	0.799	0.8	0.728
2002	0.494	0.606	0.614	0.666	0.581
Working as a craftsmen (men)					
1988	0.004	0.004	0.007	0.007	0.007
2002	0.051	0.041	0.036	0.056	0.056
Working as a craftsmen (women)					
1988	0.001	0.001	0.001	0.001	0.002
2002	0.012	0.01	0.009	0.01	0.012
Working in elementary jobs (men)					
1988	0.097	0.097	0.072	0.072	0.102
2002	0.076	0.08	0.075	0.066	0.083
Working in elementary jobs (women)					
1988	0.03	0.03	0.016	0.016	0.026
2002	0.057	0.067	0.054	0.049	0.063
Working as an employer (men)					
1988	0.007	0.006	0.005	0.005	0.007
2002	0.001	0.001	0.001	0.001	0.001

Working as an employer (women)					
1988	0.003	0.003	0.001	0.001	0.003
2002	0.001	0	0	0	0.000
Working as own-account worker (men)					
1988	0.733	0.736	0.705	0.704	0.680
2002	0.628	0.729	0.697	0.699	0.679
Working as own-account worker (women)					
1988	0.73	0.725	0.781	0.781	0.732
2002	0.536	0.645	0.656	0.699	0.651
Working as wage worker (men)					
1988	0.092	0.092	0.131	0.131	0.156
2002	0.076	0.07	0.075	0.094	0.112
Working as wage worker (women)					
1988	0.035	0.034	0.038	0.038	0.051
2002	0.023	0.034	0.027	0.036	0.047
Working as unpaid worker (men)					
1988	0.035	0.035	0.022	0.022	0.012
2002	0.048	0.028	0.032	0.022	0.017
Working as unpaid worker (women)					
1988	0.057	0.057	0.036	0.036	0.024
2002	0.05	0.031	0.036	0.022	0.017

Note: Reported outcomes for mining district is the average outcome of the mining districts, and for neighboring district it is the average outcome of the neighboring districts. Control group is the average outcome of the districts except neighboring districts and mining districts.

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Chapter 5 Does Large-Scale Gold Mining Reduce Agricultural Growth? Case studies from Burkina Faso, Ghana, Mali, and Tanzania

5.1 Introduction

This chapter provides another perspective on the impact of resource extraction on local economic growth by focusing on agricultural growth.[52] The issue of interest is whether the opening of mines has spillover effects on the local economy, and especially on the agricultural sector. Agricultural production could be affected by mining activities in several ways. Mining could lead to a rise in local wages, reduce profit margins in agriculture, and lead to the exit of many families from farming—something akin to a localized Dutch disease problem. Negative environmental spillovers such as pollution or local health problems could also dampen productivity of the land and of the farmers, and thereby reduce the viability of farming. Alternatively, mining could create a mini-boom in the local economy through higher employment and higher wages that can lead to an increase in local area aggregate demand, including for regional food crops.

Remote sensing data are used to estimate levels and changes in agricultural and nonagricultural production in mining and nonmining localities in Burkina Faso, Ghana, Mali, and Tanzania. The study investigates the spatial relationship between mining activities and local agricultural development by using a vegetation index as a proxy for agricultural production. In order to estimate the level and composition of production—agricultural and nonagricultural—at the local level, the paper selects a radius around the mining areas. For all the four countries, 32 mines were identified.

Satellite remote sensing missions are generally designed for specific applications, often earth-sciences related, such as vegetation classification and weather forecasting. Very few, if any, sensors are designed for social science applications (Hall 2010). The Defense Meteorological Satellite Program/Operational Linescan System (DMSP-OLS) sensor, also known as "nighttime lights," has attracted recent attention due to its capability to depict human settlement and development. It is sensitive enough to detect street lights and even fishing vessels at sea (Sei-Ichi et al. 2010). The light detected by the DMSP-OLS is largely the result of human activities, emitted from settlements, shipping fleets, gas flaring, or fires from swidden (slash and burn) agriculture. Therefore, nighttime light imagery serves as a

[52] This chapter is based on Andersson, Chuhan-Pole, Dabalen, Hall, Olen, Sanoh, and Tolonen 2015.

unique view of the earth's surface that highlights human activities. One of the central uses of the nighttime lights dataset is as a measure of and proxy for economic activity.

The relationship between economic activity and light has been explored by several authors, and all have concluded that there is indeed a positive relationship between the light emitted and the level of economic development within a region. This understanding has been used to estimate both GDP and economic growth. This paper is a contribution to the literature on the connection between extractive industries and local clustering of economic activity using remote sensing data.

The rest of the chapter is organized as follows. Section 2 reviews the literature on remote sensing and economic activities, with a particular focus on agriculture. Section 3 describes the data used in the study. Section 4 describes the various methodologies and their results, including the econometric results using a difference-in-differences estimation framework (previously employed to understand the economic effects of gold mining in Africa by Aragón and Rud [2015], Kotsadam et al. [2015], and Tolonen [2015]). Section 6 concludes the paper.

5.2 Remote sensing and economic activities

Nightlight and economic activities

Several recent economic studies have exploited human-generated nighttime light data to understand the structure, growth, and spatial distribution of economic activities in countries or localized areas (Chen and Nordhaus 2011; Doll, Muller, and Morley 2006; Ebener et al. 2005; Elvidge et al. 1997; Ghosh et al. 2010; Henderson, Storeygard, and Weil 2012; Sutton and Costanza 2002). An early identification of the strength of the relationship between nighttime lights and economic development was made by Elvidge et al. (1997), who explored the relationship between lighted area and gross domestic product (GDP); and population and electrical power consumption in the countries of South America, the United States, Madagascar, and several island nations of the Caribbean and the Indian Ocean. Using simple linear regression over a single year (1994/1995), they found that GDP exhibits a strong linear relationship with the lighted area.

Elvidge et al.'s (1997) study is unique in that it associated the relationship between economic activity and lighted area. Most other publications using such data related economic activity with light intensity. Doll, Muller, and Morley (2006) were one of the first to apply this relationship to estimating economic activity on a national and subnational basis. They identified a unique linear relationship between gross regional product (GRP) and lighting for the European Union and the United States using 1996/1997 data and found that one linear relationship was not appropriate since some cities were outliers. However, once the outliers were removed, they were able to generate simple linear regressions—which showed strong links between GRP and light intensity—for each country, which they used to generate a gridded map of GRP at the 5-kilometer level.

Building on this approach, Ghosh et al. (2010) use gross state product (GSP), GDP, and light intensity in 2006 for various administrative units in the states of China, India, Mexico, and the United States to obtain an estimate of total economic activity for each administrative unit. These values were then spatially distributed within a global grid using the percent contribution of agriculture toward GDP, a population grid, and the nighttime lights image. This is an improvement over Doll, Muller, and Morley (2006) in the sense that it was able to assign economic activity to agricultural areas, which are not usually picked up by the nighttime lights dataset since they are not often lit. This is an important observation about nightlight data that will inform our study.

Chen and Nordhaus (2011) were one of the first studies to exploit time series variation in GDP and nightlight. To show the strength of the correlation between economic activity and nightlight, their method assigns weights to light intensity in order to reduce the difference between the true GDP values and the estimated GDP (that is, they minimize mean squared error) for all countries of the world for 1992 to 2008. They show that while light intensity data do not add much value—that is, do not provide any additional information than actual data—to data-rich countries, the opposite is true for data-poor countries. They show that GDP estimation using nightlight in data-poor countries, both at the national and subnational level, improves substantially with nightlight data.

One of the most recent applications of the nighttime lights dataset in relation to economic activity is by Henderson, Storeygard, and Weil (2012). Rather than exploring the relationship of lights with GDP levels, they look at the relationship between real GDP growth and GDP growth estimated using nighttime light. Like Chen and Nordhaus (2011), they use a time series of growth and light data for 1992 to 2008. Their statistical model correlates GDP growth using country-specific economic data with light intensity values. Similar to Chen and Nordhaus (2011), they construct different weights for the light data and existing economic data based on the quality of the economic data. They found that for countries with "bad" data, there are often large differences (both positive and negative) between the recorded economic growth and the estimated growth.

In general, this short review of the literature using remote sensing data leads to two conclusions. First, it demonstrates that such data provide a strong and accurate prediction of economic activity. Second, although various types of remote sensing data are available, the one that is most widely used tend to be nightlight data. To date, most of the studies have used light intensity, rather than lighted area, to explain either GDP or its growth within and across countries in a given year and, on a few occasions, over time. However, nightlight, while certainly informative of human activity, does not exhaust economic activity in all places. In particular, in countries where electricity is unreliable and there is significant reliance on generators for production activities, nightlight could be underestimating economic activity. This would be true especially if the generators are turned on at all at night for cost reasons. In addition, in countries that are mostly rural and where the mainstay of the economy is agriculture, an overreliance on nightlight might miss a big fraction of economic activity, even if electricity is in fact reliable. Fortunately, remote sensing data can be used for capturing agricultural activities, as well, and the next section discusses one such datum.

The Normalized Difference Vegetation Index and agricultural production

Numerous methods exist for estimating production of agricultural commodities at a specified geographic area using remote sensing technology. But most approaches rely on the idea that vegetation, including crops, is very reflective in the red and near-infrared (NIR) wavelengths. Combinations of these two wavelengths (that is, vegetation indexes) are good measures of plant vigor and are the mainstay of nearly all approaches to crop yield estimation (Lobell 2013). Yields are then estimated through establishing the empirical relationship between ground-based yield measures and some vegetation indexes, typically the Normalized Difference Vegetation Index (NDVI).

Errors in remote-sensing crop-yield estimates vary, mainly as a function of sensor properties (spatial-, temporal-, and spectral-resolution) and landscape complexity. Classification of crop types is more problematic in regions characterized by multiple crops with similar life cycles (that is, phonologies), or in regions with intercropped fields (Lobell 2013). Additional complexity is added with cassava, a major crop for which even farmers themselves have difficulty estimating yields. This is basically because it is a root crop with staggered harvesting, but also with widely differing above-ground architecture. Sometimes overlooked is the problem of cloud cover in satellite-based remote sensing, which could severely limit the number of available observations for a particular geographic region. Nevertheless, yield estimation in mixed cropping systems, characteristic of African smallholder agriculture, should be possible, using a remote sensor platform with the correct properties. This indeed is the case, and the next section describes the data that is used to obtain local economic production, including agriculture.

Long-time analysis of NDVI can reveal important information on vegetation anomalies caused by variations in rainfall, temperature, and sunlight (irradiance) as well as the trend for a certain location. Phenological metrics, such as the start and end of growing season(s), length of season, mid-season time, seasonal amplitude in NDVI, and rate of increase and decrease at the beginning and end of the season can be related to management and crop yields for individual years and for longer periods. Medium-resolution remote sensing data from MODIS[53] are available from 2000 onward, aggregated into 16-day averages. For every 16 days observations are available on how the vegetation changes at each pixel level. Phenological metrics are extracted using the Timesat software, which gives information in graphs showing how the vegetation changes at every pixel (Jönsson and Eklundh 2012).

For mapping output of agricultural products using remote sensing that can be compared to other data that are thought to control crop yields, we use explanatory variables, such as greenness, temperature, moisture levels, and management variables, which are then statistically analyzed to derive the relative importance of each variable in driving crop yields. There are several examples of this approach found in the literature (for example, Lobell et al. 2005), but few that account for spatial autocorrelation and other peculiarities associated with spatial data analysis. Thriving on the possibilities of remote sensing data (large sample size compared to others), we attempt to identify interactions, nonlinearities, or thresholds that are not evident in small samples and with ordinary statistical tools.

A second method to study yield gap causes is to examine the spatial distribution of average yields with the average calculated over varying lengths of time. The basic idea is that averages calculated over longer periods will show less spatial variation than averages for shorter periods, since factors that are less persistent tend to cancel out across years. This approach has been used extensively by Lobell in various study sites (Lobell et al. 2010). Among other things, the steepness of these curves can provide insight into the persistence of spatial yield differences throughout the study period. This can then be related to other persistent factors (soil quality, hydrology, and so forth). Lack of persistence of yield patterns does not suggest that, for example, farmer skills or socioeconomic factors are not important, but that variations in these factors are not sufficient to explain yield differences.

5.3 Data

Three sources of remote sensing data are used to estimate the effects of mining on local economic activity: nighttime lights, NDVI, and forest loss. Nighttime lights data are from the National Oceanic and Atmospheric Association’s National Geophysical Data Center (NOAA-NGDC). The NOAA-NGDC produces three annual nighttime lights products: cloud-free composite, average visible lights composite, and stable lights composite.[54] For this study, these data were processed in two steps. First, gas flares were removed using a set of ESRI[55] shapefiles available from NOAA-NGDC, which contain polygons outlining the location of gas flares for each country. Second, the data were intercalibrated to allow

[53] MODIS–the Moderate Resolution Imaging Spectroradiometer—is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites launched by the U.S. National Aeronautics and Space Administration (NASA).
[54] See NOAA-NGDC (2014b) for a description of each of these datasets.
[55] ESRI is an international supplier of geographic information system software.

cross-year analysis. The intercalibration procedure developed by Elvidge et al. (2009b) was aimed at overcoming the limited comparability of the DMSP-OLS data by calibrating each composite against one base composite. It is a regression-based technique that works under the assumption that the lighting levels in a reference area have remained relatively constant over time and can therefore be used as the dependent variable.

Table 5.1 shows the satellite-year pairs that are used for the intercalibration. As indicated in the table, satellite F18 and year 2010 (denoted as F182010) was chosen as the base composite because, overall, its pixels contained the highest intensity, measured by digital numbers (DN).[56] Next, for each composite the following quadratic regression equation was estimated:

$$y = C_0 + C_1 x + C_2 x^2$$

Table 5.1 shows the resulting calibration coefficients (*C*), which were applied to each composite so that a new value (*y*) was calculated based on the original value (*x*). Any values over 63 were truncated so that the range of the values remained between 0 and 63. In principle, we can obtain light-intensity data for very small areas, up to a cell size of 1 km^2. Alternatively, one can take the average over small areas and create 21 composites, each representing one year of nighttime lights between 1992 and 2012.

Since the focus of the analysis is on assessing the impact of mining on local economic activity, a measure of the total intensity of lighting is created-- a sum of light (SOL)--for all the cells around the mining areas and for each unit of the lowest administrative level possible in each country. The latter serves the purpose of helping us link the intensity of light to local economic activity, where unlike the areas around the mine, the local here is defined as district.

The NDVI[57] data are provided as a global dataset, with a 16-day temporal resolution and a spatial resolution of 250 x 250 meters. NDVI is a dimensionless spectral index that relates to the photosynthetic uptake by vegetation (Myneni and Williams 1994; Sellers 1985). It is calculated from the near infrared (NIR) and red wavelength bands by using the following relationship:

$$NDVI = (NIR - Red) / (NIR + Red).$$

[56] In their study, Elvidge et al. (2009b, 2013) selected F121999 as the base composite. The difference in the selection is attributed to the fact that Elvidge et al. (2009b; 2013) were intercalibrating a worldwide dataset, while the present study examines only the African case.
[57] The NDVI from MODIS vegetation indexes product MOD13Q1 were used (ORNL DAAC 2011).

Table 5.1 Intercalibration Coefficients

Satellite	Year	C_0	C_1	C_2
F10	1992	0.0577	1.8322	-0.0140
	1993	-0.1031	1.9334	-0.0156
	1994	0.0711	1.9056	-0.0155
F12	1994	0.0996	1.5284	-0.0086
	1995	-0.0196	1.6398	-0.0108
	1996	0.0850	1.7066	-0.0119
	1997	-0.0270	1.5579	-0.0092
	1998	-0.0345	1.4509	-0.0078
	1999	0.0394	1.3969	-0.0070
F14	1997	-0.0204	2.1047	-0.0186
	1998	0.1002	2.0889	-0.0188
	1999	-0.0281	1.9474	-0.0161
	2000	0.0920	1.8814	-0.0153
	2001	-0.0131	1.7926	-0.0135
	2002	0.0784	1.7011	-0.0122
	2003	-0.0185	1.7744	-0.0133
F15	2000	-0.1015	1.4326	-0.0073
	2001	-0.0916	1.4454	-0.0071
	2002	-0.0326	1.3646	-0.0060
	2003	-0.0387	2.0021	-0.0168
	2004	0.0820	1.8514	-0.0144
	2005	-0.0311	1.7861	-0.0130
	2006	-0.0035	1.8146	-0.0135
	2007	0.1053	1.8927	-0.0151
F16	2004	0.0017	1.6334	-0.0107
	2005	-0.0734	1.8601	-0.0143
	2006	-0.0087	1.5660	-0.0091
	2007	-0.0205	1.3583	-0.0060
	2008	-0.0179	1.4378	-0.0073
	2009	0.1349	1.5622	-0.0095
F18	2010	0.0000	1.0000	0.0000
	2011	0.0938	1.2698	-0.0055
	2012	0.0122	1.1210	-0.0024

It has previously been shown that NDVI is related to, for example, the vegetation greenness, leaf area index (LAI), and primary productivity of the vegetation (Johnson 2003; Paruelo et al. 1997). Furthermore, it has been documented that a time series of NDVI can be used to assess the changes in vegetation cover and responses over time (Hill and Donald 2003). In addition, it can be used to estimate agricultural yields (Labus et al. 2010; Ren et al. 2008). This makes it possible to evaluate the vegetation status and the agricultural productivity on a large scale, by using remotely sensed NDVI, in regions where field data are sparse.

To decrease the processing time of NDVI data, a mask was constructed to exclude areas that are not associated with the agricultural economy.[58] The mask was produced by

[58] For this purpose, the MODIS Land Cover Type product (MCD12Q1) was used (Friedl et al. 2010).

combining land covers from the MODIS Land Cover Type product. The MODIS land cover scheme identifies 17 land cover classes,[59] which include 11 natural vegetation classes, 3 developed and mosaic land classes, and three nonvegetated land classes. Here, desired classes were Croplands (Number 12) and Cropland/Natural vegetation mosaic (Number 14). For areas within these two classes, yearly amplitude NDVI was calculated.

The recent global dataset[60] of Hansen et al. (2013) was used to quantify forest loss annually. This is a map of the extent, loss, and gain of global tree cover for 2000 to 2012 at a spatial resolution of 30 meters. The dataset improves on existing knowledge of global forest extent and change by being spatially explicit, quantifying gross forest loss and gain, providing annual loss information, and quantifying trends in forest loss. Forest loss was defined as a stand-replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale. Tiles were merged into larger composites and reclassified into 12 layers, one for each year, thus separating each individual forest loss year. Instead of sum of lights, sum of forest loss was calculated in the same way as nightlights.

In addition, agricultural production data was obtained from the statistical offices in Ghana, Tanzania, and Mali to analyze the relationship between NDVI and agricultural production. The data were compiled at the district level and represent all agricultural products produced during one year. Ghana had data for 2001 to 2012, Tanzania for 2007 and 2008, and Mali for 2002 to 2007.

Finally, official GDP data were also obtained from the World Bank World Development Indicators open data database (World Bank Group 2014). Data were downloaded for each country on a yearly basis from 1992 to 2012. All GDP data are expressed in constant 2005 U.S. dollars.

5.4 Growth Model and Results

In order to use these remote sensing data, it has to be demonstrated that these data can indeed predict or track the pattern of data collected through statistical offices. In other words, it is important to demonstrate the strength of the correlation between the remote sensing data and the actual data that are collected by administrative agencies in countries. Especially, for NDVI, some knowledge of the agricultural production at district levels, and preferably at even more local administrative units, is needed.

In this spirit, this section has three parts. First, it establishes the correlation between NDVI and actual agricultural production. Second, it estimates the national and local growth model based on time series analysis covering 2001 to 2012 at the district level in the case countries

[59] These are the land cover classes defined by the International Geosphere Biosphere Programme (IGBP).
[60] Annual forest loss data were downloaded from http://www.earthenginepartners.appspot.com/science-2013-global-forest/download.html.

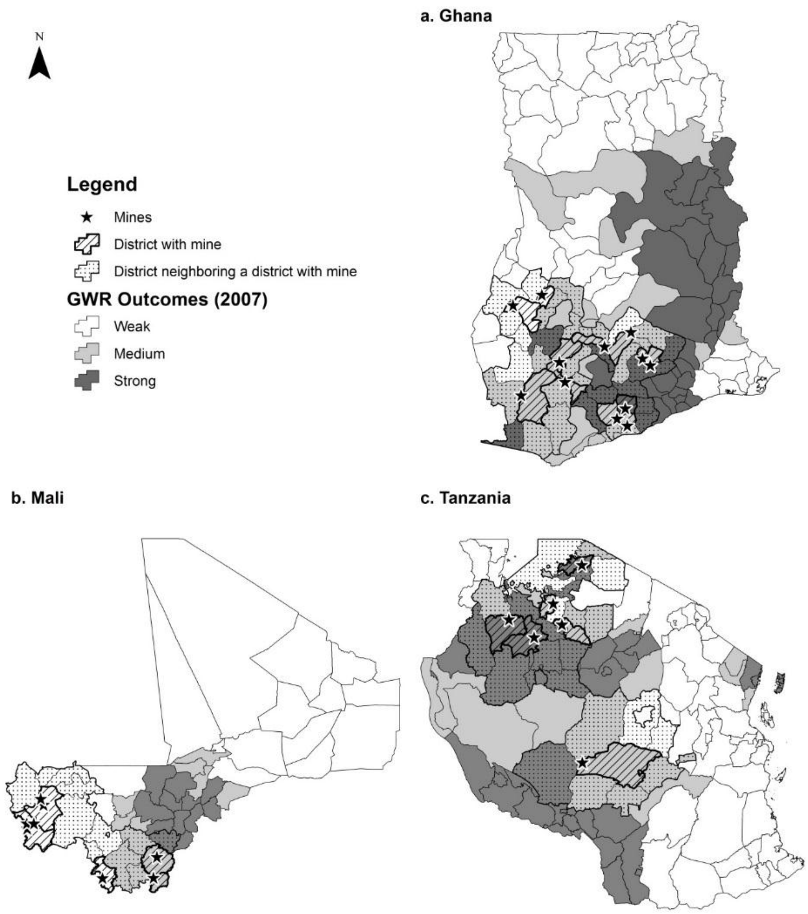
and combining nightlight, NDVI, and forest loss data to estimate the size of the local economy. Third, it applies a difference-in-differences framework to estimate the effect of mining on local economic activity, with a particular focus on local agricultural production.

NDVI and agricultural production

The remote sensing data allow the computation of NDVI for areas of any size, but actual agricultural production are only available at the district level for this study. Therefore, the first task is to show a spatial correlation of NDVI and actual agricultural production at district levels. An important difference between spatial and traditional (a-spatial) estimations, such as OLS regression, is that spatial statistics integrate space and spatial relationships directly into their models. Depending on the specific technique, spatial dependency can enter the regression model as relationships between the independent variables and the outcome variable, between the outcome variables and a spatial lag of itself, or in unexplained (that is, error) terms. Geographically weighted regression (GWR) is a spatial regression, applied to the small geographic areas, which generates parameters disaggregated by the spatial units of analysis. This allows for assessment of the spatial heterogeneity in the estimated relationships between the independent and dependent variables (Fotheringham, Brundsdon, and Charlton 2002).

The analysis shows a strong association between actual production of agricultural products and NDVI using spatial regression. Figure 5.1 illustrates the varying spatial relationship between the two estimates of agricultural production using 2007 data: NDVI and official statistics covering agricultural production. Other years show similar results, and the summary of the strength of the association is shown in the Annex (Annex figure A.5.5 and table A.5.1). The sum of NDVI at the district level is used as a predictor for the level of agricultural production. The pattern that emerges is one of a highly-to-moderately-strong correlation between agricultural production and NDVI in areas with high population densities. In most years and countries—with the exception of Mali—over 60 percent of the variation in district-level agricultural production can be explained by the differences in the average district-level NDVI intensity (see Annex table A.5.1). We are not able to determine whether the agricultural data include nonmarketed production, which in all these countries could be substantial. That said, the strong correlation between NDVI and agricultural production gives us confidence to use NDVI to predict agricultural production for small areas—say, around the mine.

Figure 5.1 GWR dependent variable total agricultural production by district and independent variable, sum of NDVI intensity, by district, 2007



National Growth Model

In addition to its impact on agriculture, there interest in knowing whether mining has substantial economic benefits—spillover effects—on local economies. The previous section showed that the strong association between NDVI and agricultural production justifies the use of the NDVI data for measuring the changes to agricultural production around the mines. Similarly, one could use the nightlight data, which have been demonstrated to predict economic activity, to capture changes to the local economy around the mines. While district-level agricultural output data is available, district-level GDP information is not. Consequently, first a national model is needed to estimate aggregate GDP and then parameters from such a model are used to obtain local economic production.

The basic estimation strategy follows Henderson et al. (2012), whose framework can be shown as:

$$\gamma_{jt} = \widehat{\psi} x_{jt} + c_j + d_t + e_{jt} \qquad (1)$$

where γ_{jt} is the true GDP of country j in time t. x_{jt} is the level of observed nighttime light at corresponding country and time. c_j and d_j are country and year fixed effects, and e_{jt} is the error term. As stated above, this is a model of the aggregate economy. It suggests that the total production or total economic activity (or its changes) is explained by level of measured nightlight (or its percentage growth) observed by satellite adjusted for some country- and time-invariant effects and an error term.

Following standard practices, the error term is assumed to be uncorrelated with GDP measurement. Given that the GDP and the nightlight come from two independent sources, the assumption would seem to be appropriate. However, using gridded data of land cover and nighttime light, we find that it is possible for agriculture's value-added to increase without emitting more observable nighttime light into space. If this is the case, then the error term is actually dependent on the agricultural share, since the higher the agricultural share the higher the measurement error from the nighttime lights.

Given this observation, our estimation follows the framework in equation (1), but takes note of the fact that not all economic growth, especially in heavily agricultural societies, is captured by growth in observed nighttime light only. The working assumption here is that nighttime light observed in space is the result of growth in only the nonagricultural sector. We therefore split the Henderson et al. (2012) model into a separate nonagricultural (equation 2) and agricultural (equation 3) parts, which are then combined in equation 4.

$$\gamma_{jt}^{na} = \widehat{\psi}^{na} x_{jt}^{na} + c_j^{na} + d_t^{na} + e_{jt}^{na} \qquad (2)$$

$$\gamma_{jt}^{a} = (\widehat{\psi}^{a1}\ \widehat{\psi}^{a2}\ \dots\ \widehat{\psi}^{an}) \begin{pmatrix} l_{jt}^{a1} \\ l_{jt}^{a2} \\ \vdots \\ l_{jt}^{an} \end{pmatrix} + c_j^{a} + d_t^{a} + e_{jt}^{a} \qquad (3)$$

Equation (2) is the familiar model that links GDP level (or growth) to the sum (or growth) of nighttime lights. We argue here that this model is mostly predictive of nonagricultural data. In equation (3) we extend this model to the agricultural sector by introducing two variables: MODIS NDVI and forest loss. Finally, a year dummy (year 2004 as a cutoff year) is added to obtain three models of income (growth) for each country, combining nightlight, NDVI, forest loss, and a year dummy—see equations 4–6. The rationale for using a year dummy and specifically using 2004 is related to Ghana's rebasing of their GDP around 2006, and most of the commodity prices started rising around that time.

$$Log\ GDP \sim Log\ Nightlight + Year\ dummy \quad (4)$$

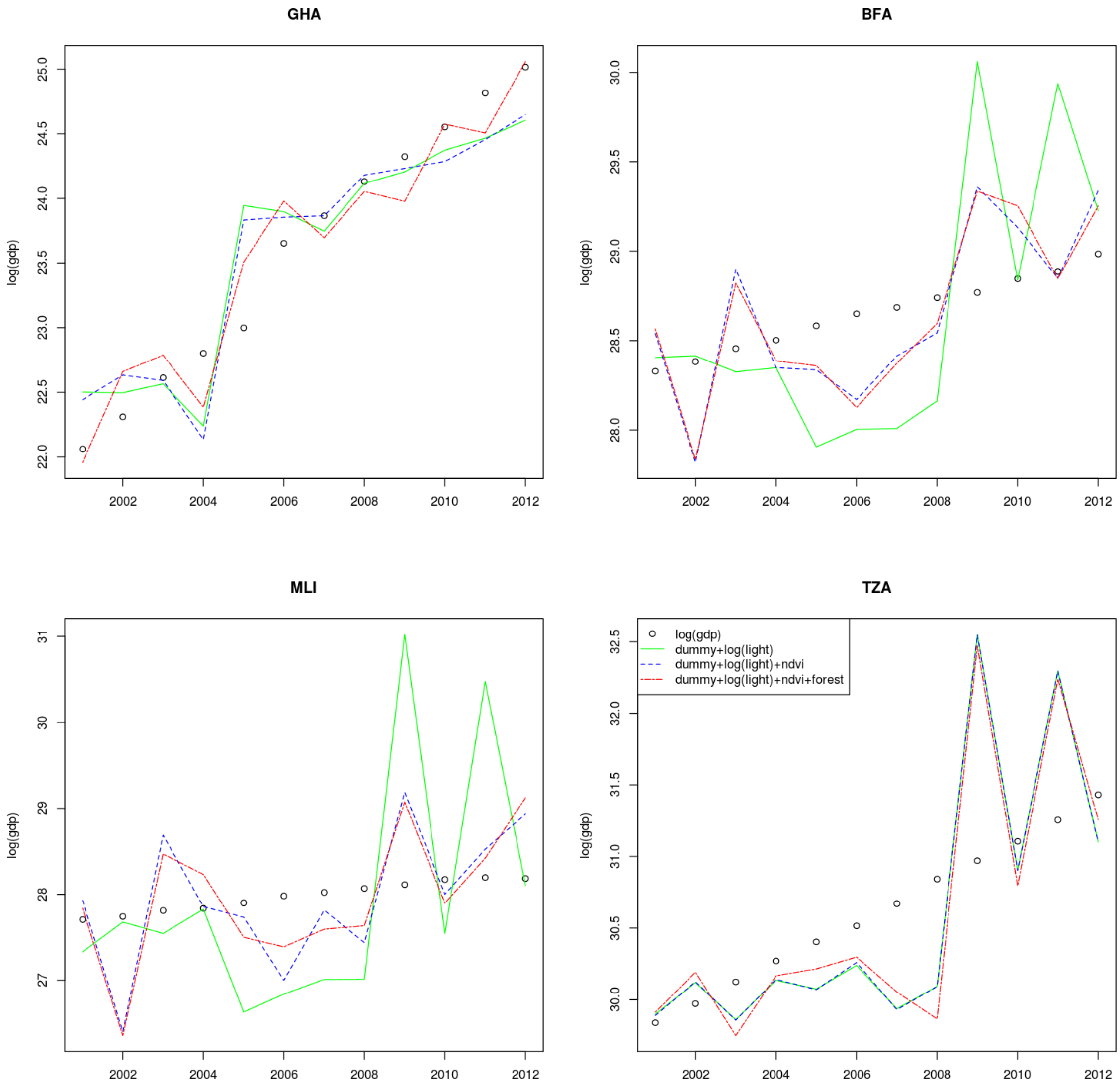
$$Log\ GDP \sim Log\ Nightlight + NDVI + Year\ dummy \quad (5)$$

$$Log\ GDP \sim Log\ Nightlight + NDVI + \ Forestloss\ + Year\ dummy \quad (6)$$

The model is designed so that the regression line departs from the origin with the y-intercept being equal to 0. The rationale behind not using the intercept is that in the second step of the model, we are estimating local growth by using the national growth model to fit with local parameters at the district level. The dynamics of the local economy are dependent on the relationship between the variables used in the national growth model. Including a national intercept term would result in a mismatch due to the spatial scale of the local estimations.

Figure 5.2 shows the correspondence between the actual evolution of aggregate production and the pattern of predicted output that can be obtained using the three different models (4–6) for each country.

Figure 5.2 Actual and predicted log (GDP) using 3 different models, 2001–12



Three observations can be drawn from figure 5.2. First, the remote sensing data are strongly predictive of the actual evolution of GDP in all countries and with better predicted levels of GDP when including all three types of remote sensing data. The best fit is the model for Ghana, especially the period after year 2004. In Mali and Burkina Faso, the actual log (GDP) and predicted log (GDP) (using log nightlight, forest loss, and NDVI) are very close for almost every year except for larger spikes in 2009 and 2001. By contrast, for Tanzania, while the correlations are strong, there are periods when the remote sensing data underestimates and others when it over-predicts total production. Similar spikes in the data, especially for log nightlight, can be observed in Tanzania. The odd pattern in the last years of the model for Burkina Faso, Tanzania, and Mali is similar to the pattern observed for light data at the global level (Annex figure A.5.1). This pattern might be explained by a combination of the following reasons related to nighttime light: real variation in nighttime light data between the years, calibration effects, and truncation of values over 63 (light-intensive over 63)

In addition, as suspected, nightlight alone is not sufficient to predict aggregate production. While it is true that nightlight stands out as strongly correlated with GDP, inclusion of the NDVI improves the fit of the model (table 5.2). In fact, the country models seem to suggest that nightlight with NDVI performs better than any other specification (for example, nightlights, NDVI, and forest loss) in predicting log (GDP). Only in Ghana is the forest loss statistically significant. Results from the other countries do not show any significance by adding forest loss, so this variable is dropped in all the estimation models.

Table 5.2 Multiple linear regression coefficients for growth model specified in equations 4–6

	Model specification	dummy		light		ndvi		forest		r2
Ghana	log(gdp) ~ 0+ log(light) + dummy	1,6512	***	1,8172	***					0,837
	log(gdp) ~ 0+ log(light) + ndvi+dummy	1,6370	***	1,7550	***	1,713E-06				0,844
	log(gdp) ~0+ log(light) + ndvi + forest+dum	1,7860	***	1,7590	***	3,644E-06		-2,34E-06	*	0,915
Tanzania	log(gdp) ~ 0+ log(light) + dummy	0,3340		2,5921	***					0,489
	log(gdp) ~ 0+ log(light) + ndvi+dummy	0,3322		2,5913	***	4,347E-08				0,488
	log(gdp) ~0+ log(light) + ndvi + forest+dum	0,5441		2,6175	***	7,163E-08		-1,58E-07		0,483
Mali	log(gdp) ~ 0+ log(light) + dummy	-1,0713		2,5732	***					0,201
	log(gdp) ~ 0+ log(light) + ndvi+dummy	-0,4041		1,3282	***	1,064E-05	**			0,223
	log(gdp) ~0+ log(light) + ndvi + forest+dum	-0,4554		1,3731	**	1,009E-05	**	2,62E-06		0,259
Burkina Faso	log(gdp) ~ 0+ log(light) + dummy	-0,6375		2,6873	***					0,314
	log(gdp) ~ 0+ log(light) + ndvi+dummy	-0,1954		1,8140	***	8,188E-06	**			0,434
	log(gdp) ~0+ log(light) + ndvi + forest+dum	-0,2595		1,8477	***	7,821E-06	**	5,12E-07		0,433
	Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1									

Finally, even though agriculture accounts for the largest share of economic activity in all these countries, NDVI is strongly significant only for the model of Burkina Faso and Mali. Adding forest loss to the model does not change the model fit, and the variable is only significant in Ghana. Finally, the year dummy is strongly significant for Ghana, but does not influence the results for the other countries.

Table 5.3 Standard error of residuals between model and observed, together with average of observed and modeled GDP

	Burkina Faso	Ghana	Mali	Tanzania
Average Log (GDP)	28.65	23.59	27.98	30.62
Average Log (model GDP)	28.65	23.60	27.96	30.60
Residual Standard Error	0.67	0.43	1.39	0.72

Growth model at district levels

Ideally, we would like to estimate a model linking GDP at the local level to georeferenced data. Unfortunately, while the georeferenced data can be compiled for areas smaller than even a district, administrative data for district-level GDP is not available. Therefore, the parameters of the relationship between GDP and georeferenced data at the national level are used to impute district-level production in each case study country. The models are based on the regression results from equations (4–6) and presented in table 5.3. Thus, the local growth model is based on the national growth model.

When developing the growth model for districts, several methods were used in order to provide an accurate local dimension of the local economy. Population data and average household expenditure on district levels were included as weights in the model estimating local growth patterns. However, population at the district level was highly correlated with nightlight intensity at the district levels, and average household expenditure at the district level was highly correlated with GDP at the local levels (see Annex figures A.5.3 and A.5.4 for correlation analysis), and therefore not used in the estimations.

The results of the district-level growth patterns are displayed in a series of maps and graphs in the Annex. Annex figure A.5.2 presents maps of the imputed growth patterns at the district level. The maps tag districts into those that are predicted to have had negative, moderate, or high growth. These maps provide a visual display of the geography of growth in each country.

A look at the maps leads to three main conclusions. First, average growth in mining districts appears to be higher than in nonmining districts. In Ghana, the average growth rates turn positive if the growth in districts neighboring the mining districts area taken into account. The map suggests that effects on mining could evolve differently around mining and nonmining areas in different countries. And the differential evolution could have an impact on local economic growth. However, to test whether these spatial patterns of measured local economic growth are due to mining activities requires a more rigorous test than a mere visual inspection. A suitable test and the results are presented in the next section.

Nightlights and NDVI in a Difference-in-Differences Framework

Empirical Framework

To understand whether nightlights and the greenness index in mining communities are linked with the onset of mining, a difference-in-differences empirical estimation strategy is used.[61] This strategy allows comparison of outcomes in the geographic proximity of mines with areas farther away, both before and after the mines start producing. In effect, this involves making three comparisons: close to and far away, before and after, and both comparisons at the same time. The cross-sectional differences in areas with an active mine, and without an active mine are modeled as:

$$\mathrm{Y_{jt}} = \beta_1 \mathrm{active_{jt}} + \varepsilon_\mathrm{j}$$

where *Y* is the outcome variable (nightlights and NDVI), active is a binary variable that takes value 1 if the mine is active in that year, and subscript *j* is for the mine and *t* for the year. The importance of proximity can be modeled as:

$$Y_j = \beta_1 close_j + \varepsilon_j$$

where close captures the cross-sectional difference between areas that are close to mines and those that are further away. Interest is in knowing the relative change that happens in the geographic proximity of mines with the onset of the mine, compared to what happens far away from the mine. This is captured by the difference-in-differences estimation model, which includes an interaction effect of the two binary variables:

$$Y_{jt} = \beta_1 active_{jt} + \beta_2 close_j + \beta_3 active_{jt} * close_j + \delta_j + \varepsilon_{jt}$$

where δ_j is a mine fixed effect, which means that any change that is peculiar to a mine is accounted for. Year fixed effects, which will take care of year-specific shocks that happen across all mines, are also captured. To decide the relevant distances for examining the footprint of gold mines, the analysis draws guidance from recent studies in the African

[61] This strategy is employed to understand the economic effects of gold mining in Africa by Aragon and Rud 2015; Chuhan-Pole, Dabalen, Kotsadam, Sanoh, and Tolonen 2015; and Tolonen 2015.

context.[62] These studies find that areas up to a 20-km radius are relevant, and that beyond 50 km the mines have little economic footprint. Moreover, we rely on the geographic results found in this paper. Consequently, a distance of 10 km is chosen to understand the footprint close to mines. This is compared with an area that is 10 km, 20 km, 30 km, and 50 km to 100 km away. The total sample size is 32 gold mines located in Burkina Faso, Ghana, Mali, and Tanzania.

Results

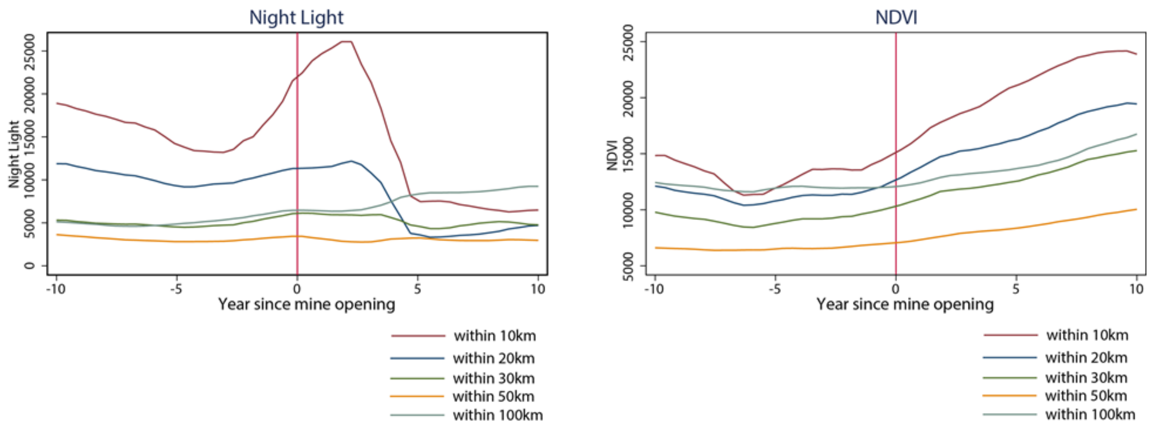
Figure 5.3 explores the change in the different distances from the mine, over the mines' lifetime. On the horizontal axis is the mine year, counting from 10 years before mine opening, highlighted by the red vertical line, to 10 years after mine opening. The figures are based on summary statistics, and do not control for any systematic differences across the mines. Overall, it seems like areas very close to mines are on a steeper trend in nightlights than are areas farther away, especially as one gets closer to the mine opening year, which is highlighted by the red vertical line. One interpretation of this pattern is that from a few years before the mine starts extracting gold, economic activity that emits nightlight increases in these areas. One reason why this happens before the actual mine opening year is because mines are capital-intensive and the local economy is stimulated during this investment phase, a pattern confirmed in previously mentioned econometric studies.

For NDVI, no big difference in patterns is observed across the areas. Although both areas seem to be on an upward sloping trend, this needs to be interpreted with caution, because it can be driven by the unbalanced sample[63]. If anything, we detect that areas close to mines are getting relatively greener over time compared with areas further away.

[62] See footnote 51.

[63] The sample is unbalanced as the data on nighlights start in 2002, but mines may have opened long before 2002, as well as after. If the mines opened before 2002, we will have night lights data only during the active period of the mine. Such mines would then add to the estimates of night lights on the right side of the red line, but not to the left. There are too few mines for which we have night lights the whole 20-year period to do these figures on a perfectly balanced subsample.

Figure 5.3 Nightlight, NDVI over mine lifetime



Note: Nonparametric (local polynomial smooth) measures of nightlight and NDVI close to mines. Years since mine opening on the x-axis counts the number of years from mine opening, with before the opening on the left of the 0, and years after mine opening to the right of the 0. Nightlights and NDVI are measured as averages across limited geographic areas, varying from within 10 km from the mine center point, to 20 km, 30 km, 50 km, and 100 km.

Table 5.4 shows the regression results from the strategies outlined in the Empirical Framework section. The results indicate that there are clear increases in nightlights close to mines. The strongest effects are found within 10 km of a mine (panel A, column 1). The measures are simple differences, and compare within a given area before and after mine opening. The larger the distance used to define the area close to a mine, the smaller the effect sizes are. Note that these estimates are simple differences and they do not take into account local trends in nightlights (for that, see the difference-in-difference analysis below).

Table 5.4 Simple difference specification: Comparing before and after mine opening

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Distance	**10 km**	**20 km**	**30 km**	**40km**	**50 km**
Panel A. Log nightlights					
Active mine	0.704**	0.446***	0.281*	0.235	0.468***
	(0.272)	(0.135)	(0.146)	(0.149)	(0.070)
Observations	620	620	620	620	620
R-squared	0.649	0.728	0.775	0.820	0.896
Panel B. Log NDVI					
Active mine	0.026***	0.014*	0.014	0.030**	0.049
	(0.009)	(0.007)	(0.024)	(0.012)	(0.061)
Observations	347	347	347	347	347
R-squared	0.601	0.709	0.649	0.635	0.452
Mine FE	Yes	Yes	Yes	Yes	Yes

Note: Clustered standard errors at the mine level in parentheses. The simple difference is capturing the percentage increase in nightlights (panel A) and NDVI (panel B) after mine opening within X km of a mine (10, 20, 30, 40, or 50 km). The simple difference is thus a comparison of values before and after mine opening within the same geographic area. ***p<0.01, **p<0.05, *p<0.1.

There is also the possibility that the model may be overestimating the effect size because it does not capture changes in the composition of local production with just nightlights. For instance, if households engaging in subsistence farming did not have electricity, but demand more of it in order to change to more modern sectors at the time of opening of the mine, then the increased demand for electricity will lead to an increase in nightlights. However, the decrease in farming that will result from occupational switching will not be reflected in the changes in nightlight if subsistence farming does not use electricity. In such a scenario, the effect of the mine on the local economy would be overestimated.

Findings from the difference-in-differences analysis are presented in table 5.5. The results do not show any robust increases in nightlights or NDVI in mining communities (20 km) compared with those further away (20 to 100 km). The estimated effects are insignificant for the main treatment coefficient *active_close*. The statistically significant coefficient for active in the first specification shows that there are more nightlights across the whole area after mine opening compared with before. The coefficient is insignificant when controlling for year fixed effects, which indicates that there are trends in nightlights. Assessing the visual evidence in figure A.4.3, suggests that there is only a modest increase in nightlights over the area within 20 km of a gold mine around the time of the opening, but that this is not true in the long run.

Table 5.5 Difference-in-differences specification

	(1) Nightlight	(2) Nightlight	(3) NDVI	(4) NDVI
active_close	-0.540	-0.545	-0.052	-0.034
	(0.365)	(0.375)	(0.270)	(0.265)
active	0.692***	0.191	0.316	-0.028
	(0.204)	(0.240)	(0.228)	(0.232)
close (20 km)	0.209	0.199	-0.144	-0.168
	(0.333)	(0.344)	(0.207)	(0.200)
Mine FE	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
Observations	1,063	1,063	684	684
R-squared	0.655	0.693	0.691	0.727

Note: Clustered standard errors at the mine level in parentheses. The difference-in-differences estimate compares outcomes close to mines with far away (20 to 100 km), and before and after mine opening. The two years preceding the mine opening year are excluded from the analysis. Close is defined as within 20 km of a mine. ***p<0.01, **p<0.05, *p<0.1

If mines increase the urbanization rate or lead to decreased local farming--as found by Aragón and Rud 2015--greenness in mining areas should decrease. In short, values of the NDVI measure of greenness used in our model should decline. In table 5.4, panel B shows that areas close to mines have higher levels of NDVI (column 2, 3, and 4). This could be indicative of mining areas being more rural in general. However, the interaction terms (table 4.5, column 3 and 4) are insignificant and negative, indicating that NDVI does not change statistically with the onset of mining.

5.5 Conclusions

The objective of this chapter was to use remote sensing data to estimate the level and growth (or decline) of local economic activities around the mining areas in Burkina Faso, Ghana, Mali, and Tanzania. The analysis was divided into two parts.

First, it established the spatial relationship between NDVI and actual agricultural production at the district level on one hand, and nightlights and overall economic output (GDP) on the other. The results were encouraging. It was found that the NDVI—or greenness index—and nightlights are good predictors (a relatively high r-squared) of economic activities in these countries. However, forest loss as a predictor of economic growth did not provide increased explanatory power to model economic growth on the national level, so forest loss was dropped when modeling economic growth on local levels. The remote sensing datasets used in the study covered 2001–12, providing not only high spatial resolution but also a time series perspective in order to account for change over time.

Second, having shown that remote sensing data provide a useful measure of economic activity, the chapter makes use of these remote sensing data to compare growth in economic activities around mining areas to those far away using a difference-in-differences framework.

The findings can be summarized in two points. First, the analysis of a selected set of 32 gold mines from four African countries (Burkina Faso, Ghana, Mali, and Tanzania) suggests that the onset of mines is associated with increases in economic activity—as proxied by nightlights—within the vicinity of the mines. Graphic analysis of the night lights data show strong increases in night lights mining communities within 10km from a mine in the years immediately before mine opening, and the years following mine opening. A simple-difference analysis illustrates that the very near areas (within 10km) have significantly higher levels of economic activity after mine opening. However, the difference-in-difference analysis illustrates that over time, the areas near the mines are not significantly better off than areas further away. This may partially indicate that with time, the economic benefits from mining spread over a larger area from the mine's center point.

The finding that economic growth increases is in contrast to the common perception that views large-scale mines as economic enclaves separated from the local economies. Proximity is defined as an area within 10 km, 20 km, 30 km, or 40 km from the location of the mine, and the control group is drawn from an area 50 to 100 km away. Second, despite the risks that mines pose to agricultural productivity, for example, through environmental pollution or structural shifts in the labor market, there is no evidence of a decrease in greenness—which is the measure of agricultural production. Furthermore, the effects of small-scale and artisanal mining activities, common in the study countries, upon economic growth and greenness are not discussed within this report.

Annex

Figure A.5.1. Log (Global light sum) 2008–12

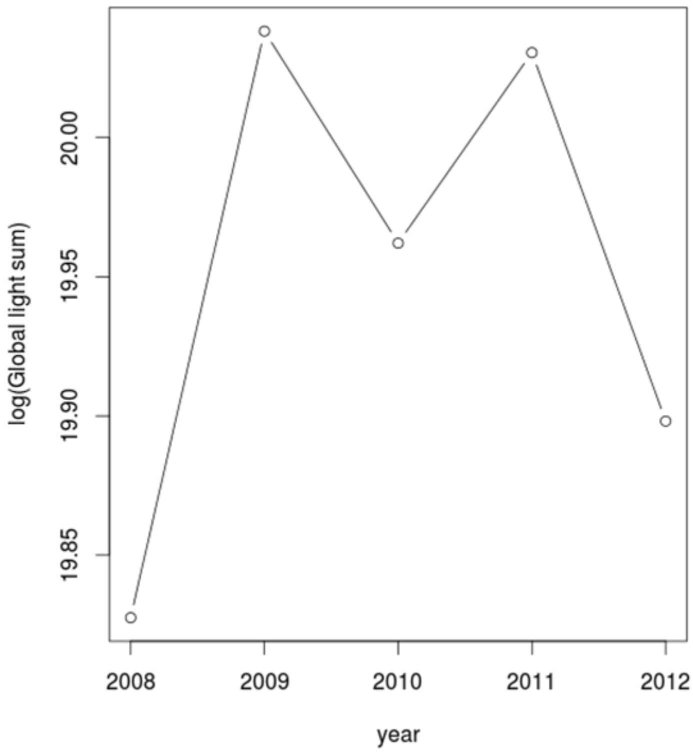


Figure A.5.2 Spatial analysis of average growth in districts (2001–12) estimated by growth model

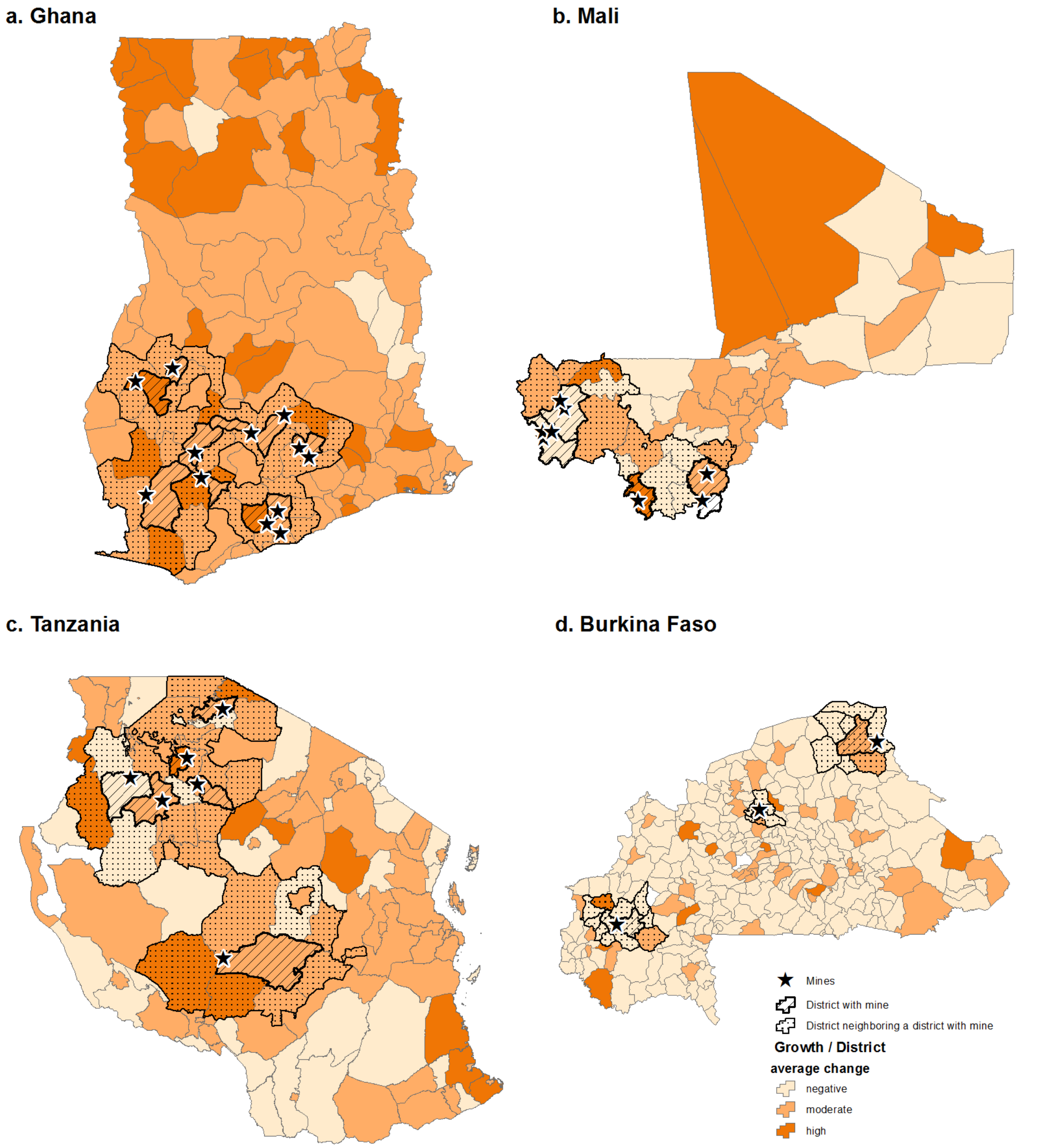
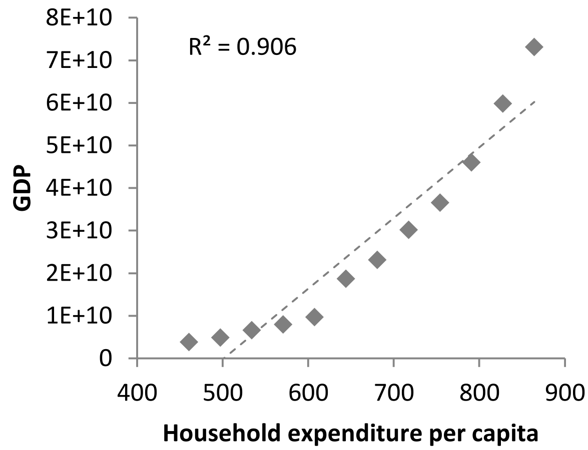
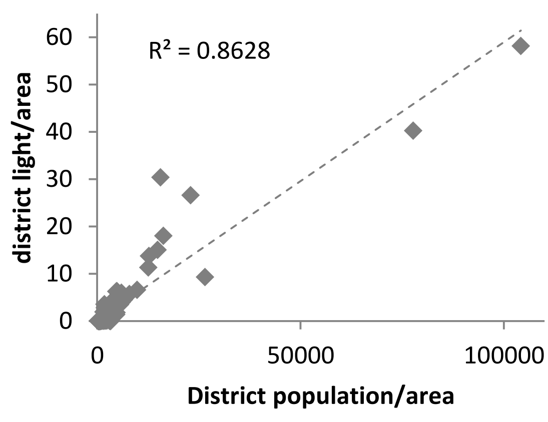


Figure A.5.3 Correlation between GDP and household expenditure per capita levels for Ghana year 1991/92 and 2005/06



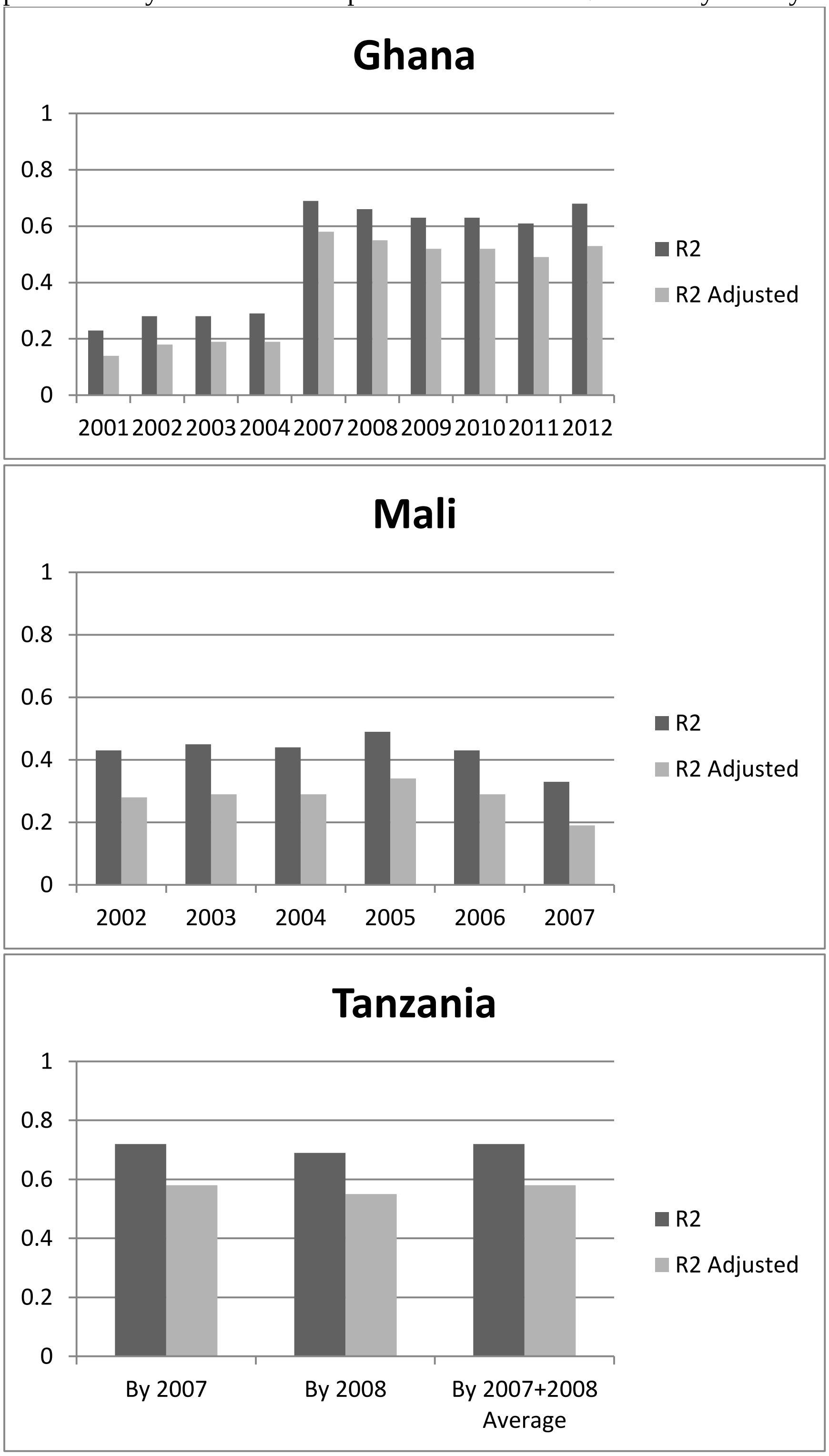
Source: GDP data World Bank Indicators and Ghana Living Standards Surveys 1991/92 and 2005/06.

Figure A.5.4 Correlation between nightlight intensity and population on districts levels for Ghana year 2010



Source: DMSP-OLS processed by authors and population data provided by the World Bank.

Figure A.5.5 GWR – Local R-squared for relationship between Dependent variable Total agricultural production by district and Independent variable NDVI Intensity sum by district



Source: NDVI processed by authors and agricultural production data provided by the World Bank.

Table A.5.1 GWR – Local R-squared for relationship between Dependent variable Total agricultural production by district and Independent variable, sum of NDVI Intensity, by district

Country	**Year**	**R2**	**R2 Adjusted**
Ghana	2001	0,23	0,14
Ghana	2002	0,28	0,18
Ghana	2003	0,28	0,19
Ghana	2004	0,29	0,19
Ghana	2007	0,69	0,58
Ghana	2008	0,66	0,55
Ghana	2009	0,63	0,52
Ghana	2010	0,63	0,52
Ghana	2011	0,61	0,49
Ghana	2012	0,68	0,53
Mali	2002	0,43	0,28
Mali	2003	0,45	0,29
Mali	2004	0,44	0,29
Mali	2005	0,49	0,34
Mali	2006	0,43	0,29
Mali	2007	0,33	0,19
Tanzania	2007	0,72	0,58
Tanzania	2008	0,69	0,55

Source: NDVI processed by authors and agricultural production data provided by the World Bank.

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