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Mining Booms in Africa and Local Welfare Effects: Labor Markets, Women's Empowerment and Criminality

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Wild honey smells of freedom
The dust - of sunlight
The mouth of a young girl, like a violet
But gold - smells of nothing.
Anna Akhmatova

Chapter 1

Introduction

For the past two centuries, Africa's natural resource wealth first drew the interest of colonial empires and then drove a thirst for independence that has been critical in shaping present day African development. Parts of the continent have benefited from this natural endowment—for example, megacities such as Johannesburg have grown on the sites of gold mines—while other parts of the continent have visibly gained little from their extracted resources.

In the decades following independence, several countries failed to reap the benefits from their sub-soil wealth. Ghana, the profitable former Gold Coast Colony, saw gold production plummet at dawn of independence in 1957, and it remained low until the 1990s (Hilson, 2002). In Nigeria, oil revenues often failed to generate increases in economic wellbeing: the nation's oil rich regions experienced ecological disasters rather than human development (Watts, 2004). In stark contrast, Botwana's diamond riches led the country to double digit GDP growth rates from the 1970s and onwards. It has been argued that Botswana's institutions, including pre-colonial and early colonial institutions were pivotal in determining this success story (Hjort, 2010; Acemoglu, Johnson, and Robinson, 2003).

The last two decades have seen a new natural resource revolution take place in Africa. The continent's opportunities for high economic growth are being transformed by new discoveries of natural resources—oil, natural gas, and minerals—and rising commodity prices.The extractive sectors are the receiving the largest share of foreign direct investment and they contributed to two-thirds of total export growth between 2002 to 2012 (Chuhan-Pole et al., 2013). The inflow has been driven by a supercycle of mineral prices, growing demand from emerging markets such as China, and the never-ending need for energy sources. But what will this revival of the natural resource sector bring for African economic development?

Noted development scholar Paul Collier argues that Africa's natural resources can provide an exceptional opportunity for growth (Collier, 2010)—if managed correctly. To ensure that the extractive industries bring wealth, governments need to focus on discovering, exploiting, taxing, and investing while maintaining strong political institutions (Collier and Laroche, 2015). However, few would argue that the extractive sector has been managed that responsibly to date. The list of potential adverse effects is long. Dependency on exports of natural resource commodities makes countries vulnerable to world market price shocks. Price and production shocks can drive social and political instability. And as the extractive wealth is non-renewable, countries risk losing their most important income stream if no new discoveries are made.

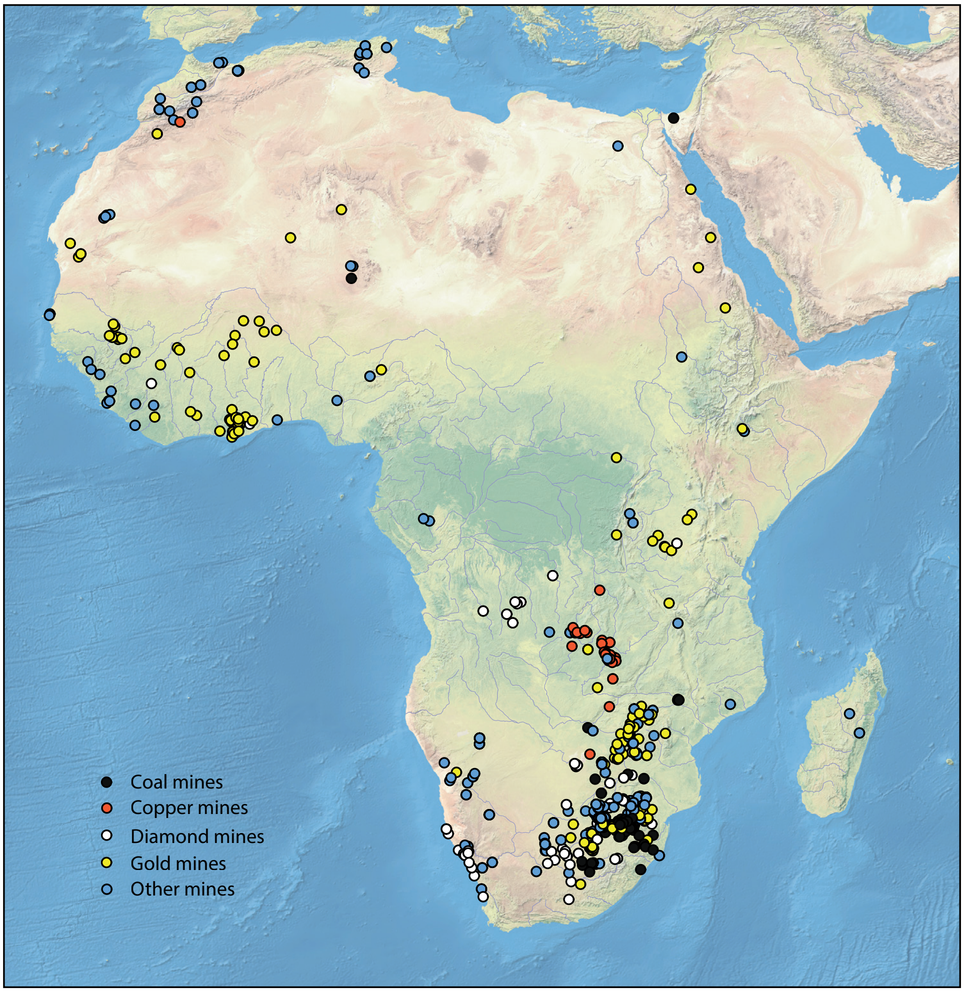


Figure 1.1: Large Scale Mining Sites in Africa from 1975 to 2013

Notes: Data on mineral extraction sites from IntierraRMG. The map shows large-scale mining sites in Africa 1975-2013.

The extractive sector's ability to generate sustainable economic development has long been disputed: is there a macro-economic natural resource curse (Sachs and Warner, 2001)? The resource curse predicts that natural resource extraction leads to over-specialization of the economy in this volatile and depletable sector. It also predicts that discoveries lead to political instability due to elite capture of rents (Leite and Weidmann, 2002) and conflict over resources[1]. Moreover, under conditions where there are gender segregated labor markets and Dutch disease effects, it has been hypothesized that the sector can result in a male focused economy, with little demand for women's labor supply (Ross, 2008).

[1] See van der Ploeg, 2011 for an overview

On the other hand, history shows that good governance of natural resource income can lead to sustained growth. Upon the discovery of diamonds in Botswana, it quickly went from being one of the poorest countries in the world in the late 60s to sustained double digit growth. The country sustained an average growth rate of 7% over 40 years (Hjort, 2010). Extractive industries can bring government funds through collected taxes and royalties. However, cases like Botswana are the exception rather than the rule. There are numerous examples of countries in Africa failing to collect a significant share of the natural resource income. Zambia, a country heavily reliant on copper exports, received just 1.5% of the value of these copper exports through corporate tax (Standing and Hilson, 2013). The average royalty rate for gold mines in Africa was only 3% in 2010 (Gajigo et al., 2012). Ghana increased the rate to 5% in 2010, and more countries are likely to follow and renegotiate current rates[2].

Macro-economic and fiscal effects aside, extractive industries might have welfare effects on local communities. This aspect of the sector has received much less focus within the research community. Recent advances in data collection, such as geocordinated household surveys and the introduction of natural resource databases with geographic identifiers, have made this research agenda possible. In the seminal development economics book "Strategy of Economic Development" (1958), Albert O. Hirschman argued that the extractive industries are enclaves with few benefits for the local economy. However, 57 years later, we have identified that there are in fact spillovers and have begun to learn about their economic importance and the welfare effects on local populations. Localized effects have been demonstrated in recent evidence from the U.S. (for natural gas, e.g. Allcott and Keniston, 2014, for coal e.g. Black et al., 2005), Peru (for gold, Aragon and Rud, 2013), Brazil (for oil, see e.g. Caselli and Michaels, 2013), Zambia (see Wilson 2012), and other resource abundant areas.

This dissertation attempts to understand the local welfare implications of one of the major extractive industries: the large scale mining industry. The research focuses on Africa. A continent with a long tradition of large scale mining and a diverse mining sector (see Figure 1.1). Despite this, when I commenced this research in 2011, evidence from the economic literature on the implications of large scale mining on local African economies was scarce. Wilson's excellent study (Journal of Health Economics, 2012) found that sexual risk taking behavior of young adults decreased in copper mining towns during the mining boom in the early 21st century. The evidence has continued to grow, and there is now a body of research exploring the effects of large scale mining on local labor markets (Kotsadam and Tolonen, 2013[3]), health (von der Goltz and Barnwal, 2014), the environment (Aragon and Rud, forthcoming), and social conflict (Berman et al., 2014).

The idea that large scale mining operations have no effects on the livelihoods of local populations is quickly becoming less credible. Figure 1.2 shows the effect of large scale mining on the local economies comparing the near vicinity of mines (within 10km) with further away (30-50km). As sometimes claimed by experts in the field, local economic effects are found during the investment phase (gray shaded area) which is two to three years before production start. By the time the mine opens (the red vertical line), the local economy has already seen a boost in night light intensity. The geographic extent is yet to be fully understood. It will likely depend on numerous factors, including population density, market integration, road networks, and commuting distances. In some cases, the effects may be limited to a 10 kilometer area around the mine, in others, they may reach beyond 20 kilometers from mine center point.

[2]One important framework for increased transparency within the sector has been defined in the Extractive Industries Transparency Initiative (EITI) which aims at negotiating fair deals and redistribution of funds. More info at https://eiti.org/eiti.

[3]Appearing in the current volume as Chapter 2

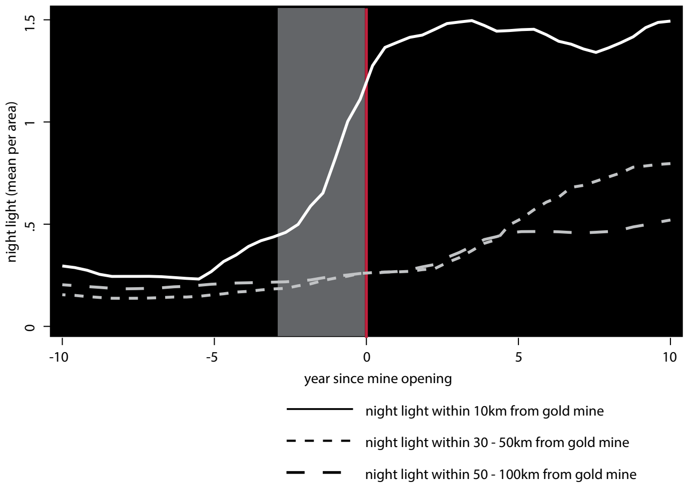


Figure 1.2: Night Lights Around Gold Mines

Notes: Non-parametric estimates of night lights within 10km, 30-50km, and 50-100km from gold mines. Horizontal axis shows year since mine opening, and the red vertical line shows the mine opening year. The sample of gold mines comes from Chapter 3.

This dissertation "Mining Booms in Africa and Local Welfare Effects: Labor markets, Female Empowerment, and Criminality", explores the effects of large scale mining in three related but independent chapters. Chapter 2 analyzes labor market effects across the African continent, chapter 3 focuses on women's empowerment and infant health in gold mining communities in West and East Africa, and chapter 4 explores the links between criminality and mining in South Africa. Using large household survey data sets and official data records, I employ quasi-experimental research designs and techniques of spatial econometrics to identify the causal effects of large scale mining on local welfare.

In chapter 2, "African Mining, Gender and Local Employment" (joint with Andreas Kotsadam), we perform the first cross-national study testing these hypotheses with micro-data. It is a contentious issue whether large scale mining creates local employment, and the sector has been accused of hurting women's labor supply and economic opportunities. This chapter uses the rapid expansion of mining in Sub-Saharan Africa to analyze local structural shifts and the role of gender in determining outcomes. We match 109 openings and 84 closings of industrial mines to survey data for 800,000 individuals and exploit the spatial-temporal variation. With mine opening, women living within 20 km of a mine switch from self-employment in agriculture to working in services or they leave the work force. Men switch from agriculture to skilled manual labor. Effects are stronger in years of high world prices. Mining creates local boom-bust economies in Africa, with permanent effects on women's labor market participation.

Next, I explore if industrial development leads to more women's empowerment. Chapter 3, "Local Industrial Shocks, Female Empowerment and Infant Health: Evidence from Africa's Gold Mining Industry", explores the causal effects of a continent-wide exogenous expansion of industry on female empowerment and infant health. The chapter uses the recent rapid increase in gold mining in Africa as a quasi-experiment. The identification strategy relies on temporal (before and after mine opening) and spatial (distance to mine) variation, as well as exogenous variation in the price of gold in a difference-in-difference analysis. Using a large sample of women and children living within 100 km of a mine, the analysis shows that the establishment of a new mine increases income earning opportunities within the service sector by 41%, makes a woman 23% less likely to state a barrier to healthcare access for herself, and decreases women's acceptance rate of domestic violence by 24%. Also, despite risks of environmental pollution from gold mining, infant mortality is reduced by more than half of its original value. In particular girl infants face better chances of survival. I exclude the possibility that effects are driven by increased schooling attainment made possible by investment in schooling infrastructure, or that service jobs are limited to prostitution. Yet I cannot rule out that urbanization is part of the mechanism. The findings are robust to different assumptions about trends, distance, and migration, and withstand a novel spatial randomization test. The results support the idea that entrenched norms regarding gender can change rapidly in the presence of economic development.

In chapter 4, "Criminality and Mining: Evidence from South Africa", I explore, jointly with Sebastian Axbard and Jonas Poulsen, the links between mining and criminality in South Africa. South Africa has a long history of mining, and is plagued by economic and social inequality, and rampant criminality. The study is, to our knowledge, the first to investigate whether extractive industries can cause property and violent crime in a middle-income country. We focus on South Africa, a country with a significant mining industry and high crime levels, similar to Botswana, Brazil, and Mexico. Our empirical strategy exploits time and geographic variation in mining, in addition to fluctuations in international mineral prices, to estimate the effect of mining activity on crime. In contrast to earlier findings on other forms of social conflict, we find that areas endowed with higher levels of natural resources show no increase in crime when a mine opens and in fact have lower crime levels when the mine is active. However, the closure of a mine leads to a large and significant increase in both property and violent crime. Subsequently, we show that the migration flows and income opportunities created by the mining industry are two important channels through which mining affects criminality. The findings illustrate that the volatile nature of the sector can be a threat to social stability and security.

These three independent chapters have much in common. All three focus on the local economic implications of large scale mining, and the welfare implications, either in terms of gender equality, women's empowerment, infant health or criminality rates. In total, the dissertation analysis uses data from 30 countries with different levels of development, from Togo and DRC, to South Africa and Nigeria. Since the start of the first project, chapter 2 in 2011, more large mines have opened across the continent. In West Africa, the gold industry is rapidly expanding (as seen in chapter 3). The more mature industry in southern Africa has a higher number of mines closing down (as seen in chapter 4). For this reason, chapter 2 that focuses on large mines across 29 countries, and chapter 4 focusing on South Africa, explore heterogeneity in both mine opening and mine closing. Chapter 3 focuses only on mine opening, as fewer mines have closed down during the time of analysis. Moreover, there are strong differences in production. South Africa has among the deepest mines in the world, and the mining industry is, by and large, more labor intensive and focused on deep shaft mining. The large gold mines analyzed in chapter 3 are almost exclusively open pit mines, which is a relatively less labor intensive production method.

The welfare effects found span both the positive and the negative: in chapter 2, we show that mining can provide non-agricultural employment—however, total employment decreases. Chapter 4 illustrates that mining communities might be more vulnerable to surges in crime upon mine closure. Chapter 3 illustrates that gold mines generate local economic shocks that can be norm shifting and have strong positive effects on infant survival. While these three chapters demonstrate outcomes spanning a range of indicators, important in determining social development, it is, however, too limited a set to provide a full cost-benefit analysis of large scale mining investment on welfare. Important indicators for local welfare are not analyzed—environmental degradation, the risks accidents, health and safety for the miners, relocation, land rights, and measures of equity. A shortcoming of this dissertation is that it remains agnostic as to what best-practice is, and what is the fair level of local social development that ought to be expected from large scale mining investments. Moreover, future research must investigate how large scale and small scale mining can, and do, co-exist, and the long run effects of large scale mining activities. Despite these caveats, the methods and the results in this volume form an important basis for understanding the true social and environmental costs associated with resource extraction on local communities. As societies reliance on the wealth of the earth continues to grow undiminishing, we must look beneath the surface of this complex industry and understand how we can use these riches for the benefit of all who find them in the ground beneath their feet.

Chapter 2

African Mining, Gender, and Local Employment

Abstract

It is a contentious issue whether large scale mining creates local employment, and the sector has been accused of hurting women's labor supply and economic opportunities. This paper uses the rapid expansion of mining in Sub-Saharan Africa to analyze local structural shifts. We match 109 openings and 84 closings of industrial mines to survey data for 800,000 individuals and exploit the spatial-temporal variation. With mine opening, women living within 20 km of a mine switch from self-employment in agriculture to working in services or they leave the work force. Men switch from agriculture to skilled manual labor. Effects are stronger in years of high world prices. Mining creates local boom-bust economies in Africa, with permanent effects on women's labor market participation.

JEL Classification : J16, J21, O13, O18

2.1 Introduction

Africa's opportunities are being transformed by new discoveries of natural resources and their rising prices (Collier 2010), and the mining sector is the main recipient of foreign direct investment in Sub-Saharan Africa (World Bank, 2011). Whether the discovery of natural resources is a blessing or a curse to the economy and to a country's citizens is a contentious issue (see Frankel 2010 or van der Ploeg 2011 for overviews), and natural resource dependence is linked to various outcomes at the national level: institutions (e.g., Mehlum et al., 2006a, 2006b), corruption (e.g., Leite and Weidmann 2002), civil war and conflict (e.g., Collier and Hoeffler 2004, 2005), rent appropriation by an elite (e.g., Auty, 2001, 2007), democracy (e.g., Barro 2000; Jensen and Wantchekon 2004), and female labor force participation (Ross 2008, 2012).[1]

While the country-level economic and political effects of extractive industries are well explored, the research on their local economic effects is nascent. The present paper adds to recent literature on local effects of natural resources (e.g. Allcott and Keniston 2014; Aragon and Rud, 2013; Berman et al., 2014; Caselli and Michaels 2013; Michaels 2010; Wilson 2012), by investigating the effects of large-scale mineral mining on local labor markets. We use the best available survey data for Africa, Demographic and Health Surveys (DHS).[2] The main focus is on women's labor market opportunities, and we contrast our findings with the effects for men. Access to employment improves women's lives and is listed among the top five priorities for promoting gender equality in the 2012 World Development Report (World Bank, 2012).

It is theoretically ambiguous whether industrial mining increases or decreases female employment. The African Mining Vision, formulated by the member states of the African Union, together with the African Development Bank and the United Nations, spells out the risk that extractive industries may consolidate gender disparities in economic opportunities, with losses to women as a by-product of such industries (UNECA, 2011). Similarly, Ross 2008, 2012 claims that exploitation of natural resources hurts women's employment via both demand and supply channels. In his model, female labor supply is reduced via a household income effect, spurred by higher male incomes and/or increased government transfers. The demand for female labor decreases as export-oriented and female-dominated manufacturing is crowded out by Dutch disease effects. He tests his theory using cross country regressions of female labor force participation on oil wealth and finds that oil rich countries have fewer women working, a finding he claims is also valid for mineral mining. There is, however, little reason to expect these effects in Sub-Saharan Africa (SSA). First, the manufacturing sector in rural SSA is small (see Bigsten and Söderbom 2006 or Isham et al., 2005 for an overview).[3] Second, if women have the opportunity to shift to the service sector, the demand for female labor need not decrease. Women are overrepresented in sales and services in SSA, but underrepresented in production and manufacturing, as shown by data from ILO's Key Indicators of the Labour Market database (ILO 2011).

The effects of natural resource extraction on the local economy are often described in terms of linkages and multipliers (e.g., Eggert 2002; Aragon and Rud, 2013). Local multipliers describe the effect of an employment

[1] Most of the literature on the resource curse, including Ross (2008, 2012), has focused on the national level. The national level focus and cross country-based literature face severe endogeneity problems. Differences in resource abundance are endogenous to factors such as institutions, civil wars, and growth (Brunnschweiler and Bulte, 2008a, 2008b, 2009; Bruckner and Ciccone 2010; Maystadt et al. 2013). The efficiency of the economy in general, see Norman 2009 and the protection of property rights can influence the search for and exploitation of resources see Wright and Czelusta, 2003.

[2] DHS focuses predominantly on women but we add information on partners' employment as well as employment for a smaller sample of men.

[3] Fafchamps and Söderbom (2006) use data from nine Sub-Saharan African countries and find that the proportion of female workers is only 12 percent in manufacturing firms. The manufacturing sector in SSA has also been found to be largely non-tradable, perhaps due to a long history of import restrictions on manufactured goods (Torvik, 2001), which would reduce potential Dutch disease effects.

increase in one sector on employment in other sectors. Moretti 2010 shows that an increase in the production of tradable goods leads to increased local demand for non-tradables as the number of workers and their salaries increase. However, the multipliers for tradables depend on local changes in labor costs, since tradable goods have prices set nationally or internationally (Moretti 2010; Moretti and Thulin 2013).

The strand of literature on linkages and multipliers argue for positive local employment effects. If the multipliers are small, we will find economically and statistically insignificant effects. Such findings would support the traditional view of mineral mines as having few or no linkages to the local community. This "enclave" theory was first hypothesized by Hirschman (1958) and became a stylized fact in the second part of the last century (UNECA, 2011). There is limited empirical evidence for this theory. The coal mining boom of the 70's in the US resulted in modest local employment spillovers but increasing wage rates (Black et al., 2005), and contemporary oil and gas booms in the US has increased district employment levels (Allcott and Keniston, 2014). A study of local welfare effects around the world's second largest gold mine in Peru found support for the enclave hypothesis, in absence of policies for local procurement of goods (Aragon and Rud, 2013).

If the multiplier effects are stronger, we expect an increase in male and female labor force participation with female employment concentrated in services and sales and male employment concentrated in manual labor, reflecting the gender segregation in the Sub-Sahara African labor markets. Qualitative studies have found that women dominate the provision of goods and services around mines in Africa (Hinton 2006; ILO 1999), while they are not much engaged in the mining sector directly.[4] Spillover effects on the tradable sector are less likely to substantially affect the demand for female labor because women are not strongly represented in the tradable sector, including manufacturing and construction.

The effect on labor supply in agriculture is *a priori* ambiguous. A mine expansion can change local agriculture through a variety of channels: competition over land use, expropriation and changes in land prices (UNECA, 2011), pollution (Aragon and Rud, 2015), intra-household reallocation of labor including substitution effects, and demand changes for agricultural goods.

A novelty of the present paper is that it connects production data on 874 industrial mines starting in 1975 to DHS household survey data for women aged 15 – 49, spanning over two decades using spatial information. The unique combination of datasets with more than 500,000 sampled women and almost 300,000 partners in 29 countries enables us to investigate local spillover effects on employment by a difference-in-difference method. By exploiting the spatial and temporal variation in the data, we compare people living close to a mine with those living further away, and individuals living close to a producing mine with those who live in the vicinity of a mine that is yet to open. We include region fixed effects and thereby control for time-invariant differences between regions, such as time-stable mining strategies, institutions, trade patterns, openness, sectoral composition, level of economic development and gender norms. In addition, by including regional specific time trends we make the identification strategy less reliant on assumption of similar trends across areas.

We show that mine opening triggers a structural shift, whereby women shift from agricultural work to the service sector, or out of the labor force. The effect on services is substantial; it is estimated at a more than 50% increase from the sample mean. The results are robust to a wide battery of robustness checks, such

[4]One notable exception is artisanal and small scale-mining activities such as grinding, sieving etc.; i.e., activities confined to traditional mining activities. In both small- and large-scale mining, women rarely go underground into pits, for which there are often taboos and stigmas (ILO, 1999).

as using different measures of distance and excluding migrants. Our results of a shift toward service sector employment are supported by findings that women are more likely to earn cash and women who work are less likely to work seasonally after a mine has started producing. A back-of-the-envelope calculation estimates that more than 90,000 women get service sector jobs as a result of industrial mining in their communities, and more than 280,000 women leave the labor force. The effects of mine openings wear off with distance and are no longer statistically significant at 50 kilometers from a mine, and mine closing causes the service sector to contract. The partners of the surveyed women shift away from agriculture into skilled manual work with mine opening; this effect reverses once a mine closes. The overall decrease in work force participation induced by mine opening is gender-specific; work participation for women decreases by 5.4 percentage points with mine opening (equivalent to 8.1% change), whereas the corresponding effect for men is a decrease of 3.2 percentage points (equivalent to a 3.3% change). Using changes in world prices for ten minerals we further show that the effects are stronger in years when prices are higher.

There are large and persistent differences in value added per worker in agriculture and non-agriculture sectors in developing countries (Gollin et al., 2014). This difference indicates misallocation of workers, with too many workers in low yielding agriculture. In this paper, we show that mine opening can pull people from low value added sectors to higher value added sectors, such as services and skilled manual labor. We note a larger decrease in agricultural participation, than the observed increase in service sector employment for women. This indicates that both push and pull factors might be at hand. We conclude that mining has the power to stimulate non-agricultural sectors, and provide cash earning opportunities. However, mining creates a boom-bust economy on the local level in Africa, as the newly stimulated sectors contract with mine closing.

In the next section we present the data. In Section 3, we lay out the empirical strategy. In Section 4, we present the empirical results and in Section 5, we show robustness tests and heterogeneous effects, and in Section 6, we make concluding remarks.

2.2 Data

We use a novel longitudinal data set on large-scale mineral mines in Africa, from IntierraRMG. We link the resource data to survey data for women and their partners from the Demographic and Health Surveys (DHS), using spatial information. Point coordinates (GPS) for the surveyed DHS clusters, a cluster being one or several geographically close villages or a neighborhood in an urban area, allow us to match all individuals to one or several mineral mines.

From a mine center point, given by its GPS coordinates, we calculate distance spans within which we place every person. These are concentric circles with radii of 5, 10, 15, 20, 25 km and so on, up to 200 kilometers and beyond 200 km.

We construct an indicator variable that answers the questions: Is there at least one active mine within x kilometers from the household? If not, is there at least one future mine (coded as inactive), or one past mine (coded as suspended) within x kilometers? If still no, the person will be coded as living in a non-mining area. If she lives within a given distance from more than one mine, she will belong to the treated group if at least one mine was producing in the year she was sampled. We assume that individuals seek employment around any mine situated within x kilometers from the home location and that benefits from an active mine dominate those from an inactive mine. A future mine is assumed to have little effect on the local economy, even if there may be economic activity associated with the pre-production stages. Thus, a person close to an active mine as well as an inactive mine will be assigned active=1 and inactive=0, since the categories are mutually exclusive. When we look at mine opening effects, all women close to suspended mines are excluded from the analysis.

Beyond the cut-off distance of x kilometers, transportation costs are assumed to be higher than benefits accruing from employment opportunities. Behind this assumption lie two assumptions, i.e., the costs in terms of transportation and information increase with distance, and the footprint of a mine decreases with distance. The chosen baseline cut-off distance is 20 kilometers, but the assumptions motivate us to try different distance cut-off points.

A woman lives on average 246 kilometers away from a mine (variable *distance*) and 363 kilometers away from an active mine (*distance to active*) as given by Table 2.1. 8,195 women (1.6% of the sample) live within 20 kilometers of at least one active mine, 2,334 (0.5%) live within 20 kilometers of at least one inactive mine (but no active and no suspended mines), and 6,812 (1.3%) live close to a suspended mine.

2.2.1 Resource data

The Raw Materials Data (RMD) data comes from IntierraRMG (see IntierraRMD 2013). The dataset contains information on past and current industrial mines or future industrial mines with potential for industrial-scale development, geocoded with point coordinates and yearly information on production levels. The panel dataset consists of 874 industrial mines across Africa. For these mines, we have production levels in 1975 and then for each consecutive year from 1984 to 2010.

Of the 874 mines in Africa, 275 are matched to a geographical cluster in the DHS data. All clusters are matched to mines, but not all mines are matched to clusters. This is because some mines are located in remote and sparsely populated areas or are densely clustered, or because we have no DHS sample for the country (e.g., South Africa). Considering only the mines that are closest to at least one cluster, 51 mines had opened by 1984, 109 mines opened during the following 26 years, and 90 mines closed during the same period (see Appendix Table A.3).

This is, to our knowledge, the only existing mine production panel dataset. While the quality with respect to the exact levels of production is uncertain, the state of the mine (inactive, active, or suspended) is reliable. The metric used in reporting production volumes differs between companies producing the same mineral. Comparisons of production volumes are thus not possible.

The RMD data focuses on mines of industrial size and production methods, often with foreign or government ownership. Most mines are owned by Canadian, Australian or UK listed firms. Since the 1990s Africa has experienced a rise in large-scale, capital-intensive production, and today the continent is an important producer of gold, copper, diamond, bauxite, chromium, cobalt, manganese, and platinum (UNECA 2011). The industrial mine industry is heavy in capital and firms are often large and multinational. There are several production stages: exploration, feasibility, construction, operation and closure. In contrast to the later stages, the exploration phase is often undertaken by smaller firms who obtain a three year exploration license. Large mining firms enter mostly in the post-exploration phase. In the feasibility phase, the company determines if the deposit is viable for commercial exploration. If it is deemed so, the company will apply for a mining license. The average length of such a license is 23 years in Africa, and can be renewed upon termination. The licenses are obtained from the government and the application process takes on average 2 to 3 years (Gajigo et al., 2012). The mine life, i.e., the length of the production phase, depends on the ore deposits and the world price, among other things. In our data set, the average life length of a mine is ten years. After production, there is a reclamation process (Gajigo et al., 2012). Focusing on industrial scale production, the mines in the dataset constitute a subset of existing mines and deposits in the region, excluding small scale mines and informal or illegal mines. The external validity of the results from the main empirical strategy is therefore limited to large-scale mining.

Industrial mining may exist alongside or replace small-scale and artisanal mining (ASM). While the production levels of ASM-type activities are small, they are an important source of livelihood in Africa.[5] Twenty-one countries in Africa are estimated to employ more than 100,000 people each in ASM, with Ghana and Tanzania above one million people each. Together, these two countries are estimated to have 13.4 million people dependent on ASM ("dependent" implying indirect employment and families of miners) (UNECA, 2011). The current definition of small-scale mining operations includes a cap of 50 employees and operations that are labor rather than capital intensive. Artisanal mining is characterized by traditional and often hand-held tools and may be of an informal and/or illegal nature. Similarly to large-scale mining, there are taboos regarding women's participation in underground work, yet women as well as children often engage in other ASM operations. In order to get a more complete picture of the effects of mining, we complement the main analysis using datasets from the U.S. Geological Survey (USGS) and the Center for the Study on Civil War (CSCW) on diamond mines. The USGS data covers a wider variety of mines and deposits beyond those of industrial size, but has the drawback of not including time-varying production levels. Similarly, the CSCW data includes all diamond mines, but no production levels.

2.2.2 DHS data

We use micro data from the Demographic and Health Surveys (DHS). The DHS data are obtained from standardized surveys across years and countries. We combine the women's questionnaires from all 67 surveys in Sub-Saharan Africa that contain information on employment and GPS coordinates. The total dataset includes 525,180 women aged 15-49 from 29 countries. They were surveyed between 1990 and 2011 and live in 20,967 survey clusters in 297 sub-national regions.[6]

In Figure 2.1 we show the distribution of the mines and the DHS surveys used across Africa. The countries included are shown using lighter to darker red colors, where a darker color indicates more sampled clusters. The data cover large parts of Sub-Saharan Africa; Table A.1 in the Appendix shows the distribution of the sample by country. Table A.2 in the Appendix shows the distribution of the sample by years.

Definitions and summary statistics for our dependent and control variables are shown in Table 2.1, the occupational status (*working*) relates to whether the respondent had been working during the last 12 months: 66% of the women responded affirmatively. Women who are not working may be engaged in child care, household production, or backyard farming. The information on employment is disaggregated by sector of activity in Table 2.1. Note that a woman can only belong to one sector, which she states as her main

[5] 3.0–3.7 million people in Africa were estimated to be engaged in small-scale or artisanal mining at the end of the last century, according to the ILO (1999). A more recent report from the UN and African Union estimates that 8.1 million people are engaged in ASM.

[6] The cluster sizes range from 1 to 108 women. The mean number of women in a cluster is 25 and the median is 24. In most cases, the regions correspond to the primary administrative division for each country. Where coding into the primary divisions is not possible in the DHS data, due to natural regions being used instead (e.g., North-East, North-West, etc.), we use the existing natural regions. We largely follow Kudamatsu (2012) to make the coding consistent over the years. We complement the classification using Law (2012), which is available on www.statoids.com and which is the updated version of Law (1999). The regions are not of equal sizes; rather, they range from 30 to 22,966 sampled women. The average sample size of a region is 1,769 and the median is 1,201.

occupation. The main focus of this paper is three occupational categories, given their relative importance. These are agriculture (total 33%), sales (16.8%) and services (3.6%). However, all categories are reported in Table 2.1 and the results for all categories are also presented for the baseline regressions. The surveys include demographic variables, place of residence, education and religious affiliation. Regarding migration, women state in what year they moved to their current place of residence. However, no information is collected on previous place of residence or place of birth.[7] Table 2.2 shows labor market outcomes for the women's partners for all occupational categories. Partner's labor force participation is near universal at 96.6% and many (40.9%) are self-employed in agriculture. In addition, 11.3% are employed as agricultural workers and 13.7% are skilled manual workers.[8]

2.3 Empirical Strategy

With several waves of survey data combined with detailed information on mines, the estimation relies on a spatial-temporal estimation strategy, using multiple definitions of the mine footprint area based on different proximity measures and alternative definitions of the control group.

Assuming that people seek employment at any mine falling within a cut-off distance, our main identification strategy includes three groups with the baseline distance 20 km: (1) within 20 kilometers from at least one active mine, (2) within 20 kilometers from an inactive mine (defined as a mine that is not yet active), but not close to any active mines or suspended mines, and (3) more than 20 kilometers from any mine. The baseline regressions are of the form:

$$Y_{ivt} = \beta_1 \cdot active + \beta_2 \cdot inactive + \alpha_r + g_t + \delta_{r*time} + \lambda X_i + \varepsilon_{ivt}$$

where the outcome Y, mainly the occupation[9], of an individual i, cluster v, and for year t is regressed on a dummy *(active)* for whether the person lives within 20 kilometers of at least one active mine, a dummy *(inactive)* for whether the person lives close to a mine that has not started producing at the time of the survey, region and year fixed effects, region-specific linear time trends, and a vector X of individual level control variables. In all regressions, we control for living in an urban area, age, years of education, and indicators for religious beliefs.

Interpreting the coefficient only for *active* (20 km) builds on the premise that the production state (*active* or *inactive*) of the mine is not correlated with the population characteristics before production starts, i.e., that a mine does not open in a given location because of the availability or structure of the labor force in that geographical location. This is a potentially strong assumption because wage labor and population density may influence mining companies' investment decisions or could jointly vary with a third factor such as accessibility or infrastructure. Including the dummy variable for inactive mines allows us to compare areas before a mine has opened with areas after a mine has opened, and not only between areas close to and far away from mines. For all regressions, we therefore provide test results for the difference between *active* (20 km) and *inactive* (20

[7] Not all survey rounds include information on migration. In the sample, the year of the last move is available for 428,735 women.

[8] Examples of skilled manual jobs are bakers, electricians, well drillers, plumbers, blacksmiths, shoe makers, tailors, tanners, precious metal workers, brick layers, printers, and painters.

[9] Occupations are as a set of dummy variables indicating main occupation in the last year. More information about the occupational outcomes variables are provided in Table 2.1.

km). By doing this we get a difference-in-difference measure that controls for unobservable time-invariant characteristics that may influence selection into being a mining area.

Exploiting within-country variation leads to more robust causal claims (e.g., Angrist and Kugler 2008 ; Buhaug and Rød 2006; De Luca et al., 2012; Dube and Vargas 2013 on conflicts, Wilson 2012 on sexual risk taking behavior in Zambia's copper belt; and Aragon and Rud 2013 on the local economy in Peru). With region fixed effects, we expect that only time-variant differences within regions are a threat to this identification strategy. That is, we control for time-invariant regional mining strategies, institutions, level of economic development, sectoral composition, and norms regarding female work force participation. Nonetheless, the exact location of a mine within a country or region may still be influenced by factors other than abundance of resources. The placement of mineral deposits is random (Eggert, 2002), but the discovery of such deposits is not. In particular, the literature suggests that discovery depends on three other factors (Krugman 1991 and Isard et al., 1998): (i) access to and relative price of inputs, (ii) transportation costs, and (iii) agglomeration costs. If selection into being a mining area, even within a country or region, is based on factors other than mineral endowments that are stable over time, we can control for such factors. We control for region fixed effects and region specific time trends and thereby allow for different time trends across sub-national regions.

The interpretation of the coefficients from our estimation strategy relies on the population being the same before and after mine opening. We are using a repeated cross-sectional dataset, and we discuss in the robustness section how we deal with this issue by using the available information on migration. Additionally, we worry that the control group in the baseline definition is inherently too different from the population living in mining areas. Several measures are taken to ensure that the results are not driven by such dissimilarities, including using region fixed effects and geographically limiting the area from which the control group is drawn. Furthermore, the estimation strategy could capture other changes that happen parallel to and irrespective of the mine opening. Mine industrialization and employment changes could be driven by improvements in infrastructure. We use the best available data on road networks in Africa and explore whether the results are stable. Different fixed effects, for the closest mines and for different types of minerals, are also included to verify the robustness of the results. We cluster the standard errors at the DHS cluster level, but we also present results where the standard errors are clustered at the regional level, at the level of the closest mine, and for multi-way clustering at both the DHS cluster and the closest mine.

2.4 Results

We start by exploring the evolution of employment over time. Figure 2.2 shows the trends in service level employment for those within 20 kilometers and those between 20 and 200 kilometers from a mine. The treatment group follows a similar trend as the control group in service sector employment until mine opening, but at a lower level. Service employment increases sharply once the mine opens[10]. The levels equalize somewhat at the tenth year, which, in part could be due to a geographic dispersion of the effects with time (the control group is limited to within 200 km). Such a dispersion effect would explain the increase in service employment in the control group. The decline in the treatment group close to the tenth year may be a result of mine closings since mine length in our sample is, on average 10 years. This hypothesis is supported by the right-side figure showing that service employment is higher close to mines that are going to close, but have

[10] An increase in service sector employment is noted shortly before mine opening, which corresponds to the investment phase of the mine.

not yet done so. This difference in service level employment decreases as the date of closing appears and reverses once the mine closes. Similar trends are obtained if we have the residuals after controlled regressions instead of levels (figures are available upon request). Appendix figures A.2 and A.3 show these trends for our four main outcomes of interest.

The main results following the empirical strategy previously outlined are reported in Table 2.3, with Panel A showing women's outcomes and Panel B the outcomes for these women's partners. The first variable, *active (20 km)*, captures the difference in outcomes between individuals living close to a producing mine and those living farther away. In Panel A, we see that the coefficient is positive and statistically significantly correlated with the woman working, working in the service sector, and working with unskilled manual work (significant only at the 10 percent level). The second variable, *inactive (20 km),* shows the difference between women living close to future mines and women living further away. We see that women in mining areas before the mine starts producing are more likely to work, especially as self-employed agricultural workers.

Due to the possibility of non-random mine placement, we use a difference-in-difference strategy, whereby the effect of a mine opening can be read out as the difference between the coefficients for *active (20 km)* and *inactive (20 km)*. Test results are presented for this difference $(\beta_1 - \beta_2 = 0)$ henceforth. This difference shows that there is a decline of 5.4 percentage points in the probability that a woman is working when a mine opens in the area (which is calculated by the difference between *active* and *inactive*: 2.6 - 8.0 = 5.4). Investigating the sectoral composition of the effect, it emerges that the decline in overall employment is driven by a decline in agricultural self-employment, an effect which is partly offset by an increase in service sector employment. The increase in the likelihood of working in the service sector is substantial at 2 percentage points. The sample mean of engaging in service sector jobs is 3.6 %, so the increase in the likelihood is over 50 %. Trying to quantify the effect of mine opening on female service sector employment, we make a back-of-the-envelope calculation and estimate that 94,402 women have benefited from service sector jobs generated by the industrial mining sector, while 283,206 women left the labor market.[11]

With respect to selection, it is also interesting to interpret the coefficient for *inactive* as the correlation between living in a mining area and our outcomes before the mines have any industrial-scale production. The statistically significant results for *inactive* show that there may be selection into being a mining area, which is not fully accounted for by including region fixed effects. We posit three possible reasons why the likelihood of women working is higher around inactive mines: (1) these are geographical areas with an agricultural focus, where women are more likely engaged in economic activities outside of the household; (2) the coefficient captures pre-opening effects (e.g., jobs generated in the prospecting and investment phase); and (3) the artisanal and small scale mining activities that may employ women directly, in addition to indirectly generating employment. The first hypothesis is supported by the baseline results, where a large share of the population engages in subsistence farming. We explore the second hypothesis by looking at trends in employment (Figure 2.2 and Figure A.2). According to the visual evidence, there is an increase in service sector employment and a decrease in agricultural employment during the pre-production phase, but the effects are small in magnitude and confined to the last years before mine opening. Regarding the third hypothesis, we explore direct employment in mining, and see that mining employment for women does not change with

[11] According to the World Bank Indicators for 2011, the Sub-Saharan African female population aged 15-65 is estimated to 236,241,202 people. In our sample, approximately 1.6% percent live within 20 kilometers of an active mine. Our baseline estimates indicate that 2% of the women close to mines benefit from service sector employment, amounting to 73,727 women, and that 202,749 women left the labor market. Using a 25 kilometer distance span from an active mine, we estimate that 94,402 women gained employment in the service sector, and 283,206 women left the labor market.

mine opening (see Table 2.5)[12].

For partners, there is a decreased probability of working, driven by a drop in agricultural employment. A substantial and positive effect of mine opening on men's employment in skilled manufacturing is identified.

We choose a baseline distance of 20 kilometers from the mine. Although this distance cut-off does not maximize the effect size, we find it reasonable for four reasons: (1) the geocoordinates in the DHS data are randomly displaced up to 5 kilometers, and for 1% of the sample up to 10 kilometers whereby small distance spans introduce more noise; (2) the geocoordinates in the mining data reflect the centroid of the mining area. With too small an area, we are likely to capture the actual mining site rather than the surrounding communities; (3) the sample size increases rapidly with distance, which increases the robustness of the results; and (4) using distances longer than 20 kilometers, we fail to capture the mine footprint. In Section 2.A.1 in the Appendix we discuss this extensively and we show different results based on other cutoffs and specifications.

We next examine the effects of a mine closing on employment. The results are shown in Table 2.4. The effects are not entirely symmetrical to the effects of mine openings. Initially, mine openings induced an increase in the likelihood of service sector employment for women, an effect that is offset by the time of mine suspension. Agricultural self-employment increases, but the effect is not statistically significant, and the magnitude is much smaller than the decline induced by mine openings. These results indicate that the localized structural shifts spurred by mine openings are not reversible for women; i.e., women are inhibited from going back to agricultural production after a mine closing. In contrast, male partners increase agricultural self-employment after mine closings, but experience a contraction in skilled manual and agricultural employment. There is a small increase in clerical jobs and a small decrease in professional work, but the magnitudes are negligible.

We further explore whether jobs are created in mining per se. A subset of the surveys includes information on whether a woman or her partner work in mining. The categorization unfortunately differs between DHS survey rounds, and hence these variables can only be taken as indicators of engagement in mine activities.[13] We run regressions on whether a woman or her partner is engaged in mining using three different mine datasets (RMG, USGS or the CSCW diamond dataset). Table 2.5 shows that industrial scale mining has no effect on employment in mining for women, as there is no statistically significant difference between active and inactive in Column 1. Neither do we find any statistically significant correlation for USGS mines, that may include small-scale mining sites. The USGS mine measure does not contain information on the type, timing, or significance of the mining activities. Anecdotal evidence suggests that it is common for women to engage in some type of artisanal and small-scale mining (ASM) activities, which this mine measure partly captures. Using the diamond dataset from CSCW, no correlation is found for women. In contrast, being within 20 kilometers of a mine is significantly and positively associated with the woman's partner being engaged in mining for all three mine estimates, and there is an effect of mine industrialization in the RMG data. Mine openings increase the likelihood of the husband being a miner by 4.1 percentage points, which is a large increase relative to the sample mean of 2.6%.

Despite women seldom taking part in the large-scale mining, their labor market outcomes are substantially affected by industrial mining. The sectoral composition of the labor market effects for women is different from that of their partners. We continue by further assessing the robustness of the findings for women because we

[12] Direct employment in mining can also capture small scale and artisanal mining employment.

[13] Possible categories include: mine blasters and stone cutters; laborers in mining; miners and drillers; miners and shot firers; laborers in mining and construction; gold panners; extraction and building workers; mining and quarrying workers; and laborers in mining, construction and manufacturing.

do not have all the necessary variables for the partners. In Section 5.2, however, we will conduct some extra analysis for a smaller sample of men for whom we have information on cash earnings and seasonality of work. We furthermore choose to restrict the focus to our four main outcome variables due to their relative importance. Results for all other variables are available upon request.

2.4.1 Other measures of occupation

To further assess the effects on employment changes, we investigate the effects of mining on remuneration and seasonality of work. We have data on how women are paid for work outside the household and whether they work all year, seasonally, or occasionally. The sample is smaller because the question is not asked in all DHS survey rounds. Being close to an inactive mine is associated with a higher probability of earning in-kind only and negatively correlated with earning cash (Panel A of Table 2.6), and women are less likely to work seasonally after mine opening, and more likely to work occasionally (Panel B). This is a finding in line with previous results, signaling that mining areas have a higher share of agricultural workers prior to production. The probability of earning cash increases by 7.4 percentage points (0.014 - (-0.060)) with mine opening and this effect is statistically significant. We also see a statistically significant reduced probability of being paid in-kind only or being paid both cash and in-kind. The effects indicate that the labor market opportunities for women change with mining. Mine opening induces a shift from more traditional sources of livelihoods, such as subsistence farming which is seasonal by nature and oftentimes paid in kind, to more cash-based, all year or occasional sectors such as services.

In more recent years, DHS has surveyed men based on the same questionnaire used for women's labor market outcomes. The male sample is, however, much smaller. This sample of 128,135 men (Table 2.6) indicate that men have higher cash earning opportunities (Panel C) and are less likely to work seasonally after mine openings (Panel D), in line with the results for women. The surveys of men produce very similar results to the partner regressions for the main occupational outcomes (results are available upon request).

2.4.2 Migration

Inward migration can be spurred by natural resource and mining booms and there is evidence of the creation of mining cities (Lange 2006 in Tanzania), urban-rural migration (around small-scale mines; Hilson 2009) as well as work-migration (Corno and de Walque 2012). Such migration patterns can cause a selection issue where women and their partners have moved to mining areas for work. While urbanization and inward migration are possible channels through which the multipliers work, we are also interested in knowing if the original population benefited from the expansion. The data is repeated cross-sectional data. By restricting the sample to women who have never moved, we try to show that our effects are not driven by women who have migrated inward. The results can be seen in Table 2.7 and resemble the baseline results both in terms of direction of effects and statistical significance.

We conduct several other robustness tests of our baseline results and these are extensively discussed in Appendix Section 2.A.2. Most importantly, the results are qualitatively unchanged if we restrict the sample to only having control groups closer to the mines or if we control for distance to roads and add fixed effects for mineral and closest mine. The results are also robust to different clusterings and we examine the intensity of mining finding that living closer to several mines magnifies the effects.

2.5 Heterogeneous impacts

2.5.1 Heterogeneous Effects by World Mineral Prices

Labor market effects are likely to be stronger in years with high mineral prices, due to higher production and higher wages. We therefore interact our variables of interest, active and inactive, with yearly world prices. The world price data comes from RMG and is available for ten of the most important minerals (gold, silver, platinum, aluminum, copper, lead, nickel, tin, zinc and palladium) for the years 1992 to 2011.[14] Prices are normalized with 1992 as baseline price, set to zero. The variables active and inactive are interacted with the yearly normalized prices, and test statistics for the difference between these interaction terms are presented. This allows comparisons of the difference in the price effects for those having an active mine nearby and those having an inactive mine nearby.

Table 2.8, Panel A presents the results for women's employment. The baseline coefficients for active (20 km) and inactive (20 km) are now interpreted as the relation between closeness to a mine and employment when the normalized prices are zero, i.e. when the prices are at their 1992 level. We see that while the difference between active and inactive points in the same direction as in the baseline regressions, the effects are generally not as large. The price interaction terms indicate that higher prices lead to stronger labor market effects. In particular, higher prices lead to larger negative effects of mine openings on working, driven by less self-employment in agriculture but partly offset by a larger increase in service work. Higher prices also intensify the effects for men (Table 2.8, Panel B). High prices lead to a larger decrease in self-employment in agriculture, and increase in service sector, sales, and manual employment.[15]

World prices are arguably exogenous to local labor conditions and this robustness exercise thereby strengthens our confidence in our main empirical strategy. Effects are, as expected, stronger in times of high prices. The results are indicative that women are more likely to leave the labor market in times of higher prices, possibly due to a household income effect spurred by higher male incomes, although we can only speculate so. However, in such times women are more likely to benefit from a service sector expansion.

2.5.2 Other heterogeneous effects

Which women benefit from the mine expansion?

Mining can create non-agricultural job opportunities, allowing women to earn more cash and work outside the traditional and dominating agricultural sector. The uptake of jobs for women will likely depend on income (making her household richer) and substitution effects. The income effect is linked to the supply side argument in Ross (2008, 2012,), where women's employment is modeled to decrease as their husbands earn more money. If this channel is correctly hypothesized, the effects will differ depending on a woman's marital status. Interacting the treatment variables with marital status (1 if being married or having a partner, 0 otherwise) we find little difference in the effects between the two groups (Table 2.9).

[14] This restricts the sample to 266,020 women and 138,483 husbands. The sample is nonetheless generalizable to the wider sample as indicated by similar descriptive statistics and baseline results (results are available upon request).

[15] For men we note some statistically significant correlations between prices and living close to an inactive mine. This may be due to increased investments in mining in those periods or increased intensity of small scale mining.

Panel B of Table 2.10 in the Appendix further show the effects of mine openings for the sample of 4,628 women whose husbands we know are miners. We note a negative effect on employment for these women, a large increase in sales employment, and a decline in agriculture and, although only statistically significant at the 12 percent level, a substantial decrease in service employment.

We must be careful in interpreting the results as supporting or rejecting the income effects story because marital status is a choice, implying that married women are different from non-married women, and because marital status may be endogenous to mine activities. Mining communities are characterized by a high ratio of men to women and a transient labor force (see work by Campbell 1997 on gold mines in South Africa, and Moodie and Ndatshe 1994 for a historic analysis), aspects that can change the marriage market and relationship formation. However, we do not find any evidence that mining changes relationship formation (see Table A.11 in the Appendix).

By restricting the sample to women who married for the first time before the mine closest to them opened, we explore heterogeneous effects with less concern that marital status may be endogenous to mine activity. We find that they are also more likely to be working in services (Table 2.10 Panel A).

The youngest population, i.e., young women aged 15-20, may face different choices when growing up in mining areas. We therefore analyze them separately (see Table 2.10 Panel C). We find that these women are less likely to work and less likely to work in agriculture. We also test if it the case that the effect of mines differs between societies with high and low participation of women in the service sector. To this end we use data from the ILO on share of women in the service sector (ILO 2011) and interact an indicator variable for being in a country with a high share of women working in services (above the median in the ILO data is defined as a high share). The results are shown in Table A.12 in the Appendix. We confirm that women are more likely to work in service sector jobs in these countries, but the interaction effect of being in a high female service country and in an active mining area does not increase the effect further. If anything, there seems to be less of an effect in countries with high participation of women in the service sector.

Employment opportunities matter for women. For welfare, it also matters what types of jobs are offered. We try to rule out the possibility that the increase in female employment in the service sector is driven by engagement in the sex industry. Using lifetime number of sexual partners, which should increase with sex trade activity, we find no indication of sex trade among women in active mining areas (Table 2.11). In fact, there is a clear negative effect of mine openings on the number of sexual partners. Considering groups that may be at more risk, such as young women (aged under 25), women working in the service sector, and women without a partner, there is also a decrease in the number of sexual partners. Finally, we find no statistically significant difference in the likelihood of the woman never having sexual intercourse, and no change in the use of a condom in the last intercourse.

Artisanal and small-scale mining

To investigate the relationship between employment and a broader set of mines, we use the USGS and CSCW datasets. The results show that living within 20 kilometers from an USGS mine is associated with roughly a one percentage point increase in the probability of working in sales or services and a 2.6 percentage point decrease in the probability of working in agriculture (see Panel A of Table A.13 in the Appendix). For diamond mines, we find that the probability of working in agriculture is 5.3 percentage points lower, the probability of working in sales is 2.8 percentage points higher, and the probability of working in services is

0.6 percentage points higher if the woman lives within 20 km of a diamond mine (Panel B of Table A.13 in the Appendix). The results using these other datasets are in line with the findings using the main dataset.

2.6 Conclusion

The discovery of natural resources across the African continent brings hope for millions of poor people, but there are also fears that the resources will be a curse rather than a blessing (Collier 2010). In particular, one fear spelled out in The Africa Mining Vision is that gender inequality in economic opportunities may increase with mining. Using detailed data on industrial mining in Sub-Saharan Africa, we explore whether mining generates local employment opportunities for women and men. Based on GPS coordinates, we merge individual level data with mining data, which enables a highly localized analysis of spillover effects. We then employ a difference-in-difference estimation strategy to compare areas that are close to mines with areas farther away, before and after the production has started.

The results show a localized structural shift where a mine opening offers new employment opportunities for women. There is a decrease in agricultural employment and an increase in service sector employment, and an overall drop in labor force participation. The changing local economy brings secondary effects for women with more cash employment and non-seasonal work. For men, we see a structural shift focused on increasing work in skilled manual jobs and decreasing self-employment in farming.

The effects of mine closing are not symmetrical for women; mine suspension leads to reduced service sector employment, yet women do not shift back to agricultural production to the same extent as they left it when the mines opened. Instead, the employment rate remains low, indicating that the localized structural shifts are not reversible. For men, the effects of opening and closing are almost symmetrical. This indicates that mining works as a boom-bust economy on the local level in Africa, but with permanent effects of women's labor market participation.

The results are robust to a wide battery of checks, such as using different distance cut-offs and different classifications of the control group, including different types of fixed effects and exclusion of migrants. The results are quantitatively important. We calculate that more than 90,000 women may have gained a service sector job as a result of mine openings, but, in parallel, more than 280,000 women left the labor market. Female employment is likely to foster female agency and is also argued to be important for child health, schooling, and child survival (see Duflo 2012 for an overview). Future studies should investigate the impacts of mining on these aspects as well. Using world market prices for ten different minerals we also find that the effects are strongest in periods when prices are higher.

We have not assessed the quality of the new work opportunities and whether women are facing decent and productive employment as a result of mining. Value added per worker differs between sectors in developing countries. The gap between agriculture and non-agriculture sectors has been found to be large (on average four times higher) and persistent according to national accounts. The difference remains after considering human capital and work hours differentials using micro-data (Gollin et al., 2014). The productivity difference is indicative of a misallocation of workers, with too many workers in agriculture. In this paper, we have shown that mine opening can pull people from low value added sectors to higher value added sectors, such as services and skilled manual labor. We also see that the probability of earning cash incomes increases for both men and women.

Our results are broadly consistent with the U-shaped development of female labor force participation with development as outlined by Goldin (1995). She shows that participation is initially reduced as women move from the farm but eventually increases as women enter the more advanced segments of the labor market. Whether women are winners in the scramble for Africa's resources can only be concluded via a full welfare analysis. Such a welfare analysis must explore if women are voluntarily leaving the agricultural labor force in higher numbers than those accessing new employment in services. Moreover, future analysis must seek to asses how women are affected by potential environmental pollution and effects on household bargaining power.[16]

[16]To do a complete community welfare analysis, an even longer list of outcomes must be assessed. These include e.g., environmental effects such as deforestation, land degradation, pollution of air and water sources, as well as social issues such as displacement, inequality and tension between miners and non-miners, intra household economic inequality, the spread of HIV/AIDS, and boom and bust economies (UNECA 2011).

Tables and Figures

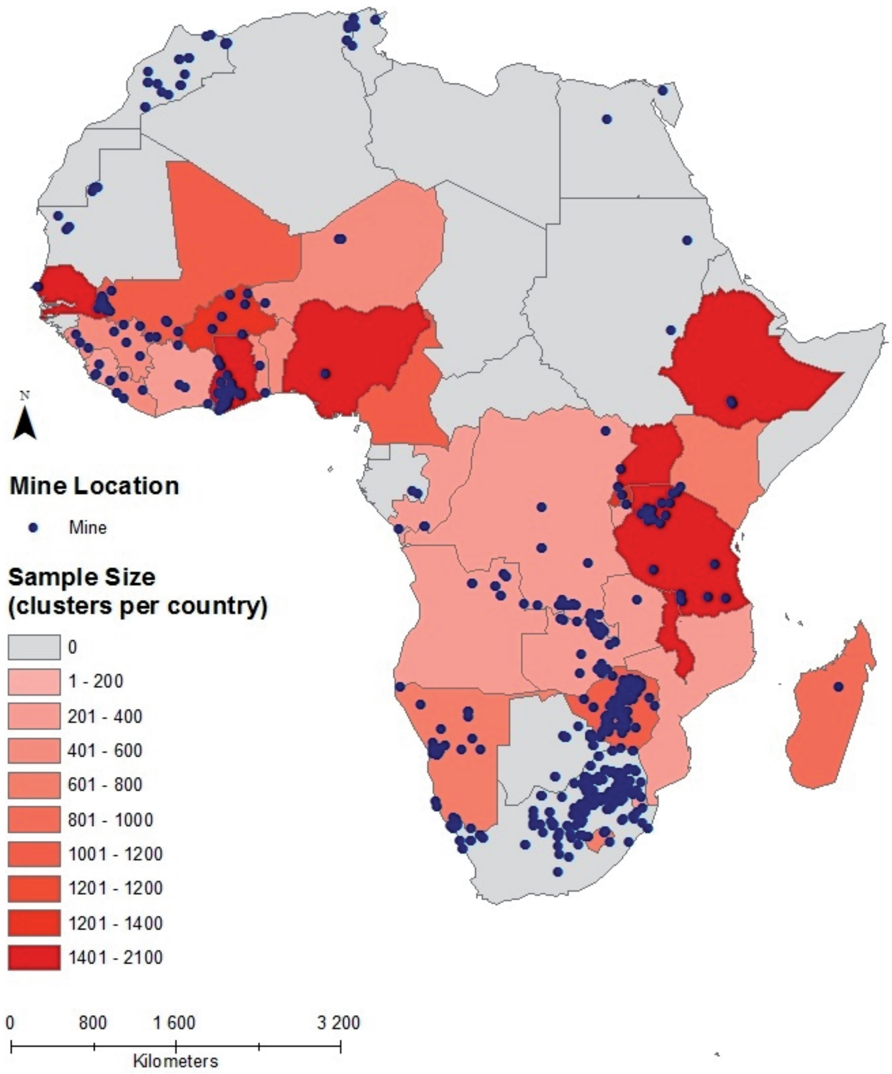


Figure 2.1: Mines and DHS Clusters by Country

Notes: Source: The map shows African large-scale mining sites in Africa 1975-2010. Countries with geo-coordinated DHS data are colored red, indicating the number of surveyed clusters per country.

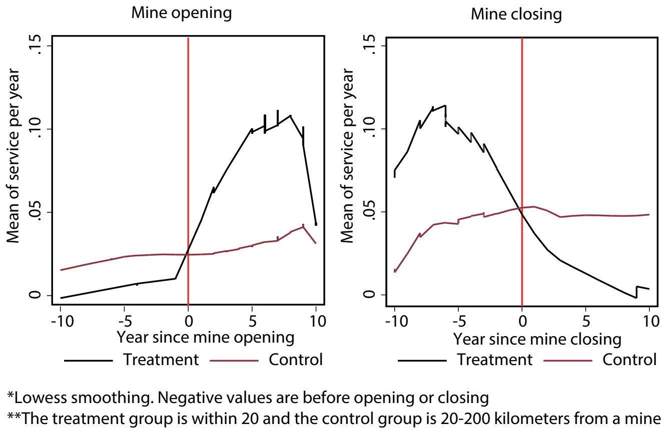


Figure 2.2: Trends in Service Sector Employment

Table 2.1: Descriptive Statistics for Women

Variable	Definition	Mean	St. dev.
Mine variables			
distance	Distance to closest active or inactive mine (km).	246.4	211.0
distance to active	Distance to closest active mine (km).	363.6	247.2
active (20 km)	At least one active mine < 20 km.	0.016	0.125
inactive (20 km)	At least 1 inactive mine < 20 km, no active/suspended.	0.005	0.067
suspended (20 km)	At least one suspended mine < 20 km, no active.	0.013	0.113
Main dependent variables			
Working	1 if respondent is currently working.	0.659	0.474
Services	1 if respondent is working in the service sector.	0.036	0.187
Profess.	1 if respondent is a professional.	0.027	0.161
Sales	1 if respondent is working with sales.	0.168	0.374
Agric. (self)	1 if respondent is self-employed in agriculture.	0.276	0.447
Agric. (emp)	1 if respondent is employed in agriculture.	0.054	0.023
Domestic	1 if respondent is employed as a domestic worker.	0.010	0.101
Clerical	1 if respondent is employed as a clerk.	0.010	0.097
Skilled manual	1 if respondent is employed in skilled manual labor.	0.046	0.209
Unskilled manual	1 if respondent is employed in unskilled manual labor.	0.030	0.172
Other dependent variables			
Cash	1 if respondent is paid in cash.	0.462	0.499
Cash & Kind	1 if respondent is paid both in cash and in kind.	0.167	0.373
Kind	1 if respondent is paid in kind.	0.083	0.275
Not paid	1 if respondent is not paid.	0.289	0.453
Seasonally	1 if respondent is working seasonally.	0.320	0.467
All year	1 if respondent is working all year.	0.569	0.495
Occasionally	1 if respondent is working occasionally.	0.111	0.314
Control variables			
urban	1 if respondent is living in an urban area.	0.327	0.469
age	Age in years.	28.400	9.560
schoolyears	Years of education.	4.200	4.344
christian	1 if respondent is Christian.	0.591	0.492
muslim	1 if respondent is Muslim.	0.338	0.473
Migration			
non mover	1 if respondent always lived in the same place.	0.457	0.498
Marital status			
partner	1 if respondent has a partner.	0.671	0.470
N		512,922	

Table 2.2: Descriptive Statistics for Partners

Variable	Definition	Mean	St. dev.
Working	1 if partner is currently working.	0.966	0.474
Services	1 if partner is working in the service sector.	0.054	0.187
Profess.	1 if partner is a professional.	0.073	0.161
Sales	1 if partner is working in sales.	0.110	0.374
Agric. (self)	1 if partner is self-employed in agriculture.	0.409	0.447
Agric. (emp)	1 if partner is employed in agriculture.	0.113	0.226
Domestic	1 if partner is employed as a domestic worker.	0.008	0.100
Clerical	1 if partner is employed as a clerk.	0.020	0.097
Skilled manual	1 if partner is employed in skilled manual labor.	0.137	0.209
Unskilled manual	1 if partner is employed in unskilled manual labor.	0.044	0.172
N (partner)		277,722	

Table 2.3: Mine Opening and Occupation for Women (Panel A) and Men (Panel B)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Working	Service	Profess.	Sales	Agriculture self-employment	Agriculture employment	Domestic	Clerical	Skilled manual	Unskilled manual
Panel A : Woman										
active (20 km)	0.026***	0.020***	0.000	0.000	-0.010	0.001	0.002	0.003	0.005	0.005*
	(0.010)	(0.005)	(0.003)	(0.008)	(0.012)	(0.007)	(0.002)	(0.002)	(0.004)	(0.002)
inactive (20 km)	0.080***	-0.000	0.005	-0.014	0.060**	0.005	-0.003	0.009**	-0.005	0.023
	(0.020)	(0.005)	(0.005)	(0.015)	(0.024)	(0.008)	(0.002)	(0.004)	(0.011)	(0.016)
observations	512,922	512,922	512,922	512,922	512,922	512,922	512,922	512,922	512,922	512,922
sample mean	0.659	0.036	0.027	0.168	0.276	0.054	0.010	0.010	0.046	0.030
active-inactive=0	6.164	7.147	1.065	0.745	7.087	0.138	2.821	1.837	0.728	1.338
p value (F-test)	0.013	0.008	0.302	0.388	0.008	0.710	0.093	0.175	0.394	0.247
Panel B : Husband or partner										
active (20 km)	0.003	0.013**	0.008	0.005	-0.039**	-0.021	-0.002	-0.005*	0.034***	0.011*
	(0.005)	(0.006)	(0.006)	(0.008)	(0.016)	(0.013)	(0.002)	(0.003)	(0.012)	(0.006)
inactive (20 km)	0.034***	0.002	0.020*	0.008	-0.013	0.015	-0.001	-0.003	-0.002	0.007
	(0.010)	(0.014)	(0.011)	(0.011)	(0.030)	(0.018)	(0.005)	(0.008)	(0.010)	(0.012)
observations	277,722	277,722	277,722	277,722	277,722	277,722	277,722	277,722	277,722	277,722
sample mean	0.966	0.054	0.073	0.110	0.409	0.113	0.008	0.020	0.137	0.044
active-inactive=0	8.075	0.502	0.990	0.054	0.587	2.521	0.121	0.104	5.229	0.081
p value (F-test)	0.004	0.479	0.320	0.816	0.444	0.112	0.728	0.747	0.022	0.775

Occupational variables are indicator variables taking a value of 0 or 1. A person can only respond 1 to any of the categories. Occupations are not conditional on stating any occupation. Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, urban dummy, age, years of education, and religious beliefs. The coefficients of interest are active (20 km) and the difference between active (20 km) and inactive (20 km) capturing the shift that happens with mine opening. The p-values presented show if this difference is significantly different from zero. *** p<0.01, ** p<0.05, * p<0.1

Table 2.4: Mine suspension and Occupation for Women (Panel A) and Men (Panel B).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Working	Service	Profess.	Sales	Agriculture self-employment	Agriculture employment	Domestic	Clerical	Skilled manual	Unskilled manual
Panel A : Woman										
active (20 km)	0.026***	0.020***	0.000	0.000	-0.010	0.001	0.002	0.003	0.005	0.005*
	(0.010)	(0.005)	(0.003)	(0.008)	(0.012)	(0.007)	(0.002)	(0.002)	(0.004)	(0.002)
inactive (20 km)	0.080***	-0.000	0.005	-0.014	0.060**	0.005	-0.003	0.009**	-0.005	0.023
	(0.020)	(0.005)	(0.005)	(0.015)	(0.024)	(0.008)	(0.002)	(0.004)	(0.011)	(0.016)
observations	512,922	512,922	512,922	512,922	512,922	512,922	512,922	512,922	512,922	512,922
sample mean	0.659	0.036	0.027	0.168	0.276	0.054	0.010	0.010	0.046	0.030
active-inactive=0	6.164	7.147	1.065	0.745	7.087	0.138	2.821	1.837	0.728	1.338
p value (F-test)	0.013	0.008	0.302	0.388	0.008	0.710	0.093	0.175	0.394	0.247
Panel B : Husband or partner										
active (20 km)	0.003	0.013**	0.008	0.005	-0.039**	-0.021	-0.002	-0.005*	0.034***	0.011*
	(0.005)	(0.006)	(0.006)	(0.008)	(0.016)	(0.013)	(0.002)	(0.003)	(0.012)	(0.006)
inactive (20 km)	0.034***	0.002	0.020*	0.008	-0.013	0.015	-0.001	-0.003	-0.002	0.007
	(0.010)	(0.014)	(0.011)	(0.011)	(0.030)	(0.018)	(0.005)	(0.008)	(0.010)	(0.012)
observations	277,722	277,722	277,722	277,722	277,722	277,722	277,722	277,722	277,722	277,722
sample mean	0.966	0.054	0.073	0.110	0.409	0.113	0.008	0.020	0.137	0.044
active-inactive=0	8.075	0.502	0.990	0.054	0.587	2.521	0.121	0.104	5.229	0.081
p value (F-test)	0.004	0.479	0.320	0.816	0.444	0.112	0.728	0.747	0.022	0.775

Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, urban dummy, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest. *** p<0.01, ** p<0.05, * p<0.1

Table 2.5: Direct Employment in Mining

	(1)	(2)	(3)	(4)	(5)	(6)
	RMG mine data		*USGS mine data*		*Diamond mine data*	
VARIABLES	Woman is miner	Husband is miner	Woman is miner	Husband is miner	Woman is miner	Husband is miner
active (20 km)	0.004*	0.046***				
	(0.003)	(0.011)				
inactive (20 km)	0.011	0.005				
	(0.009)	(0.021)				
usgs mine (20 km)			0.001	0.008***		
			(0.001)	(0.003)		
diamond mine (20 km)					-0.000	0.037***
					(0.002)	(0.012)
Observations	259,114	149,692	264,695	152,228	264,695	152,228
R-squared	0.026	0.071	0.026	0.069	0.026	0.070
F test: active-inactive=0	0.406	2.913				
p value	0.524	0.0879				

Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest. *** p<0.01, ** p<0.05, * p<0.1

Table 2.6: Payment and Seasonality

	(1)	(2)	(3)	(4)
Panel A : Remuneration of work for women				
VARIABLES	Cash	Cash & Kind	Kind	Not Paid
active (20 km)	0.014	-0.029***	0.015*	-0.001
	(0.015)	(0.011)	(0.008)	(0.012)
inactive (20 km)	-0.060**	0.017	0.056***	-0.013
	(0.030)	(0.019)	(0.018)	(0.030)
Observations	255,889	255,889	255,889	255,889
F test: active-inactive=0	4.864	4.469	4.485	0.155
p value	0.0274	0.0345	0.0342	0.694
Panel B : Seasonality of work for women				
VARIABLES	Seasonal	All year	Occasional	
active (20 km)	-0.075***	0.059***	0.016**	
	(0.015)	(0.013)	(0.008)	
inactive (20 km)	-0.005	0.029	-0.024*	
	(0.029)	(0.025)	(0.015)	
Observations	303,291	303,291	303,291	
F test: active-inactive=0	4.713	1.138	6.084	
p value	0.0300	0.286	0.0137	
Panel C : Remuneration of work for men				
VARIABLES	Cash	Cash & Kind	Kind	Not Paid
active (20 km)	0.073***	-0.013	-0.013	-0.047***
	(0.016)	(0.013)	(0.009)	(0.013)
inactive (20 km)	-0.009	-0.021	0.032	-0.002
	(0.037)	(0.030)	(0.034)	(0.035)
Observations	128,135	128,135	128,135	128,135
F test: active-inactive=0	4.056	0.0715	1.693	1.399
p value	0.0440	0.789	0.193	0.237
Panel D : Seasonality of work for men				
VARIABLES	Seasonal	All year	Occasional	
active (20 km)	-0.013	0.019	-0.006	
	(0.016)	(0.017)	(0.009)	
inactive (20 km)	0.004	0.051	-0.055***	
	(0.048)	(0.051)	(0.011)	
Observations	108,764	108,764	108,764	
F test: active-inactive=0	0.102	0.374	11.81	
p value	0.750	0.541	0.001	

Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest.*** p<0.01, ** p<0.05, * p<0.1

Table 2.7: Effects on Never-Movers

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
active (20 km)	0.018	0.026***	0.019	-0.029*
	(0.014)	(0.008)	(0.012)	(0.017)
inactive (20 km)	0.116***	0.007	-0.000	0.071***
	(0.026)	(0.007)	(0.018)	(0.026)
Observations	194,103	194,103	194,103	194,103
R-squared	0.218	0.091	0.143	0.341
F test: suspended-active=0	11.22	3.164	0.797	10.44
p value	0.000811	0.0753	0.372	0.00124

Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest.*** p<0.01, ** p<0.05, * p<0.1

Table 2.8: Heterogeneous Effects by World Mineral Prices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Working	Service	Profess.	Sales	Agric self-emp.	Agric emp.	Domestic	Clerical	Skilled manual	Unskilled manual
Panel A : Woman										
active (20 km)	0.073***	0.017**	0.000	0.011	0.042***	-0.015	0.005	0.003	0.010	0.000
	(0.015)	(0.009)	(0.004)	(0.012)	(0.016)	(0.014)	(0.004)	(0.003)	(0.006)	(0.004)
inactive (20 km)	0.082***	0.001	0.003	-0.016	0.061**	0.003	-0.003	0.007	-0.008	0.035
	(0.022)	(0.005)	(0.005)	(0.019)	(0.029)	(0.010)	(0.002)	(0.005)	(0.013)	(0.022)
active * price	-0.051***	0.011	-0.004	0.000	-0.070***	0.017*	-0.004**	-0.003	0.000	0.002
	(0.015)	(0.008)	(0.004)	(0.009)	(0.016)	(0.009)	(0.002)	(0.002)	(0.004)	(0.003)
inactive * price	0.021	-0.017	0.002	0.013	0.023	0.005	-0.006***	0.014	0.014	-0.028
	(0.040)	(0.014)	(0.014)	(0.022)	(0.023)	(0.006)	(0.002)	(0.010)	(0.009)	(0.020)
price	-0.017	-0.004	0.005*	-0.012*	0.023*	-0.021***	-0.002*	-0.002	0.001	-0.002
	(0.012)	(0.004)	(0.003)	(0.006)	(0.013)	(0.005)	(0.001)	(0.002)	(0.002)	(0.002)
p values										
active-inactive	0.722	0.097	0.680	0.205	0.548	0.300	0.051	0.532	0.199	0.111
active*price-inactive*price	0.091	0.084	0.695	0.583	0.001	0.262	0.335	0.117	0.163	0.137
Panel B : Husband or partner										
active (20 km)	0.021**	0.010	0.011	0.012	0.001	-0.039	-0.002	-0.008*	0.044**	-0.008
	(0.009)	(0.010)	(0.008)	(0.013)	(0.025)	(0.027)	(0.003)	(0.004)	(0.018)	(0.009)
inactive (20 km)	0.005	0.009	0.014	0.003	-0.046	0.015	-0.000	-0.002	-0.005	0.015
	(0.005)	(0.016)	(0.012)	(0.012)	(0.032)	(0.022)	(0.006)	(0.009)	(0.011)	(0.014)
active*price	-0.015*	-0.002	-0.016**	-0.001	-0.072***	0.031	-0.001	0.003	0.019	0.023***
	(0.008)	(0.012)	(0.007)	(0.008)	(0.019)	(0.019)	(0.002)	(0.004)	(0.016)	(0.008)
inactive*price	0.036***	-0.037**	0.010	-0.031*	0.103***	0.000	-0.008*	-0.007	0.019	-0.014
	(0.007)	(0.017)	(0.021)	(0.016)	(0.023)	(0.021)	(0.005)	(0.008)	(0.029)	(0.016)
price	-0.001	-0.026***	-0.003	0.034***	-0.051***	0.048***	0.004***	-0.007**	-0.005	0.003
	(0.005)	(0.005)	(0.005)	(0.006)	(0.011)	(0.006)	(0.002)	(0.003)	(0.007)	(0.004)
p values										
active-inactive	0.130	0.963	0.818	0.619	0.244	0.123	0.840	0.538	0.020	0.138
active*price-inactive*price	0.000	0.096	0.236	0.096	0.000	0.286	0.155	0.238	0.986	0.031

Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, urban dummy, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest. P-value active-inactive refers to a F-test of the difference active-inactive, p value active*price-inactive*price refers to a F-test of the difference of the interaction effects. *** p<0.01, ** p<0.05, * p<0.1. Panel A has 266,020 observations, and Panel B 138,483 observations.

Table 2.9: Heterogeneous Effects by Marital Status

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
active (20 km)	0.021*	0.015**	-0.012	0.001
	(0.013)	(0.007)	(0.008)	(0.012)
inactive (20 km)	0.067**	-0.007	0.012	0.045*
	(0.028)	(0.009)	(0.016)	(0.026)
partner	0.070***	-0.004***	0.015***	0.066***
	(0.002)	(0.001)	(0.001)	(0.002)
active*partner	0.019	0.010	-0.038*	0.029
	(0.029)	(0.009)	(0.021)	(0.034)
inactive*partner	0.007	0.009	0.020*	-0.015
	(0.013)	(0.008)	(0.010)	(0.012)
Observations	507,088	507,088	507,088	507,088
R-squared	0.200	0.091	0.136	0.356
F test: active-inactive=0	2.237	3.760	1.877	2.283
p value	0.135	0.0525	0.171	0.131
F test: act*partner-inact*partner=0	0.140	0.008	5.955	1.548
p value	0.708	0.929	0.0147	0.214

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest.*** p<0.01, ** p<0.05, * p<0.1

Table 2.10: Heterogeneous Effects for Women Married Before Mine Opening, Married to Miners, Young Women (15-20)

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
Panel A. Married before mine opening				
active (20 km)	0.003	0.029***	-0.008	-0.023
	(0.015)	(0.009)	(0.013)	(0.018)
inactive (20 km)	0.033	-0.035***	0.022	0.101
	(0.110)	(0.012)	(0.039)	(0.094)
Observations	291,395	291,395	291,395	291,395
R-squared	0.201	0.094	0.165	0.347
F test: active-inactive=0	0.0742	20.25	0.554	1.719
p value	0.785	0.000	0.457	0.190
Panel B. Married to a miner				
active (20 km)	-0.075**	-0.029	0.027	-0.069***
	(0.035)	(0.020)	(0.028)	(0.024)
inactive (20 km)	0.185**	0.080	-0.164***	0.073
	(0.086)	(0.067)	(0.050)	(0.080)
Observations	4,628	4,628	4,628	4,628
R-squared	0.172	0.133	0.191	0.319
F test: active-inactive=0	7.951	2.425	11.74	2.943
p value	0.005	0.120	0.001	0.086
Panel C. Young women (15-20)				
active (20 km)	0.004	0.007	-0.014*	-0.008
	(0.014)	(0.007)	(0.009)	(0.013)
inactive (20 km)	0.056**	-0.006	-0.012	0.057**
	(0.027)	(0.005)	(0.017)	(0.028)
Observations	138,606	138,606	138,606	138,606
R-squared	0.194	0.070	0.109	0.290
F test: active-inactive=0	3.069	2.085	0.0149	4.463
p value	0.079	0.149	0.903	0.035

Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** p<0.01, ** p<0.05, * p<0.1

Table 2.11: Lifetime Number of Sexual Partners and Condom Use

	(1)	(2)	(3)	(4)	(5)	(6)
	Lifetime number of sexual partners				Never sex	Used condom
Sample	All	Under 25	In services	No partner	All	All
VARIABLES						
active (20 km)	-0.106*	-0.107**	-0.726***	-0.223	0.011**	-0.006
	(0.055)	(0.051)	(0.151)	(0.142)	(0.005)	(0.005)
inactive (20 km)	0.771***	0.708***	0.492**	0.691***	0.001	-0.014*
	(0.172)	(0.175)	(0.224)	(0.156)	(0.009)	(0.008)
Observations	210,456	64,672	12,049	49,128	512,922	350,797
R-squared	0.093	0.087	0.076	0.079	0.252	0.142
F test: active-inactive=0	23.61	20.02	20.15	19.17	1.145	0.749
p value	0.000	0.000	0.000	0.000	0.285	0.387

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest.*** p<0.01, ** p<0.05, * p<0.1

2.A Appendix

The Appendix presents results that are not central to the understanding of the paper, but that can be used for extra information. It also shows a wide battery of robustness checks. The Appendix presents extra summary statistics in Section A.1 and further robustness checks, treatment heterogeneity, and effects on other outcome variables in Sections A.2-A.5. Finally, we present analyses based on other mining data sets in Section A.6.

2.A.1 Heterogeneous effects by distance

The empirical strategy relies on a decreasing footprint with distance from a mine. As seen in Table A.5, there are large and highly statistically significant effects of mine openings up to 25 kilometers away, and there is a shift from agriculture to service sector jobs or to leaving the work force. The largest effects are found using a cut-off of 5 kilometers and the most statistically significant effects are for distances up until 15 kilometers. The probability of having a service sector job within 10 kilometers of an active mine is 2.8 percentage points higher and this gives a total effect (coefficient for *active* – coefficient for *inactive*) of 4.0 percentage points. Similarly, the probability of working in agriculture within 10 kilometers of an active mine is 4.9 percentage points less (*active*) and the effect of mine opening at this distance is a reduction of 16.2 (*active* – *inactive*) percentage points. At 50 kilometers away from the mine center point, we no longer find significant difference in outcomes comparing active and inactive mining communities. Women living within 50 kilometers of a mine are more likely to work, to work in agriculture, and less likely to work in sales, but there is no extra effect of the mine opening. Table A.4 shows the sample sizes broken down by treatment status (*active*, *inactive* and *suspended*) for the different distances.

As shown in Table A.6, we get consistent results using continuous measures to the closest active mine. *Distance to closest active mine* captures the distance in kilometers (scaled by a hundred) from the DHS cluster to the closest active mine (Panel A), limited to 200 kilometers (Panel B), or taken in logs (Panel C). The results from these regressions show that being further away from an active mine is correlated with less employment, less service sector employment, and less agricultural work for women. We also do a horse race with the logged distance to the closest mine regardless of activity (*distance to closest mine*) and do the same with the logged distance to the closest active mine. In accordance with previous results, we find that the shorter the distance to an active mine, the larger the share of the female population engaged in services. We see the opposite results for agriculture - the distance to an active mine is positive, but the distance to any mine is negative.

Table A.6 Panel E, we show results from a spatial lag model indicating that the strongest effects for services are found within 10 km of an active mine. The probability of working in services is 3.2 percentage points higher for women living within 10 kilometers of an active mine, whereas the likelihood of an agricultural job is 3.8 percentage points lower. The results are illustrated in Figure A.1, showing that agricultural employment is much lower close to an active mine, and increases with distance from an active mine, while the service sector employment decreases with distance from mine. The strongest effects are found very close, within 10km and 20km.

2.A.2 Additional robustness tests

In this section we perform a series of robustness tests for the main results. We start by limiting the range of the control group as people living in areas far away may be too different for a meaningful comparison. Reducing the sample to include a control group within 200 km, the sample is reduced to half the initial size. Nonetheless, we see in Table A.7 that all effects point in the same direction and are still statistically significant.

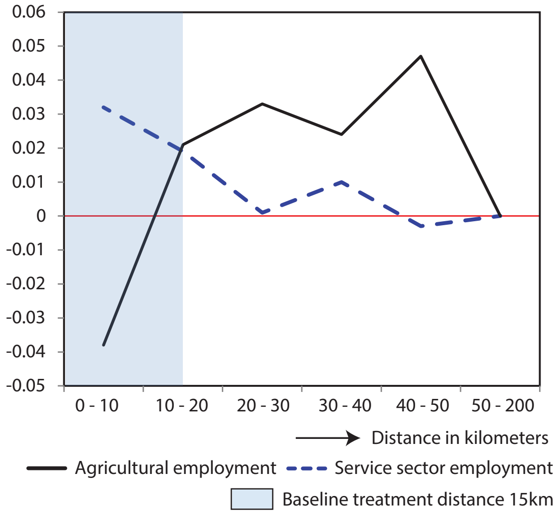
Another concern is that we capture unobserved time-variant heterogeneity across clusters rather than the effects of mines. Access to infrastructure is one possible factor at work, and we include proximity to roads as an extra control variable to see whether the results remain robust. Unfortunately, the road data is not time variant and is only available for a subset of countries. The results are presented in Table A.8, using data from the African Development Bank for Benin, Central African Republic, Cameroon, DRC, Mali, Niger, Senegal, and Togo. We see that the effects of mine openings are similar, but that the sample size is significantly reduced when we restrict the sample to these countries and control for being within 50 kilometers of a road. This analysis cannot ensure that road construction is not driving the results, but it shows that there is no difference in the effects of mines in areas with roads as compared to the effect in areas without large roads. We think it unlikely that time-varying road infrastructure explains the main findings in this paper.

Intuitively, living near several active mines should affect labor market opportunities more than living close to only one mine. To investigate whether agglomeration of mines creates stronger effects, we include a measure of mining intensity. The intensity score, which equals the number of active mines within 100 kilometers, is significantly associated with our main occupational outcomes. As shown in Table A.9, an extra mine within 100 km is correlated with an increased likelihood of women working and working in services and agriculture, but decreases the likelihood of women working in sales. The magnitudes of the effects increase if we consider treatment intensity. For example, having two extra mines within 100 kilometers would increase the probability of working in services by 3.3 percentage points (1.5+0.6*3+0), and this increase is statistically significant at the one percent level.

All our regressions include region fixed effects, regional time trends, and year fixed effects in addition to our individual level control variables. We also cluster the standard errors at the DHS cluster level. In Table A.10, we show that our main findings are robust to the inclusion of fixed effects for the closest mine and mineral fixed effects. In Panel B, we also show that the results hold for clustering at the regional level and at the closest mine level, as well as multi-way clustering on both the closest mine and the DHS cluster.

2.A.3 Appendix Tables and Figures

Figure A.1: Spatial Autoregressive Model: Agricultural and Service Sector Employment



* Figure A.1 shows the result from Table A.6 Panel E. The x-axis measures distance from an active mine and the y-axis the coefficients for the 10km distance bins. The control group if further away than 50km but within 200km.

Table A.1: Distribution of the Sample by Country

Country	Number of women	Country	Number of women
Benin	11,633	Mali	36,453
Burkina Faso	22,489	Mozambique	4,912
Burundi	9,329	Namibia	15,783
Cameroon	29,785	Niger	14,024
Central African Republic	5,877	Nigeria	49,125
Congo DR	9,717	Rwanda	24,756
Cote d'Ivoire	11,103	Senegal	29,677
Ethiopia	29,216	Sierra Leone	7,186
Ghana	14,918	Swaziland	4,879
Guinea	14,389	Tanzania	10,792
Kenya	16,493	Togo	8,500
Lesotho	3,311	Uganda	34,899
Liberia	3,981	Zambia	7,107
Madagascar	24,047	Zimbabwe	23,493
Malawi	47,306	Total	525,180

Table A.2: Distribution of the Sample by Year.

Survey year	Number of women surveyed	Survey year	Number of women surveyed
1990	8,738	2001	18,847
1991	3,867	2003	40,615
1992	6,472	2004	22,249
1993	8,171	2005	55,878
1994	13,956	2006	35,799
1995	9,685	2007	20,805
1996	5,446	2008	70,136
1997	7,023	2009	8,223
1998	25,502	2010	81,749
1999	16,424	2011	23,902
2000	41,693	Total	525,180

Table A.3: Closest Mines Opening and Closing 1975-2010.

Year	Mines opening	Mines closing
Between 1975 and 1984	51	6
1984	9	1
1985	1	2
1986	1	0
1988	7	1
1989	1	3
1990	5	0
1991	3	2
1992	4	2
1993	3	1
1994	2	1
1995	3	1
1996	3	2
1997	9	4
1998	6	4
1999	4	8
2000	4	5
2001	5	7
2002	6	2
2003	4	4
2004	2	7
2005	6	2
2006	7	2
2007	4	9
2008	4	9
2009	3	5
2010	3	0
Total	160	90

Table A.4: Sample Size by Treatment Variables.

At least one	...active mine	...inactive mine	...suspended mine
within 5 km	905	519	1 029
within 10 km	2 651	739	3 895
within 15 km	5 573	1 131	5 338
within 20 km	8 195	2 334	6 812
within 25 km	11 647	3 202	9 859
within 30 km	15 697	3 970	12 431
within 50 km	30 209	7 719	26 233

Table A.5: Cut-off Distances

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture	Obs.
active (5 km)	0.038	0.023	-0.017	-0.008	
	(0.025)	(0.016)	(0.017)	(0.033)	
inactive (5 km)	0.214***	-0.022	0.034	0.133***	
	(0.043)	(0.014)	(0.032)	(0.023)	
p value: active-inactive=0	0.000	0.030	0.157	0.001	518,705
active (10 km)	0.020	0.028***	0.010	-0.049***	
	(0.017)	(0.011)	(0.013)	(0.019)	
inactive (10 km)	0.154***	-0.012	0.015	0.113***	
	(0.033)	(0.011)	(0.025)	(0.021)	
p value: active-inactive=0	0.000	0.007	0.845	0.000	515,839
active (15 km)	0.018	0.024***	-0.000	-0.024*	
	(0.012)	(0.007)	(0.009)	(0.015)	
inactive (15 km)	0.136***	-0.001	-0.002	0.111***	
	(0.024)	(0.009)	(0.019)	(0.023)	
p value: active-inactive=0	8.92e-06	0.0304	0.937	8.13e-07	514,396
active (25 km)	0.023***	0.018***	0.003	0.001	
	(0.009)	(0.005)	(0.007)	(0.011)	
inactive (25 km)	0.064***	0.000	-0.014	0.045*	
	(0.017)	(0.004)	(0.014)	(0.023)	
p value: active-inactive=0	0.035	0.007	0.285	0.082	509,875
active (50 km)	0.039***	0.004	-0.013**	0.043***	
	(0.008)	(0.003)	(0.006)	(0.010)	
inactive (50 km)	0.024*	0.000	-0.012	0.025	
	(0.012)	(0.002)	(0.012)	(0.018)	
p value: active-inactive=0	0.293	0.304	0.969	0.382	493,501

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest.*** p<0.01, ** p<0.05, * p<0.1

Table A.6: Continuous Distance and Spatial Autoregressive Model

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
Panel A : Continuous distance				
Distance to closest active mine	-0.016***	-0.001	-0.000	-0.011***
	(0.003)	(0.001)	(0.002)	(0.003)
Panel B : Sample limit to 200km				
Distance to closest active mine	-0.030***	-0.009***	0.005	-0.030***
	(0.007)	(0.002)	(0.005)	(0.010)
Panel C : Log distance				
ln Distance to closest active mine	-0.023***	-0.007***	0.002	-0.015***
	(0.004)	(0.002)	(0.003)	(0.005)
Panel D : Horse race log distance				
ln Distance to closest active mine	-0.000	-0.005***	-0.001	0.011*
	(0.005)	(0.002)	(0.004)	(0.006)
ln Distance to closest mine	-0.028***	-0.002*	0.005*	-0.031***
	(0.004)	(0.001)	(0.003)	(0.004)
Panel E: Spatial lag model				
Distance to closest active mine				
0-10km	0.027	0.032***	0.003	-0.038*
	(0.018)	(0.011)	(0.013)	(0.020)
10-20km	0.028**	0.019***	-0.015	0.021
	(0.012)	(0.006)	(0.010)	(0.016)
20-30km	0.022**	0.001	-0.008	0.033**
	(0.011)	(0.005)	(0.008)	(0.013)
30-40km	0.004	0.010**	-0.026***	0.024*
	(0.011)	(0.005)	(0.008)	(0.014)
40-50km	0.022**	-0.003	-0.019**	0.047***
	(0.011)	(0.004)	(0.008)	(0.014)
Observations	495,832	495,832	495,832	495,832

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** p<0.01, ** p<0.05, * p<0.1

Table A.7: Sample Restriction 200km

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
active (20 km)	0.025**	0.020***	-0.002	-0.008
	(0.010)	(0.005)	(0.008)	(0.013)
inactive (20 km)	0.067***	0.002	-0.015	0.051**
	(0.020)	(0.005)	(0.015)	(0.025)
Observations	264,905	264,905	264,905	264,905
R-squared	0.220	0.095	0.157	0.395
F test: active-inactive=0	3.635	5.902	0.631	4.496
p value	0.0566	0.0151	0.427	0.0340

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Please see Table 3 for more information about coefficients of interest. *** p<0.01, ** p<0.05, * p<0.1

Table A.8: Road Network

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
active (20 km)	0.104***	0.031**	0.001	0.018
	(0.039)	(0.016)	(0.026)	(0.033)
inactive (20 km)	0.196***	0.001	-0.008	0.139***
	(0.046)	(0.019)	(0.022)	(0.022)
road within 50 km	-0.004	-0.001	-0.018***	0.025***
	(0.007)	(0.001)	(0.004)	(0.009)
Observations	151,355	151,355	151,355	151,355
R-squared	0.169	0.049	0.146	0.318
F test: active-inactive=0	2.330	1.417	0.0692	9.245
p value	0.127	0.234	0.793	0.00237

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** p<0.01, ** p<0.05, * p<0.1

Table A.9: Mining Intensity

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
active (20 km)	0.018*	0.015***	0.007	-0.019
	(0.010)	(0.005)	(0.008)	(0.013)
inactive (20 km)	0.080***	-0.000	-0.014	0.065***
	(0.020)	(0.006)	(0.015)	(0.024)
intensity	0.009**	0.006***	-0.007***	0.012***
	(0.004)	(0.001)	(0.002)	(0.004)
Observations	518,368	518,368	518,368	518,368
R-squared	0.198	0.092	0.142	0.354
F test: active+2*intensity-inactive=0	3.800	11.83	0.143	4.714
p value	0.0513	0.000583	0.706	0.0299

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. Intensity is a count variable for the number of active mines that are near. *** p<0.01, ** p<0.05, * p<0.1

Table A.10: Fixed effects and Clusterings of the Standard Errors

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture	(5) Working	(6) Service	(7) Sales	(8) Agriculture
Panel A. Mineral and mine fixed effects.								
active (20 km)	0.029***	0.019***	-0.002	-0.001	0.035***	0.012**	-0.004	0.011
	(0.010)	(0.005)	(0.008)	(0.013)	(0.010)	(0.005)	(0.009)	(0.014)
inactive (20 km)	0.081***	0.001	-0.017	0.069***	0.073***	-0.000	-0.022	0.067**
	(0.020)	(0.005)	(0.016)	(0.025)	(0.020)	(0.005)	(0.015)	(0.027)
Observations	478,288	478,288	478,288	478,288	518,368	518,368	518,368	518,368
Mineral FE	YES	YES	YES	YES	NO	NO	NO	NO
Mine FE	NO	NO	NO	NO	YES	YES	YES	YES
F test: active-inactive=0	5.627	6.399	0.829	6.609	3.038	2.769	1.112	3.509
p value	0.0177	0.0114	0.362	0.0102	0.0814	0.0961	0.292	0.0611
Panel B. Clustering of standard errors at the regional, the closest mine, and closest mine, as well as DHS cluster level.								
active (20 km)	0.026	0.020**	0.001	-0.009				
	(0.016)	(0.010)	(0.012)	(0.020)				
	(0.015)	(0.008)	(0.012)	(0.018)				
	[0.015]	[0.008]	[0.012]	[0.018]				
inactive (20 km)	0.081**	0.000	-0.014	0.065**				
	(0.033)	(0.007)	(0.025)	(0.022)				
	(0.034)	(0.006)	(0.026)	(0.032)				
	[0.034]	[0.006]	[0.026]	[0.032]				
Observations	518,368	518,368	518,368	518,368				
p value region	0.0923	0.0618	0.481	0.0128				
p value (mine level)	0.0973	0.0359	0.518	0.0205				
p value [mine and DHS cluster]	0.0962	0.0350	0.518	0.0198				

Notes: Panel A: robust standard errors clustered at the DHS cluster level in parentheses. Panel B: robust standard errors clustered at region, the mine in parentheses and at the mine and cluster level in brackets. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.11: Marriage Market Outcomes

VARIABLES	(1) Divorced/separated	(2) Partner	(3) Single	(4) Widow
active (20 km)	0.002	-0.002	-0.006	0.006**
	(0.003)	(0.007)	(0.006)	(0.002)
inactive (20 km)	-0.004	0.004	0.000	-0.001
	(0.004)	(0.013)	(0.012)	(0.004)
Observations	512,534	512,534	512,534	512,534
R-squared	0.032	0.219	0.359	0.058
F test: active-inactive=0	1.236	0.149	0.242	2.073
p value	0.266	0.699	0.623	0.150

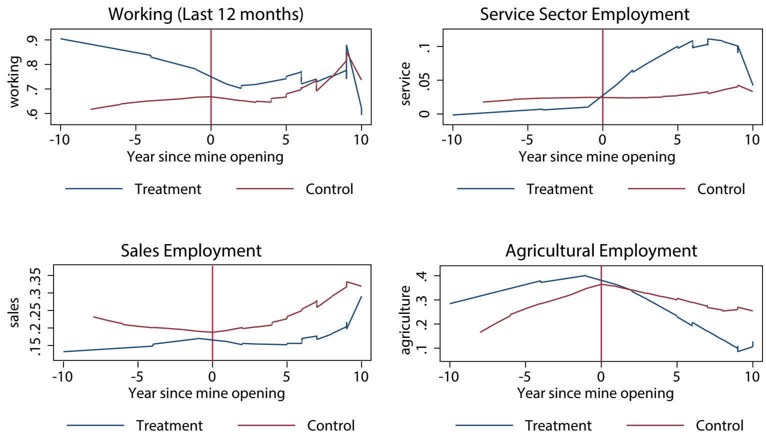
Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** p<0.01, ** p<0.05, * p<0.1

Table A.12: Heterogeneous Country Effects by Service Sector Participation

VARIABLES	(1) Working	(2) Service	(3) Sales	(4) Agriculture
active (20 km)	0.023*	0.017**	0.006	-0.010
	(0.014)	(0.007)	(0.010)	(0.016)
inactive (20 km)	0.022**	0.000	-0.003	0.023**
	(0.009)	(0.003)	(0.007)	(0.011)
highservice*active (20 km)	-0.005	-0.022**	0.010	0.012
	(0.019)	(0.009)	(0.017)	(0.025)
highserv	-0.300*	0.161***	0.141	-0.174
	(0.165)	(0.055)	(0.099)	(0.154)
Observations	372,635	372,635	372,635	372,635
R-squared	0.208	0.081	0.139	0.357
F test: active-inactive=0	0.000812	4.376	0.543	2.566
p value	0.977	0.0365	0.461	0.109

Notes: Robust standard errors clustered at the DHS cluster level in parentheses. All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** p<0.01, ** p<0.05, * p<0.1

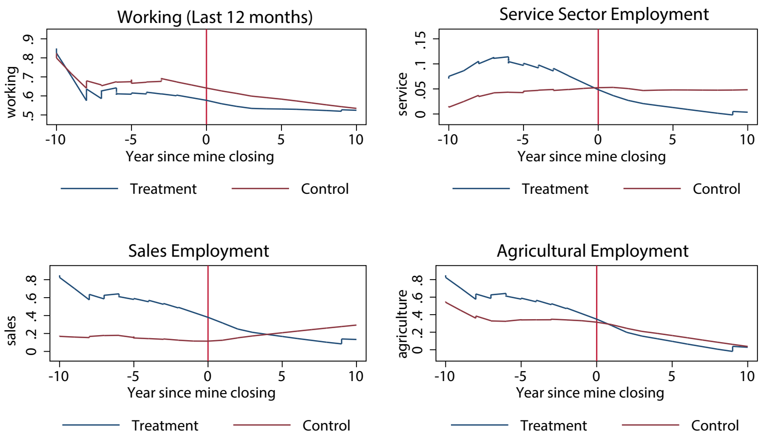
2.A.4 Trends outcomes



*Negative values are before opening

Raw correlations - Control between 50-200 km

Figure A.2: Non-Parametric Investigation of Trends in Outcomes at Opening



*Lowess smoothing. Negative values are before closing

Raw correlations - Control between 20-200 km

Figure A.3: Non-Parametric Investigation of Trends in Outcomes at Closing

2.A.5 Correlations using U.S. Geological Survey (USGS) and CSCW diamond data

Since our empirical strategy requires data on production over time, we are not able to include all mines in the region. Hence, our results may not be generalizable to the effects of other, in particular smaller, mines. While we cannot completely overcome this problem, we show below that the cross-sectional results using all mines in the region obtained from USGS point in the same direction as our difference-in-difference results with the RMG data. The cross-sectional results are shown in Panel A of Table A.13. We find that being close to a USGS mine is positively associated with being in services and sales and negatively associated with agriculture. These results are in line with anecdotal evidence pointing to female engagement in services and sales and that mining activities may compete with agriculture in terms of land use. There is significant diamond mining in Africa, and while the RMD includes some diamond mines, it does not capture all diamond mines. The RMG data set excludes all mines that produce only diamonds. To correct for this and explore the effects of diamond mining on local women's employment opportunities, we use the CSCW data set. This diamond data set has GPS coordinates for the mines, but does not contain production data. The identification strategy here is thus the same as the one for the USGS data sets. The results are presented in Panel B of Table A.13. We find that being close to a mine is associated with a higher probability of engaging in sales and a lower probability of working in agriculture.

Table A.13: Correlations using USGS Mining and CSCW Mining Dataset

	(1)	(2)	(3)	(4)
VARIABLES	Working	Service	Sales	Agriculture
Panel A. USGS data.				
usgs (20 km)	-0.003	0.009***	0.008***	-0.026***
	(0.004)	(0.002)	(0.003)	(0.005)
Observations	525,180	525,180	525,180	525,180
R-squared	0.197	0.091	0.141	0.355
Panel B. CSCV diamond data.				
dia (20 km)	0.001	0.006*	0.028***	-0.053***
	(0.009)	(0.004)	(0.010)	(0.013)
Observations	525,180	525,180	525,180	525,180
R-squared	0.197	0.091	0.141	0.355

Notes: Robust standard errors clustered at the DHS cluster level in parentheses.All regressions control for year and region fixed effects, regional time trends, living in an urban area, age, years of education, and religious beliefs. *** p<0.01, ** p<0.05, * p<0.1

Chapter 3

Local Industrial Shocks, Female Empowerment, and Infant Health: Evidence from Africas Gold Mining Industry

Abstract

Can industrial development empower women in developing countries? This is the first paper to explore the causal effects of a continent-wide exogenous expansion of industry on female empowerment and infant health. The paper uses the recent rapid increase in gold mining in Africa as a quasi-experiment. The identification strategy relies on temporal (before and after mine opening) and spatial (distance to mine) variation, as well as exogenous variation in the price of gold in a difference-in-difference analysis. Using a large sample of women and children living within 100 km of any gold mine, the analysis shows that the establishment of a new mine increases income earning opportunities within the service sector by 41%, makes a woman 23% less likely to state a barrier to healthcare access for herself, and decreases women's acceptance rate of domestic violence by 24%. Also, despite risks of environmental pollution from gold mining, mine opening reduces infant mortality by more than half. In particular, girl infants face better chances of survival. I exclude the possibility that effects are driven by increased schooling attainment made possible by investment in schooling infrastructure, or that service jobs are limited to prostitution. Yet I cannot rule out that urbanization is part of the mechanism. The findings are robust to different assumptions about trends, distance, and migration, and withstand a novel spatial randomization test. The results support the idea that entrenched norms regarding gender can change rapidly in the presence of economic development.

Although gold and silver are not by nature money,
money is by nature gold and silver.
Karl Marx

3.1 Introduction

Gender inequality and discrimination are, in part, caused by poverty and binding constraints where women's and girls' needs are not prioritized (Duflo, 2012; Miguel, 2005). When economic factors are the determinants of inequality, economic growth could work as a remedy. This could happen in two ways: first, by making everyone better off as poverty is reduced, and second, by narrowing the gender inequality gap as the necessary trade-offs between men's and women's welfare become less acute. Alleviating the physical constraints automatically makes women better off, but it is unclear whether it changes the norms that led to their initial disadvantage. Poor countries are more likely to have norms that favor men (Jayachandran, 2014) and weaker women's rights (Doepke et al., 2012), but little is known about the causality running from economic development to a more gender-equal society.

The main contribution of this paper is to provide causal estimates of a continent-wide establishment of a modern industry on female empowerment. Using the rapid and exogenous expansion in gold mining in Africa as a quasi-experiment, I employ two different identification strategies: a difference-in-difference method and a method using the world price of gold as a proxy for mining activities. Female empowerment is broadly defined, but for the purpose of this study I measure it using the following outcomes: (a) economic empowerment: access to employment and cash earnings, (b) physical empowerment: intrahousehold bargaining power, access to health care and normative attitudes toward domestic violence, and (c) infant survival rates.

The large-scale mining boom in Sub-Saharan Africa provides a unique opportunity to explore the effects of local industrialization on female empowerment. In particular, its main establishment decisions do not depend on local population characteristics but on geological characteristics uncorrelated with preexisting local economies. Most of the knowledge we have on the link between industrialization and female empowerment comes from analyses of the manufacturing industry (e.g., Heath and Mobarak, 2014). However, such estimates are less reliable if the establishment decisions depend on local labor market characteristics. In labor-intensive manufacturing industries, one factor of production may be of particular relevance: women's labor supply.

The establishment of a new mine is not conditioned by local labor force characteristics. First and foremost, the necessary condition for mining is a mineral deposit, which is a random geological anomaly (Eggert, 2002). In addition, in open pit gold mining, the capital to labor ratio is high, and the industry is dominated by a few large multinational firms (Gajigo et al., 2012) that are not integrated in the local economy prior to mine opening. This means that the mining sector provides a quasi-experimental setting that allows exploring of the general equilibrium effects of local industrial shocks on female empowerment.

In addition to the literature on manufacturing, there is a well-identified literature on female empowerment that is based on randomized control trials (RCT). Interventions range from cash transfers to information provision, vocational training and beyond. Well-implemented RCTs have the advantage of providing robust causal estimates, but they also have the disadvantage of providing little evidence on how interventions could be scaled up. Scaling up can prove difficult because of general equilibrium effects that may not be well understood within the experimental design, or because the scaling up of programs can be prohibitively costly[1].

The present study provides complementary evidence to the RCT literature. Moreover, beyond providing the general setting for understanding the economic dynamics of female empowerment, it allows us to understand two issues of major policy relevance within the mining industry itself. First, the pace with which the mining boom is progressing across the continent, with few signs of slowing down, confirms that the internal validity of the study is of major policy relevance. I use a large household survey data set from Demographic and Health Surveys, covering more than 55,000 women and 48,000 children living within 100 km from a gold mine and consisting of information from 27 surveys and conducted in nine countries. The high gold price[2] and the growing demand from emerging markets have led to a boom in gold extraction (see Figure 3.1), especially in developing countries. Africa now accounts for 20% of the world production of gold with South Africa as the continent leader, followed by Ghana, Mali, and Tanzania. However, there are at least 34 countries in Africa with significant gold deposits that do not yet have industrial-scale gold mining, but that are producing small quantities with traditional methods. The economic importance of the gold sector is thus predicted to grow over time (Gajigo et al., 2012), motivating a better understanding of the social implications of the sector.

Second, it provides a setting to empirically understand the gender effects of extractive industries, which have been subject to much discussion and theoretically ambiguous predictions. Natural resource extraction, in general, is accused of reducing female participation in labor markets by increasing reservation wages (via increased male male wages and income transfers to households) and by suppressing the demand for women's labor by crowding out female-dominated sectors, such as manufacturing (Ross, 2008). For similar reasons, the UN and the African Union argue in the African Mining Vision (UNECA, 2011) that the expansion of the mining sector is a threat to gender equality in Africa.

A priori, the expected effects from local industrial shocks are ambiguous. The association between women's labor force participation and economic modernization is U-shaped (Goldin, 1995). In traditional agrarian societies, the labor force participation is high. As the agrarian sector shrinks parallel with the growth of modern industries, the participation rate decreases. The negative trend remains until new sectors emerge where women can find productive and non-stigmatized employment. It seems likely that the establishment of a mine in an agrarian society risks inducing such an effect. Gold mining can decrease local agricultural productivity (Aragon and Rud, 2015) and may fail to provide sufficient compensatory employment within the mining sector, especially for women. In fact, the physically arduous nature of mining has led to it being considered a "male" sector, and in many countries there are stigmas regarding women working as miners.

However, there has been little empirical research to support these claims. The first rigorous empirical evidence of the cross-country local effects of mineral extraction shows that the roll out of mineral mining across the African continent on the one hand reduced women's labor force participation by 230,000 jobs, mostly in agriculture, but on the other hand created 90,000 jobs for women in the service sector and increased cash income-earning opportunities (Kotsadam and Tolonen, 2013), although the broader welfare impacts are less well understood.

[1] A recent Bayesian meta-analysis shows that RCTs with similar interventions show a correlation of 0.6-0.7 (Vivalt, 2014). The out-of-experiment validity of the findings is an additional subtle aspect, not yet analyzed.

[2] Gold has an advantage over other minerals for two reasons. First, gold is a special commodity: as pure gold or high-carat jewelry it is a highly liquid financial asset. The stock of gold is continuously increasing (Taurasi 2014), and the production of gold and the gold price are, if anything, positively correlated as newly extracted gold is only a fraction of the gold stock and not enough to affect the price. This implies that the world price of gold is strictly exogenous to local production.

The main empirical strategy is a difference-in-difference approach, using the spatial and temporal variation resulting from mine opening year and precise mine location. With this method, I control for initial level differences in development of the very local areas (within a threshold distance from the mine location) and the neighboring communities (within 100 km from a mine location). With country-year and district fixed effects, the analysis depends on the timing of mine opening being exogenous to local changes in empowerment and infant mortality. As a complement to the baseline method, I allow for a relaxation of this assumption and use the change in gold price to estimate the causal effects by predicting mine opening, and by using the gold price as a proxy for the intensity of mining activities.

I explore heterogeneity in responses depending on observable characteristics such as migrant status, urbanization, mining intensity, and distance from mine. I show that the results are robust to different specifications, such as the inclusion of mine fixed effects, country-year fixed effects, district time trends, and different levels for clustering. In addition, I design a spatial randomization placebo test where I randomize mine location 600 times and re-estimate the treatment effects, to exclude the possibility that a mis-specification of the model is driving the results.

Despite the sector's traditional association with male labor, women do access new types of jobs in mining communities. Service and sales employment increases by 41% for women. The estimated intention-to-treat effect size on service sector employment (9.5 percentage points) is larger than benchmark findings in RCT literature with interventions aiming to increase women's work participation. This indicates that the industry is effective in stimulating women's uptake of non-farm employment. Other determinants of welfare are also affected: there are significant gains in women's access to healthcare (a 23% decrease in stated barriers to access) and in women's attitudes to domestic violence with the acceptance rate of this type of violence decreasing by almost 24%.[3] The results reveal a stark change in attitudes to women's bodily integrity, and illustrate that pervasive norms regarding gender can change rapidly with local development. I find no effects on decision-making power between spouses, contrary to the hypothesis that mining increase men's bargaining power within the household. Moreover, exploring secondary outcomes of the economic and physical empowerment of women[4], I find that infant mortality decreases by more than half, and especially so for girls. The gender differentials are in line with previous studies that find that more income for women leads to larger improvements in health among girls than boys (Duflo, 2003; Thomas, 1990; Qian, 2008), implying that this is due more to behavior or norm changes than physical exposure to pollution. I cannot rule out that this occurs through a household income effect. While not drawing any causal conclusions about the links between gains in women's empowerment and infant mortality, low infant mortality rates must be understood as a necessary condition for women to be empowered.

I rule out that the mine opening changed women's labor market opportunities, female empowerment, and infant mortality through an education channel, or through changes in marital behavior. I also rule out that the jobs created in the service sector are limited to jobs in prostitution. The results are indicative of gains in infant health coming through a household welfare channel. Overall, the effects of the mine on social development may be reinforced by spurring an urbanization movement. The results are supportive of a story where norms

[3]The questions are listed in the Appendix, Table B.10. The domestic violence attitude questions are of the type: "In your opinion, is a husband justified in hitting or beating his wife in the following situations: *example*", and for access to healthcare: "Many different factors can prevent women from getting medical advice or treatment for themselves. When you are sick and want to get medical advice or treatment, is each of the following a big problem or not? *example*".

[4]We found no changes in women's bargaining power in the household. However, have found that women access new types of employment, are less likely to justify domestic violence, and more likely to access health care for herself.

relating to women's place in society can change rapidly with industrialization, without being mediated by an education channel.

The rest of the paper proceeds as follows: In Section 3.2, I describe the context of mining, female empowerment, and infant health. I describe the data in Section 3.3 and the empirical strategy in Section 3.4. In Section 3.5, I present the main results and the robustness specifications. I conclude the paper in Section 3.6.

3.2 Background

3.2.1 Extractive Industries

Mines are important global employers: 1% of the global workforce is thought be working in mining (ILO, 2010). It is also an important economic sector for many natural resource-rich countries. New discoveries of natural gas, oil, and minerals have led to booming foreign direct investment (FDI) in the African extractives sector, making it the largest sector in terms of FDI. The sector accounted for two-thirds of the increase in exports from Sub-Saharan Africa 2003-2008 (Chuhan-Pole et al., 2013).

Our understanding of the welfare effects of natural resource extraction is limited, especially at the sub-national level. Why natural resource endowments do not necessarily turn into high economic growth and prosperity is a much-studied conundrum (often called "the natural resource curse"; see van der Ploeg, 2011 for an overview). While the literature has shed some light on the macro-economic effects of extractive industries, it has provided little insight into the sub-national effects. A recently developing strand of literature is slowly filling the remaining gaps. Treatment variability at sub-national level allows more convincing stories to be told regarding, e.g., conflict (Berman et al., 2014), forward and backward linkages and price effects (Aragon and Rud, 2013), local Dutch disease and inequality (Loayza et al., 2013), employment opportunities (Kotsadam and Tolonen, 2013), externalities affecting agricultural productivity (Aragon and Rud, 2013b), and health effects (von der Goltz and Barnwal, 2014). The links between mining booms and sexual risk-taking behavior and the spread of HIV/AIDS have also been studied (for the copper boom in Zambia, see Wilson, 2012; for migrant miners in Southern Africa, see Corno and de Walque, 2012).

The different welfare effects of mining for women and men, boys are girls, are not well understood but sometimes hypothesized to be more strongly negative for women. A policy document from the African Mining Vision (funded by the UN and the African Union) argues that natural resource extraction is a threat to women, since it can increase the gender wage gap. Ross (2008) argues that natural resource extraction harms women's labor market participation by increasing their reservation wage through welfare transfers to their household or through higher male wages, and by decreasing the demand for female labor by crowding out female-dominated sectors such as manufacturing. A previous empirical study found partial support for this hypothesis using micro-data from 29 sub-Saharan countries (Kotsadam and Tolonen, 2013). With the onset of large-scale mining, women have shifted from agriculture to the service sector or left the labor market. A drop in the male participation rate was also found, albeit smaller in magnitude. Additionally, it has been suggested that income-earning opportunities created by the mining boom were part of the reason why sexual risk taking behavior decreased among young women in Zambian copper towns (Wilson, 2012). Beyond these studies, there are (to my knowledge) no large, micro-founded, quantitative studies exploring how natural resource extraction affects women's welfare.

Whether there is a link between natural resource extraction and violence is a contentious issue, also discussed in the "natural resource curse" literature. The focus is generally placed on the extractive industries' role in financing wars, or on their potential economic gains motivating onset of conflict and war. Such effects have been explored both cross-country (Collier and Hoeffler, 2005) and sub-nationally (Berman et al., 2014; and Maystadt et al., 2013). Within the community development literature, Aragon and Rud (2013) find that one large mine in Peru had a moderate positive effect on local crime rates. The present paper moves beyond the inter-state, intra-state, and local effects of extractive industries on social conflict. I consider attitudes to violence at the lowest level of social organization: the household.

The link between violence against women and mining has received limited attention in the literature. Within anthropological research, it has been noted that girls migrating to artisanal mining communities in Burkina Faso seeking economic opportunities risk encountering sexual harassment and being subjected to violence (Werthmann, 2009). In addition, southern African mining communities are associated with strong "masculinity" norms (Campbell, 2007), which could lead to increasing acceptance of violence against women. However, we can also imagine that if large-scale mining creates economic opportunities for women, this can decrease the acceptance of violence against women. The link between income and domestic violence is discussed in more detail in Section 3.2.2.

3.2.2 Women's Empowerment

The associations between economic development and women's empowerment are many and complex. Economic development can bring women's empowerment by providing new opportunities, at the same time as women's empowerment (for example increased school enrollment and labor force participation) can stimulate economic growth (Duflo, 2012). However, the timing of this potentially positively reinforcing process is not evident. Modernization of the economy may initially decrease women's economic activities outside the household if it does not provide employment opportunities considered suitable for women (Goldin, 1995).

Healthcare access, nutrition, and schooling are some of the areas with marked differences between men and women in developing countries (for an overview, see Duflo, 2012), and such differences can be accentuated in times of crisis. To the extreme, it has been found that unproductive women, in this case older women, are ostracized or killed by relatives in times of food shortage (Miguel, 2005). Economic development (also local economic development) can improve the situation of women by making everybody better off and households more risk resilient.

Increased labor market participation among women has been a common policy goal, and randomized control trials (RCT) haves been used to explore what policies are the most efficient. The RCT literature has found both weak (Field et al., 2010) and more moderate results on employment (Attanasio et al., 2011; Bandiera et al., 2014; Jensen, 2012). Overall, there is a consensus that it is hard to increase women's labor force participation through policy interventions. The popularity of the policy aim of increasing women's labor force participation can be attributed to its socially desirable indirect effects. For example, labor force participation and income-earning opportunities have been found to increase age at marriage (Baird et al., 2011; Bandiera et al., 2014; Heath and Mobarak, 2014; Jensen, 2012), reduce total fertility (Baird et al., 2011; Bandiera et al., 2014; Jensen, 2012), and change norms regarding ideal fertility and age at marriage (Bandiera et al., 2014), schooling, and employment (Heath and Mobarak, 2014). Manufacturing industries located in export processing zones employing women lead to a persistent higher equilibrium in girls' schooling (Sviatschi, 2014).[5]

Similarly, it has been argued that income-earning opportunities can provide protection against sexual and physical violence. Empirically, however, the link between income and domestic violence is not so clear. On the one hand, as the gender wage gap increases, women suffer more intimate partner violence (Aizer, 2010), and income can reduce the risk of being exposed to violence (Bandiera et al., 2014; Heath, 2014). On the other hand, the effects are conditional on a woman's initial status in terms of property rights (Panda and Agarwal, 2005), educational level (Heath, 2014), education in relation to her partner's (Hidrobo and Fernald, 2013), and age at marriage (Heath, 2014), so that if a woman's initial bargaining power is low, she is more likely to become a victim of domestic violence as her income increases.

In the present paper, I focus on norms concerning domestic violence. The main individual-level data source, Demographic and Health Surveys (DHS), employs a strict protocol when collecting the data and ensures that enumerators are trained for the purpose. Despite these precautions, misreporting and under-reporting are likely issues in domestic violence data. Focusing on attitudes is beneficial in this respect since, despite being related to actual experiences of violence, the gathered data is less likely to suffer from misreporting and is also more often collected by DHS, allowing for more cross-sectional and time variation. Last but not least, attitudes to own body control are important aspects of empowerment. Despite not posing any formal restrictions on behavior, own perceptions of opportunities and rights are important determinants of outcomes. For example, aspirations have been shown to play a key role in development outcomes. Child sponsorship interventions, focused on raising disadvantaged children's self-esteem and self-confidence, result in higher schooling attainments and benefiting children are more likely to work as adults (Wydick et al. 2013). [6]

In this paper, I focus on three sets of outcomes that can be important factors in determining a woman's welfare. The three sets of outcome capture both positive and normative statements regarding a woman's autonomy over resources and her body. These are (1) her intra-household decision-making power (if she has the final say in household decisions), (2) whether she can seek medical care for herself (whether certain factors hinder a woman from seeking healthcare: money, distance, and/or permission), and (3) acceptance of domestic violence (if a given condition is a valid reason for a husband to beat or hit his wife). I create three score indexes and use them in the main analysis; all the original questions are presented in the Appendix, Table B.10, and the regression results in the Appendix, Table B.4.[7]

[5]Decision-making power is expressed in three different sets of circumstances - within the household, in the exercising of property rights, and in the creation of policy. Policy makers are interested in increasing women's bargaining power on moral grounds, and/or as it is instrumental in changing other development outcomes (Duflo, 2012).

[6]Freedom from domestic violence is one important aspect of control over one's body, sexual integrity is another. An RCT combining information with vocational training found significant decreases in reported unwanted sexual activities to almost half the initial value (Bandiera et al., 2014). Notably, unwanted sexual activities is an extreme form of lack of control over one's body, and there are also many other, more common, ways in which women can lack control over their own body. The same intervention successfully targeted other outcomes as well, as it also decreased young women's economic dependence on men, early entry into matrimony and cohabitation, and teenage pregnancy (Bandiera, et al., 2014). This illustrates that for young women, economic constraints can provide threats to body and fertility control. In the more extreme case, it has been found that the supply of transactional sex is very elastic to income opportunities and economic shocks, on the intensive margin (Dupas and Robinson, 2012; Robinson and Yeh, 2011) and the extensive margin (Wilson, 2012). The latter study explores the copper boom in Zambia and finds that the supply of transactional sex and prevalence of multiple partnerships were reduced in towns that benefited from the higher copper price.

[7]Additional indicators that could help us understand female empowerment are available in the DHS. However, since they are not consistently collected across survey years and countries, we can not analyze them here.

3.2.3 Determinants of Infant Health

Despite large drops in child mortality in Sub-Saharan Africa, the issue remains pressing. On average, one in nine children dies before the age of five (The World Bank, 2014[8]). Both economic and environmental factors determine the high mortality rate. There is reason to believe that women's empowerment can help improve infant mortality rates, as infant health is contingent on the mother's health during pregnancy and her role as a caretaker during infancy.

In the canonical model of household bargaining, all income accruing to the household is pooled (Becker, 1964) and spent according to a joint utility function. Any changes in relative or absolute wage rate for men and women will, according to the pooled income hypothesis, have the same effects on infant mortality. Such predictions have failed to be empirically confirmed, however (see Browning and Chiappori, 1998; Hoddinott and Haddad, 1995; Thomas 1990; and Duflo and Udry, 2004). Windfall income to women generates larger drops in infant mortality and better anthropometrics, especially for girls (Thomas, 1990; Duflo, 2003), but also for boys (Haddad and Hoddinott, 1995). Broadly speaking, such findings indicate that women have stronger preferences for child health than men, and/or that child care and child health are considered a woman's responsibility. It also suggests that child gender preferences are important in determining outcomes. E.g. exogenous shocks to women's incomes across Chinese districts led to an increase in girls' survival rates, possibly by increasing women's perceived economic worth in a context of son preference (Qian, 2008). The effect of women's income is, however, not unambiguously positive for child health: exogenous shocks to women's wage rates led to a decrease in child survival rate in Colombia, arguably by increasing women's opportunity cost of child care (Miller and Urdinola, 2010).

The context in which we study child health is complex since the gold mining industry, like many industries, is associated with environmental degradation and pollution. The relevance of the environment in determining child health is reflected in a large, quantitative body of research. In this literature, outcomes in early childhood such as birth weight and infant mortality are linked to environmental factors affecting the fetus in utero. Environmental factors such as in utero exposure to toxins (Currie and Schmieder, 2009; Currie et al., 2011), radiation (Almond et al., 2009; Black et al., 2013), and ozone pollution (Moretti and Neidell, 2011) are studied. Beneficial effects on birth outcomes have been found after industrial clean-up processes (Currie et al., 2011)[9].

Gold mining is specifically associated with heavy metal pollution. The industry uses cyanide in the amalgamation process to separate the gold from the ore. Low level spillage of a cyanide-water mixture from tailing ponds has been reported, in addition to accidents with high level leakage[10]. The gold ore in several African countries naturally contains arsenic and heavy metals such as lead, cadmium, chromium, and nickel, which come to the surface during the extractive process. Lead exposure in utero is associated with increased risk of premature birth, low birth weight, and retarded growth (Iyengar and Nair, 2000), and lead pollution from mining activities has been linked to stunting in children (von der Goltz and Barnwal, 2014)[11]. Studies of

[8] The Millennium Development Goals, The World Bank: http://www.worldbank.org/mdgs/

[9] It is not only industry- or man-induced environmental effects that have been found to affect child health outcomes, but also weather variability (Kudamatsu et al., 2014) and weather seasonality (Currie and Schwandt, 2013) are important determinants of fetal health.

[10] A serious accident happened in May 2009 in Tanzania, with substantial effects on health, agriculture, and livestock around the mine (Bitala et al. 2009).

[11] Studies of mining areas in Ghana and Tanzania confirm the existence of arsenic in the soil and water below as well as above WHO threshold levels. The WHO thresholds are thought to be conservative, and the epidemiological literature is inconclusive regarding the health effects and birth outcomes associated with exposure to cyanide and arsenic within the WHO recommendation (ATSDR 2007: Arsenic, Cyanide), but high exposure is associated with detrimental birth outcomes (Chakraborti et al., 2003; Hopenhayn et al., 2003;

heavy metal exposure in childhood are at risk of significantly underestimating the health costs, since certain adverse effects are likely subclinical, i.e., non-detectable, in the short run. For example, cancers may only develop after years of chronic exposure. In this study I will focus solely on infant mortality outcomes. Thus, the study will neither help us understand the future health of surviving children, nor make any conjectures about the complete health status of these children in the short run.

To summarize the potential mechanisms discussed in this section, we hypothesize that household income and women's income, bargaining power, and healthcare access are negatively associated with infant mortality, whereas we expect a positive association for women's opportunity cost of time and environmental degradation. As the opening of a mine could affect all these variables, we do not make clear predictions regarding the effects of the opening of a large-scale mine on infant survival.

3.3 Data

The paper uses the best available pan-African data source with information on labor market outcomes, empowerment, fertility, and child health: the Demographic Health Surveys (DHS)[12]. DHS has the additional advantage of having GPS coordinates available for the surveyed individuals' villages and urban neighborhoods (from here on called clusters). The geographic identifiers allow us to link the village in which the mother or the child was surveyed to the gold mines. The mine data comes from Raw Minerals Group[13] and contains all large-scale gold mines across the African continent, with GPS coordinates for each mine center-point and historic production volumes from 1975 to 2013. Due to different reporting standards there is measurement error in the production volumes, so the preferred strategy is to create an indicator variable for activity status rather than using the volumes.

Combining the two data sources using the geographic information, I construct different measures of proximity. The final data set contains all DHS survey rounds that have geographic data, for countries in which there is at least one large-scale gold mine[14] that was active at least one year during the study time period. This leaves us with a repeated cross-sectional data set with four survey rounds for Burkina Faso, Ghana, Guinea, Mali, and Tanzania and three survey rounds for Cote d'Ivoire, Ethiopia, and Senegal. In addition, Demographic Republic of Congo is kept in the study despite there currently only being one available survey round (new round released October 2014). The survey years span from 1993 to 2012. Figure 3.2 shows the sample years for each country (dashed line), and the years for which we have sampled births (shaded pink). Table B.8 in the Appendix shows the sample size divided by country and survey year.

Milton et al., 2005). Nevertheless, there has been controversy regarding these findings due to the risk of omitted variable bias where exposure is linked with lifestyle habits (Kapaj et al., 2006). Epidemiological studies limited to the study of mother/infant pairs show that arsenic exposure in utero correlates with low birth weight (1,500 pregnant mothers in Bangladesh: Rahman et al. 2008), and high exposure correlates with stillbirth and neonatal death, but not with miscarriage or later infant death (the sample consisted of 202 married women surveyed during two years: von Ehrenstein, 2006). Appendix, Table B.11 explains in more detail the known effects of cyanide and arsenic.

[12]The Demographic and Health Survey collects data on health and fertility in developing countries and is funded by US-AID. More information can be found at www.dhsprogram.com. According to Nikolov it is "[p]robably the best source for demographic and health data; comparable surveys for some 70 countries. Very good coverage for Africa", NBER, 2009 (from: http://users.nber.org/~nikolovp/studentresources/datasets.pdf)

[13]More information about IntierraRMG can be found at http://www.intierrarmg.com/Homepage.aspx. The data is licensed and can be obtained by subscription.

[14]Some countries have small-scale, traditional gold extraction activities. This sector is not analyzed within this paper. Due to the informal and sometimes illegal nature of such activities, no proper account for their location and extent is available. The complete data set includes all DHS surveys that were available for download in December 2013.

Figure 3.3 shows the geographic location of the gold mines used in the analysis. To the right in Figure 3.3 we zoom in on Tanzania, highlighting the mine location (the blue circles) and the DHS clusters (purple dots). The gold mines show a pattern of geographic clustering, such as around the Ashanti gold belt in Ghana and the Lake Victoria greenstone belt in Tanzania.

Descriptive statistics are presented in Table 3.1 for women and in Table 3.2 for children and their mothers[15]. The first column (whole sample) tells us the main characteristics of the sample. Women are on average 28.7 years old, and 27% live in urban areas. A little over 40% of women have ever moved, and most work in agriculture (44%).[16]

The index variables barrier to healthcare access, accepts domestic violence, and final say in household decisions are presented in this table. These consist of averages of answers to a wider set of questions, all of which are presented in the Appendix, Table B.1. The original variables are dummy variables that take a value of one if the woman agrees with the statement, and zero otherwise. Between 23% and 48% of women think that violence can be justified, i.e., they agree with a statement that a husband has the right to hit his wife if she burns the food (23%), refuses sex (37%), argues with him (45%), neglects the children (48%), or goes out without his permission (47%). In addition, more than 50% claim to have the final say in food decisions, but only 17% have a say in how to spend the husband's income. Roughly 30% say they have decision-making power regarding healthcare and large purchases. Women in the sample also have low access to healthcare for themselves, where 88-92% of the women think that permission from a household member, distance, or money are obstacles to healthcare access. These variables are then used to construct the three indexes in Table 3.1, which take a value from 0 to 1 depending on the share of the statements that the woman agrees with.

The average number of children born to each woman is 3.26, which is below the average desired fertility of 5.4 children. The mean infant mortality in the first 12 months is almost 10%. The birth years of the children in the sample vary from 1987 to 2012, since the oldest child sampled in the first survey year, 1993, will be under six years old. Mother's age is just above 29 years on average, which means that the women in this sample are slightly older than those in the main analysis. The mothers of surveyed children also have lower education (total years of schooling) than their peers in the other sample, which may be a result of younger women being less likely to have children and thus less likely to be in the child sample, as well as positive trends in education. The summary statistics relating to the empirical model will be discussed in Section 3.4.3.

3.4 Empirical Strategy

With multiple survey rounds and historic records of openings of gold mines across Sub-Saharan Africa, the identification strategy relies on a difference-in-difference framework using several treatment definitions based on proximity to a mine. The true counterfactual in the baseline is "no mine", and I try several methods to identify the relevant comparison group by varying the definition of the control group.

[15]The women sample captures all sampled women aged 15-49. The children sample captures all children under the age of five, born to sampled women.

[16]As all variables are not collected by DHS in all rounds and in all countries, the sample size differs across these indicators. The occupational outcome variables created are binary outcome variables from an original question about main occupation. I focus here on the largest employment groups: agriculture and service and sales, as well as not working. In Section 3.A, I use all occupational outcomes in a multinomial logit.

3.4.1 Baseline Specifications

The strategy of the paper follows from an approach used by Kotsadam and Tolonen (2013) to measure local employment effects from industrial mining across a continent. More generally, the strategy links to the subfield of economic geography concerned with exploring local industrialization effects, e.g., local multipliers (Moretti, 2010), agglomeration economies, and total factor productivity (Greenstone et al., 2010), and toxic industries, housing prices, and infant mortality (Currie et al., 2012).[17]

Mining is primarily determined by the availability of a mineral deposit. Despite true deposits being random, it is not possible to argue that known deposits are truly exogenous measures. We come to know about deposits, in many cases, after long exploratory processes. The level of exploration undertaken can be determined by (1) institutions, (2) royalties and tax-rules, (3) accessibility (Eggert, 2002), and (4) expected profitability. The first two determinants are likely to only vary within-country or across sub-national regions (such as districts). The latter two may however vary within sub-national regions. I.e. that infrastructure will vary within a district, where some parts have better access to the road network and other parts less access to the road network. Deposits have been used in the natural resource literature (see, e.g., Allcott and Keniston, 2014) as an exogenous measure of mining activities. However, a deposit measure is time invariant, so by definition it only allows for a difference-in-means estimation. Instead of doing this, we take known deposits (ever extracted from 1975 to 2012[18]) and add an annual indicator for production status of the mine:

$$Y_{icdt} = \beta_0 + \beta_1 deposit_c + \beta_2 deposit_c \cdot active_{ct} + \alpha_d + \delta_{kt} + X_i + \varepsilon_{icdt} \tag{3.4.1}$$

where i indicates an individual observation, c DHS cluster, d district (sub-national administrative level 2), k country, and t year. The variables of interest are *deposit*, an indicator variable that takes a value of one if there is a deposit within a baseline distance from the community, usually 15 km, and the treatment variable indicating the presence of an active mine (*deposit*active*) in the given year. Importantly, the specification includes year fixed effects γ_t, which allows for the difference-in-difference interpretation. Moreover, the specification includes district fixed effects, α_d, country-year fixed effects, δ_{kt}, and a vector of individual level controls, X_i. In all regressions, I have limited the sample to within 100 km from a deposit and I cluster the standard errors at the DHS cluster level (unless otherwise stated).

The choice of distance is crucial for correctly estimating the treatment effects. To be transparent about the choices made regarding distance, I will show the effects from different distance cut-offs as well as a spatial lag model. Mining areas can be several kilometers wide, as illustrated by the photo of Geita Gold Mine in Figure 3.4. To capture the communities around the mine, we need to consider an area that is larger than the mine itself. However, the treatment distance needs to also reflect commuting behavior and market integration. In the late 1980s, the median worker in rural Tanzania and Ghana traveled roughly 5 km to work (Shafer, 2000). A more recent study from Cote d'Ivoire estimates by tracking mobile phone movements that the

[17] Currie et al. (2012) examine U.S. plants that produce toxic waste. Due to the risk of measurement error in reported quantities of toxic waste, the authors' preferred strategy is plant opening and closing year. For similar reasons, I rely on the opening of mines rather than annually reported production volumes because of data limitation and data quality.

[18] A deposit will here be defined as a site with a known mineral base that has been considered for production and is thus included in the IntierraRMG database. To ensure that the deposit sites used are relatively homogeneous, no deposit sites that have not been considered for industrial production or whose industrial production potential was not yet known in December 2012. A limitation of this data is that the discovery years are not known, and that we do not know what sites could have industrial production moving forward from the last data point (2012). Most deposits will thus be sites that by the end of 2012 had had some production.

average worker travels 5 km but often up to 15 km to work (Kung et al., 2013). In 2013, 80% of government workers in Kumasi, Ghana, traveled less than 10 km to work, mostly using public transport (Amoh-Gymiah and Aidoo, 2013). These estimates, plus the mine size of a few kilometers in diameter, suggest that roughly a 10-15 km zone around the mine can be considered an integrated economic area. 10-15km will be the baseline treatment distances in this paper. Moreover, an additional reason not to consider shorter distances is that the geocoordinates in the DHS data are displaced by 1-5 km, and up to 10 km in 1% of the cases, to ensure that individuals cannot be identified.

The chosen distances are in line with those used in previous studies on mining, where distances range from a maximum of 50-100 km in Aragon and Rud (2013) mapping the effects of one large mine in Peru, to 20 km in a study on agricultural productivity in Ghana close to gold mines (Aragon and Rud, 2015), 20 km in a study on labor market effects across Africa (Kotsadam and Tolonen, 2013), and 5 km in a study on pollution effects of mining (von der Goltz and Barnwal, 2014). Beyond the local analysis, there are papers exploring district level effects and shedding light on the fiscal channels (Loayza et al., 2013; Allcott and Keniston, 2014) beyond the market-based effects. One contribution of the present paper is its empirical approach to estimating distance effects in spatial analyses where a radius of influence is not known *a priori,* by carefully mapping the spatial decay function with a spatial autoregressive model.

3.4.2 Threats to Identification

The estimation strategy in this paper relies on assumptions that the timing and the placement of the mines are not driven by local changes, such as trends in labor market participation, women's empowerment, or population characteristics. The mining industry may to a lesser extent than other industries depend on local characteristics. Mine locations are first and foremost determined by mineral deposits, considered geological anomalies, and not by the availability of human capital and labor. Throughout the earth's crust there are pockets of mineral deposits, often clustered within a region (Eggert, 2002). The necessary condition determining an investment decision is the existence of a deposit; deposits are not mobile, whereas production technology and labor inputs are.

Nevertheless, we can think of various factors that could influence mine location or mine opening year. Access to, and costs of, inputs, agglomeration economies and historic legacy are considered important (Eggert, 2002). Another important factor is institutions, such as mineral property rights, openness to foreign direct investment, rules for revenue sharing of tax and royalties, and environmental regulation. Analysis of gold mining investment behavior shows that multinational gold mining firms are attracted to regions with low corruption, close to head offices, and with low-risk, stable, and transparent business environments (Tole and Koop, 2011). This is not an issue to our identification, as regulatory frameworks for businesses are predominantly national or regional. We do not expect that within-region (i.e., sub-national level 2, such as districts) differences in institutions will drive the investment decisions, assuming that institutions are homogeneous at this sub-national level.

The difference-in-difference identification strategy with district fixed effects and year fixed effects reduces the potential concern that institutions drive the mine opening and location. Effects are identified within a certain sub-national area that we can assume has homogeneous institutions. In addition, the baseline estimation specification includes country-year fixed effects accounting for national changes in policies and institutions, and results using other specifications, such as district time trends, are presented in the robustness section.

Of more concern is infrastructure for water, electricity, and transportation, which may vary within-district. Transportation infrastructure and accessibility are argued to be important in both the exploration phase and the production phase (Eggert, 2002). If mining operations create new infrastructure, our treatment is mine plus infrastructure. This is not a threat to identification, because we are interested in the total effect of the industrial shock.

If, however, mines open because infrastructure is developing in these areas, it affects the interpretation of the results as they can then no longer be understood as the general equilibrium effects of a large-scale mining shock due to the mining shock and the infrastructure shocks being conflated. We may consider this infrastructure story less likely for gold than for various other minerals. Gold is a high-value commodity, and airstrip access may be more important for transportation than railway or road network connectivity. In contrast, the extraction of high-volume resources such as coal and iron ore is heavily reliant on good infrastructure, including railways, road network, and ports (Weng et al., 2013). According to annual reports, gold mining companies operating in Africa are developing necessary infrastructure themselves.[19]

Other threats to identification are migration and urbanization. On the one hand, we are interested in the general equilibrium effects of a mining shock on the local economy. This means that we are interested in knowing how the mine affects the economic opportunities of its new and old community members, where migration and urbanization are allowed to be mechanisms. On the other hand, we are also interested in knowing the treatment effect on the original population, free from selection, in which case we have to remove migrants from the analysis. In this second case, we also allow for migration and urbanization to be part of the mechanism, i.e., maybe women's employment opportunities change through an indirect effect of a mine, like urbanization.

A final concern is the existence of artisanal and small-scale mining (abbreviated ASM), which is a large sector in terms of employment but a small one in terms of production, compared with the large-scale mining industry. No detailed, time-varying records of legal and illegal ASM activities exist (to my knowledge), and thus I cannot control for the location of such activities. In some countries and districts, ASM will be part of the land use prior to the large-scale mine. If so, we will be estimating the general equilibrium effect of the potential partial replacement of one production method with another. It is unlikely that legal ASM activities will increase with the large-scale mining activity since the large-scale mining firm will typically have the mineral rights to all findings within a larger concession area. Moreover, it is hard to make any conjectures regarding the response of the illegal mining sector, although a decrease in illegal activities is likely if property rights of the minerals are better enforced with the arrival of the large mining company.

In one particular part of the analysis does the prevalence of ASM prior to the onset of large-scale mining pose a serious threat to the identification and the understanding of the results: infant mortality. Small-scale mining is associated with mercury pollution, which can be detrimental to child survival and development. If a large-scale mine crowds out smaller-scale activities, and we estimate a positive effect on child survival, this could be due to the disappearing of the polluting, initial industry rather than the advent of a more modern industry. Since few time-varying, complete records of local small-scale mining exist, we cannot investigate this further. To overcome some of this concern, we compare the trends in infant mortality before the large-scale mine in close communities with control communities located further away (see Figure 3.6, and see Section 3.4.3 on parallel trends for further discussion). We find that infant mortality rates are indeed higher

[19] African Barrick Gold owns a private airstrip at their Bulyanhulu mine in Tanzania, and we can see another airstrip in the picture of the Geita gold mine in Figure 3.4.

in mining communities before the mine opens, but that they become lower than in the control communities afterwards, which is what we would expect if the large-scale mine has positive effects on survival (and not only through crowding-out effects).

To further convince the reader that the model is not mis-specified and the results spurious due to cross-sectional correlations, I conduct a spatial randomization placebo test.[20]

3.4.3 Parallel Trends

Difference-in-difference analysis hinges on the assumption of parallel trends. In this context, that would be that the trends in the treatment (mining) communities and the control communities (further away from a mine) would be on the same trajectory, in absence of the mine opening. We will first look at balancing tables for the treatment and control groups, and then at parallel trends.

Two balancing tables (Table 3.1 for women and Table 3.2 for children) show that there are some differences in levels pre-treatment across the treatment (Column 3) and control group (Column 2). The summary statistics indicate that women in the treatment group are of the same age but have slightly more education and more children and are less urban, more likely to work in agriculture, and less likely to work in services.[21] For children in Table 3.2, we learn that children born close to mines, but before the mine opening (Column 3), have younger but more educated mothers, are less likely to reside in urban areas, are of higher average birth order, and face higher mortality rates.[22] We find several significant differences between the control and treatment group, pre-treatment. The difference-in-difference framework allows for different levels, as long as the two groups are on similar pre-treatment trends. To investigate whether this assumption is plausible, I look at the trends in observable characteristics and outcome variables for women within 15 km from a mine, ten years before to ten years after the mine opening, and compare them with the corresponding trends for women who live 30-50 km away from mines. I use two strategies: a non-parametric estimation (local polynomial smooth) and linear trends allowing for trend breaks at the mine opening.

The decision to compare with women 30-50 km away rather than up to 100 km was made for two reasons: (1) The specification considers the first opening year of the closest mine only. Limiting the geographic area considered limits the risk that an individual is treated by an additional mine. (2) It allows for comparison across more similar people (whereas in the regression specification, district fixed effects will partly ensure this).

The non-parametric results (Figure 3.5) show no pre-mine differences in trends in age and education, yet women in mining communities may be slightly younger and more educated after the mine opening. Service and sales employment is lower in the mining communities before the mine (Figure 3.5a) but follows a similar trend as the treatment group. However, we notice an increase in service and sales employment roughly 1 to 2 years before the mine opens, which is in line with an investment story: mines are capital intensive, and employment generation can be substantial during the investment phase (we will drop these two years in the linear trend break strategy).[23] The trends in agriculture are less clear, but it seems like agricultural

[20] A further randomization test will be done, randomizing mine opening year, to convince the reader that the effects found can be interpreted as causal and not spurious effects caused by trends in empowerment and mortality rates.

[21] Note that there is variation in the mean sample year. The sample is unbalanced and different individuals will be affected by different mines. This sample year variation may explain some of the differences noted here.

[22] The average birth year in the treatment group pre-treatment is 1997, which is significantly different from the average birth year of 1999 in the control group pre-treatment. Some significant differences will stem from this.

[23] This indicates that we may consider the investment phase as part of the treatment years, although in the main analysis I assume first

employment dips around mine opening in mining communities and then reverts back to pre-mine level in the long run. The control communities are on a steadily decreasing trend. Parallel pre-treatment trends are confirmed visually for services, agriculture and barriers to health care in Figure 3.7, but are less clear for the other outcomes.

Infant mortality (Figure 3.6) follows similar trends in mining communities and non-mining communities before the mine, although the level is higher in mining communities. The two levels start converging a few years before mine opening, caused by a sharp decline in mortality in the mining communities.[24] This pattern is found for mortality in the first month, first 6 months, and first year, and for both boys and girls and for both migrants and never-movers. Total fertility among all women is on a downward trend, and while the trends are similar in the two groups 10 to 3 years before mine opening, around this time the level difference is more or less evened out. Figure 3.8 allows for linear and quadratic trends in infant mortality before and after mine opening, comparing the treatment (within 10 km) and control groups (30-50 km).[25] The pre-trends are similar across treatment and control in both the linear and quadratic specification and for migrants and never-movers.[26] Overall, the figures of the evolution of observable characteristics, outcomes, and potential confounding factors show similar pre-mine trends, supporting the use of a difference-in-difference method.[27] Additionally, the figures indicate that mining communities change their development trajectory around the time of the mine opening.

3.5 Results

3.5.1 Main Results

Determining Treatment Distance

To allow for non-linear effects with distance and better understand the geographic distribution of effects, I implement a spatial lag model. By including a lag structure for distance to deposits as well as active mines (active), we allow for two sets of non-linear spatial structures:

$$\begin{aligned} Y_{icdt} = \; & \beta_0 \\ & + \sum_d \beta_d \, deposit_c \\ & + \sum_d \beta_d \, active_{ct} \cdot deposit_c \\ & + \alpha_d + \delta_{kt} + \varepsilon_{icdt} \end{aligned} \tag{3.5.1}$$

year of production, i.e., year 0, as the start of the treatment period.

[24] We may be observing excess mortality in mining communities before the mine opens because of artisanal and small-scale mining. However, we note that the infant mortality becomes lower in these communities after the mine opening, indicating that the effect is not only due to the crowding out of a polluting industry (ASM).

[25] Two years before mine opening have been excluded since this is the investment period of the mine. There are no control variables.

[26] The p-value of a test of whether difference between the slopes is zero is provided for all linear specifications. If anything, the mining areas might show worse pre-trends compared with the control group. Despite this, we can observe a large negative jump in the trends after the mine opening.

[27] However, the differences in levels and the observed trends in the data indicate that a difference-in-difference estimation strategy is preferred over a simple difference strategy.

for $d \in \{0-10, 10-20, \ldots, 80-90\}$

Figures 3.9b and 3.9c confirm that the effects on services and agriculture are found close to mines and sharply decrease at 10-20 km. Beyond 20-30 km, we see few effects on service and sales employment and the estimates are approaching zero. For agriculture, there is more variation in the estimates, but there is a tendency for a lower participation rate in agriculture close to active mines.

Figures 3.9e, 3.9f, and 3.9g show the results for our three main variables for empowerment: barriers to healthcare access, justification of domestic violence, and final say in household decisions. Figure 3.9e for 'Barriers to healthcare access' shows that up to 20 km from a mine, women state fewer barriers to healthcare access, especially compared with women at the same distance from a non-active mine (the dotted line), for whom access is more restricted than for peers further away. For attitudes to domestic violence, there is a clear shift from higher levels of acceptance (dotted line) to lower levels of acceptance (solid line) close to mines that become active. For final say in household decisions we do not see any clear pattern, neither close to mines nor further away.

Lastly, Figures 3.9h and 3.9i show the results for infant mortality. For boys, there is seemingly insignificantly lower mortality within 10 km from a mine in active mining communities. For girls the difference between active and inactive communities is large in the closest distance bin. Before a mine opening, mortality rates are significantly higher here; after a mine opening, they are significantly lower. The effect is, however, no longer observable at 10-20 km.

These findings motivate us to consider the very close distances. For occupational outcome, especially services, it is clear that the mine impact is found within 20 km, but for domestic violence it is found within 10 km. For children, the effect is exclusively found within 10 km. As a baseline measure we will continue using 15 km, since this gives a bigger sample size and more precisely estimated effects. However, for children we ought to also consider 10 km distance bins as we note that the effects are concentrated there.

Economic Empowerment

Using the baseline specification (specified in Equation 3.4.1) and a treatment distance of 15 km, the treatment effects on all outcomes are shown in Table 3.3. Panel A shows that women in mining communities are 9.5 percentage points more likely to work in services and sales and less likely to work in agriculture (-7.2 pp, insignificant). To explore whether there is a switch from agriculture to service sector employment, I estimate a multinomial logit. I find that there is a significant decrease in agriculture (-7 pp) and a significant increase in service sector employment (11.5 pp increase) (see Table B.2 and a more detailed discussion in Section 3.A). Women are more likely to earn cash for work (baseline is insignificant, but the marginal effect from the multinomial logit is significant at 8.9 pp; see Table B.2). The effect on overall labor market participation is smaller (4.7 pp, which is a 6% change in the overall participation rate, or 1.4 pp from mlogit) and insignificant. We confirm that the onset of mining creates a structural shift whereby women shift from agriculture to service sector employment, and they are more likely to earn cash for their work[28].

[28]These results are also confirmed by the Ghana Standard Living Measurement Surveys (GLSS) using the same strategy. Results are available on request.

Physical Empowerment

Table 3.3, Panel B shows the results for three index variables measuring a woman's physical empowerment: healthcare access, attitudes to domestic violence, and final say in household decisions. The outcome variable is an index that takes a value from zero to 1. If she answers yes to all statements, the index will take a value of 1. The full list of questions is presented in the Appendix, Table B.1 and with the questions from the questionnaire in Appendix Table B.10. Using an index is a preferred strategy since it effectively limits the number of hypotheses tested and hence removes some of the concerns regarding multiple hypothesis testing. For transparency, the results for all individual outcomes are presented in Appendix Table B.4, and a discussion regarding multiple inference is found in Section 5.3.

The first index, "barriers to access healthcare," measures whether a woman thinks that money, distance, or permission is hindering her from seeking healthcare for herself. Women close to active mines are significantly less hindered in this respect, with a drop of 23%. In addition, women in mining communities are 24% less likely to accept domestic violence (Column 2). However, women in mining communities do not have significantly different final say in household decisions such as large purchases or family visits (Column 3)[29].

The results show that women's access to healthcare for themselves and attitudes regarding her bodily integrity change with local development. Barriers to healthcare access is a complex measure, since it includes not only monetary and geographic but also attitudinal constraints to access. Exploring these constraints individually (Appendix Table B.4) shows that women are insignificantly more likely to state they have permission to seek healthcare, supporting the hypothesis that norms can change quickly. A clear shift in norms is found for domestic violence. This is stark evidence that local economic shocks affecting women can rapidly change gender norms.

Infant Mortality

Infant mortality remains high in many parts of Africa. The fertility records we use have been collected in Africa over the last decades and consist of recall data provided by women aged 15-49 regarding all their births in the last five years. We believe that the data is of high quality, since births are important events that women are likely to remember, especially within a limited time frame. Despite this, there is often missing information on birth weight (an important pregnancy outcome as it is an indicator of infant health), which is attributed to high prevalence of unattended births where the weight was never recorded. For this reason, I choose to look at infant mortality when analyzing infant health.

To summarize the hypothesis from the related literature discussed in the background section, increases in household income, and especially woman's income, should affect child health positively,. Also access to healthcare is hypothesized to affect child health positively. However, if a woman's bargaining power within the household decreases and she is the main caregiver, or if the opportunity cost of child care (i.e., through women's higher wages) increases it could have negative effects on child health. Lastly, if environmental quality decreases because of pollution from a mine, it could affect child health negatively. We have already learned that a mine can increase women's labor force participation outside the household, which could have both positive effects (through the income effect) and negative effects (through the increase in opportunity cost) on survival rates. However, we have not found any significant changes in bargaining power from mining. Overall, the *a priori* effect of a mine on infant mortality is ambiguous.

[29] There are additional outcomes that are not included in the index, since they are only collected for a smaller sample.

When we analyze infant mortality, the specification will be slightly different than in the women's regressions, because we now want to consider whether there was a mine in the child's birth year, rather than in the survey year. The baseline specification includes birth year fixed effects, γ, birth month, μ, district fixed effects, α, country year fixed effects, δ, a vector for mother's characteristics, and child birth order.

Mine opening is associated with a 0.009 pp decrease in infant mortality (insignificant), and disaggregated by gender we find that the treatment effect is positive and insignificant for boys but negative for girls (see Table 3.4, Panel B) using a 15 km treatment distance. The spatial lag model did, however, tell us a story about decreasing infant mortality within the 0-10 km distance from a mine. For this reason we continue the analysis by exploring, in more detail, infant mortality at the very closest distance. Table 3.4 shows the regression results for infant mortality in the first month (Column 1), first 6 months (Column 2), and first year (Column 3) of life using a 10 km distance cutoff. The effects for neonatal mortality and mortality in the first half year (3.1 pp and 5.6 pp) are smaller than the effect for infant mortality in the first year, which is 6.0 pp. The 6.0 pp decrease in infant mortality in the first 12 months is close to a two-third decrease in mortality rates. Decomposing by gender, we find that mine opening is associated with a 4.2 pp insignificant decrease in mortality rates for boys (Column 4) and a 7.6 pp decrease in mortality rates for girls. The drop in mortality rates for girls is equivalent to a 85% decrease in incidence. Panel C furthermore confirm, when we add three treatment dummies at once (0-10, 10-20, 20-30 km), that the effects are robust within 10 km. The conflation of the effect of 0-10 km (negative significant) and 10-20 km (positive insignificant) leads to the insignificant treatment effects estimated at 15 km. To further understand the robustness of these results, and to understand why they happen within 10 km, I will continue using the 10km distance in all subsequent regressions for infant mortality, unless otherwise stated.

3.5.2 Robustness

In this section we perform sensitivity analysis to explore various specifications such as control variables, fixed effects, time trends, and clustering. We will then see if the effects are robust to different assumptions about spillover effects. Using a spatial randomization placebo test, we test whether the results are spurious due to mis-specification of the model. Lastly, we will exploit the exogenous variation in production induced by the world market gold price.

Controls, Fixed Effects, Time Trend, and Clustering

I perform several additional robustness checks to ensure that the results are robust and not sensitive to the model specification. Tables 3.5, 3.6, and 3.7 show the eight main outcome variables across 11 different specifications. The first three columns show parsimonious specifications without controls (1), with just age and education controls (2), and with the baseline specification but without urban control. For comparison, the baseline results are reproduced in Column 4. Adding an urban control does not change the results much, except for access to healthcare in Table 3.6 , which is only significantly estimated with the control, and for domestic violence and infant mortality the coefficients are slightly stronger without individual controls. Overall, the effects do not seem very sensitive to the inclusion and exclusion of individual level controls.

Moreover, we want to vary the fixed effects and clustering of data. Column 5 uses country fixed effects but not district fixed effects, which are added in Column 6. Column 7 add closest mine fixed effects, and Column 8 uses the baseline specification but with district time trend instead of country-year fixed effects.

Column 9 clusters on district instead of the DHS cluster level. Overall, this exercise shows that the regression results are stable, both in magnitudes and significance levels.[30] Please see the Appendix for further results using multinomial logit and a discussion of the multiple inference problem.

Spillover Effects

If the presence of spillovers beyond the treatment distance, we will underestimate the treatment effects[31]. In Table 3.8 Panel A, the results are re-estimated with the control group limited to individuals living more than 30 km from the mine. The estimated effects are generally slightly stronger, as expected, although the estimate for infant mortality for boys is now larger and marginally significant (Column 5). This specification could be part of the baseline specification, but since it increases researcher degrees of freedom, it is kept as a robustness strategy. Additionally, in Table 3.8 Panel B, I have dropped individuals surveyed or born two years before a mine opening. I did this in order not to contaminate the control group with individuals affected by the mine investment phase, which is on average 1-2 years long. If we exclude such individuals, the effects remain similar to baseline, although sometimes a little stronger. Moreover, I ran the regressions including individuals sampled two years before captured by a dummy. The directionality of the dummy was the same as the main treatment effects in all cases (and opposite the effects of deposit) (results available on request). This indicates that the mine had effects on the local economy two years prior to mine opening, and that if we are interested in the total mine effect we should include these years in the main estimated effects. Nevertheless, if we are interested in the production phase of the mine, the specification should be as the baseline specification.

Spatial Randomization Placebo Test

A randomization inference test can convince us that the main results are not spurious because of a mis-specified model. To ensure that the interpretation of the results is causal, I demonstrate using a spatial randomization placebo test that the exact location of the mine is needed to obtain the results. If the mine location is offset between 0 and 50 km in any direction while the mine keeps its *de facto* opening year, the results attenuate toward zero. Figure 3.11 shows the distribution of treatment effects (active*deposit) when the mine location was randomized 1,500 times, and the red lines show the initial treatment effects for the main outcome variables. The false data generated had the mine location offset by up to 50 km, implying that it in some cases will overlap with the true treatment area (set to 15 km), so we do not expect the distribution of point-estimates to be centered right at zero for those outcomes where we had a significant treatment effect, but that it is closer to the baseline point estimates. The exact p-values are presented in the figure and show that it is unlikely that the model specified in Equation 3.4.1 is driving the results for service sector employment (p = 0.019) and acceptance of domestic violence (p = 0.079).

[30] To explore if the effects are driven by certain countries, Table B.9 shows the main analysis run on a country-specific sample. Where the full model has not been possible to estimate, the space is left blank. This may be because some questions are not collected in all countries, or because the sample size for a given question is too small to estimate the full model. The effects on service sector employment (Column 3) is positive in all countries except Senegal where it is negative and significant, and Tanzania where the effect is close to zero. All coefficients on accepts domestic violence are negative, but we lose power with the sample split. Infant mortality decreased by 6.3 to 10.6 pp in all countries where we could estimate the model.

[31] The SUTVA, stable unit treatment value assumption, would be violated

The World Price of Gold

We expect a mine to produce more when the price is high, and of course, the value per ton extracted will be higher when the price is higher. This can trickle down to the economy, for example by increasing employment and wage rates. This means that we can use the world price of gold to understand how effects differ when production is stronger, or more profitable. Using the gold price for intensity of mining also provides an alternative to using the production volumes, which we want to avoid given different, non-consistent standards being used across companies, and sometimes missing data (IntierraRMG, 2013).

Gold is a special commodity that in contrast to other minerals and metals functions rather as a financial asset than as raw material used in the production of other commodities. As a financial asset, it is predominantly in the shape of pure gold or high-carat jewelry[32] and the gold supply in the market is perfectly elastic. This means that new production of gold will not have a large influence on the traded price of gold: new production is small compared with the total inventory of gold (Taurasi, 2014). I therefore assume that the investment and production decisions of a single mine, or even a mining company or a mining country, are driven by the gold price rather than the other way around. Figure 3.1 shows that the number of active mines in the study, as well as their estimated total production, increased almost in parallel with the gold price over the last 20 years.

We saw in Figure 3.1 that the world price of gold increased rapidly during the time period, and because the gold price is strictly exogenous to local population characteristics we can use it to overcome concerns that the activity of a mine is driven by local changes. I use the gold price in two different strategies. First, interacted with the main treatment variables (specified in Equation 2). If a high gold price results in higher production volumes or higher wages, we can now capture such intensive margin effects. In this specification we have two variables of interest:

$$\begin{aligned} Y_{icdt} &= \beta_0 \\ &+\beta_2 deposit \cdot goldprice_{ct} \\ &+\beta_3 deposit \cdot active \cdot goldprice_{ct} \\ &+\alpha_d + \delta_t + \varepsilon_{icdt} \end{aligned} \tag{3.5.2}$$

The specification controls for district fixed effects and a linear time trend[33]. However, we might still have endogeneity concerns in this specification, as it relies on the mine opening year. In the second stricter specification, we interact the gold price with the mineral deposit dummy. The strictest regression model thus looks like:

$$Y_{icdt} = \beta_0 + \beta_1 deposit \cdot goldprice_{ct} + \alpha_d + \delta_t + \varepsilon_{icdt} \tag{3.5.3}$$

This specification also controls for district fixed effects and a linear time trend, as well as individual characteristics. The results for these two strategies are presented in Table 3.9 Panels A and B. In Panel A,

[32] Investment in gold can be motivated by inflation fears (Adrangi et al., 2003; Blose, 2010), and as a safe haven in times of economic and financial turmoil (Baur and Lucey, 2010; Baur and McDermott, 2010)

[33] Year fixed effects are not possible to include in this specification.

we use the strategy outlined in Equation 3.5.2. A higher gold price causes less labor market participation (marginally significant), less agricultural, more service and sales employment (Column 3), less acceptance of domestic violence (Column 5), and less infant mortality (Column 8). These results are in line with the baseline results, which increases our confidence in the main strategy.[34] Panel B shows that the treatment effects are largely insignificant when we interact the deposit with the gold price, although a one unit higher gold price in a community with a deposit leads to 0.4 pp higher service sector employment, and 0.5 pp higher labor force participation.

3.5.3 Mechanisms

In this section we look closer at the mechanisms behind the results found on empowerment and infant mortality. First we explore the heterogeneous effects for the migrant and non-migrant populations, as well as the effects on urbanization. We find out whether increases in service sector employment, cash earnings, and household wealth explain some of the variation in physical empowerment and infant survival. We use an additional data source to measure wage effects for Ghana, and lastly we look at changes in marriage market outcomes and fertility.

Migration and Urbanization

We are interested in migration for two reasons: (1) because it affects the interpretation of our main results and (2) because it may be a mechanism through which the effects of the mine opening are reinforced. The main analysis covered the entire local population, enabling us to understand how labor markets, empowerment, and infant mortality have changed within these communities. However, in the presence of selective migration to these communities, we cannot interpret the effects as treatment effect on the treated since the population composition has changed. Nevertheless, we may expect migration to be a mechanism: If mining communities grow because of inward migration, this can have additional effects on economic activity and create indirect job opportunities. That said, as mining-induced migration flows can also increase the competition over jobs, resources, and services (such as healthcare), the welfare impacts of migration are *a priori* ambiguous.

The DHS provides information (for a subset of the sample, as not all survey rounds collected this data) on whether the individual ever moved. In Table 3.10 Panel A, I show the results using the baseline specification, but excluding from both the treatment and the control group anyone who ever migrated. Assuming no selective outward migration from the mining communities, we can interpret these results as treatment effects on the initial population.[35] Women born in mining communities take advantage of new service and sales jobs created by the sector (Column 2). The likelihood that a woman works in services and sales is almost 10 percentage points higher than elsewhere, which corresponds to the baseline result presented in Table 3.3 Column 3. Other observed changes for these women are in line with the main results: they are less likely to be hindered from seeking healthcare (Column 4, insignificant), less likely to accept domestic violence (Column 5, marginally significant), and infant mortality among their children decreases (Column 7, insignificant). The effect size

[34] These estimates are also run with the log of the gold price. Results are available on request. Moreover, when data permits we can run full triple difference model where the baseline model is interacted with goldprice, so we have five variables of interest. Doing this for infant mortality, we learn that an active mine is associated with a negative effect on mortality, and that the interaction between higher gold price and active mine is not insignificant.

[35] This may be a strong assumption to make if there is selective outward migration. However, the data does not allow us to identify where people have moved from in order to understand the inward and outward migration in the mining communities.

for infant mortality is however smaller than the baseline estimate, and the standard error is large. Trying to further decompose the estimate by gender, the number of treated individuals becomes too small and the standard errors increase sharply (results available on request) To further understand the treatment effect on migrant children, we can look at the trends in infant mortality (Figure 3.6). Among never-movers close and far away, the trends in infant mortality are similar up to a few years before mine opening, when mortality rates start decreasing rapidly. Overall, we see the same patterns among migrants and never-movers, although the drop in mortality is more pronounced within the migrant community.

Women who have migrated to their current localities benefit more from the opportunities created; service and sales employment and the likelihood of cash earnings increase by 16 pp (Panel B, Column 2). These women are less likely than migrants elsewhere to work in agriculture . This may indicate that it is harder to access farm land in mining communities, due to more intense competition over land resources, or that these women move to such areas to benefit from non-farm employment and therefore naturally select into services and sales. These women are also less likely to feel hindered from accessing healthcare, and their infant mortality rate decreases by 6.6 pp.

It seems like women moving to mining communities take good advantage of economic opportunities generated by mines, but that women born in these communities respond in similar ways. The results indicate that the main results are probably not driven solely by selective inward migration of individuals interested in taking advantage of new opportunities and bringing different norms, but that these individuals add to the local economy and reinforce changes that are already underway.

Large-scale mining can cause both migration and urbanization. Overall, the extent of the migratory movements caused by mining is not well explored, yet research has previously exploited work migration movements to understand health effects of mining (Corno and de Walque, 2012). Most of the research in Africa regarding work migration to mining communities has been carried out in the context of South Africa (e.g., Campbell, 1997 and Moodie and Ndatshe, 1994), which is a special case since the migrant mine labor system was started and maintained during the apartheid rule (Cox et al., 2004). African natural resource extraction has also been linked to urbanization in Africa (Lange, 2006), as the windfall income spurs the creation of "consumption cities" rather than "production cities" (Gollin et al., 2014; Jedwab, 2013). I map the share of the population who have ever migrated and the share who live in an urban community by distance from mine using a spatial lag model that allows for non-linear effects in distance. Figure 3.10 illustrates that urbanization rates are higher close to an active mine than close to a deposit. The likelihood that a community is urban is roughly 15 pp higher close to an active mine than 90-100 km away (i.e., the reference category) and compared with a deposit. The right side of Figure 3.10 shows that migration rates are 5 pp lower close to active mines than close to a deposit, where in turn the migration rates are 5 pp higher than in the control group (omitted category: 90-100 km away). This may seem surprising given the urbanization effect found previously but could be explained by more urbanization migration among the ever-migrants (which is a big share of the total population).

Age at First Marriage, Education, Prostitution and Fertility

In this section I further analyze variables that may have changed with the mine and that could drive the outcomes in the main analysis. The opening of a mine could change (1) marriage patterns (by for example increasing the availability of men through male migration), (2) schooling decisions, (3) sexual habits and engagement in sexual services, and (4) fertility patterns. As any such changes could drive the results in the main analysis, we will continue by exploring mines' effects on these variables. A major caveat to this analysis is that all these outcomes could in fact change in parallel with labor markets and empowerment. If we find changes in these variables, it will be hard to disentangle the causality between them. In fact, the processes could even be reinforcing each other. If we find no changes in these variables, however, then we can exclude them as potential mechanisms.

Age at marriage is an important determinant of women's welfare and labor market participation. There are reasons to expect that a mine could change marriage patterns. For example, a mine could increase the number of available men looking for matrimony by spurring inward migration, or it could change the quality of men available. To investigate whether changed matrimonial behavior is part of the mechanism behind the gains in women's empowerment and infant survival, we check whether a mine affects marriage formation. We do not find that women were significantly older at first marriage if there was an active mine in the community before she turned 14, 19, or 22, or ever in her life (see Table 3.11, Panel A), nor do we find any significant changes in marital status (ever married, currently married or cohabiting, or ever divorced) in mining communities (Appendix, Table B.5 Panel A). The age gap between young women and their partners is generally argued to be negatively related to a woman's bargaining power, yet we do not find any significant changes here either (Table 3.11 Panels C and D). However, we do note that the education of spouses is higher if the woman was below 22 when the mine opened (Panel D). Women aged 22 or younger at mine opening have partners with 1.825 years more education than same-age women further away. In addition, for this group, we estimate a marginal decrease in the likelihood of being in a polygamous marriage (Panel E). The estimated effect is negative also for younger girls, albeit not significant. Overall, it does not seem likely that changing marital patterns are part of the mechanisms behind the estimated impact of a mine opening on female empowerment, although we note that for partners of women who were relatively young when the mine opened to some extent have higher education and are less likely to form polygamous marriages.

Another potential mechanism is higher levels of female education. A mine can have direct impacts on schooling, since it may affect both the demand and the supply of schooling. A mining company can decide to build a school with a corporate social responsibility program, or a mine could increase schooling supply indirectly, by spurring urbanization. However, we find little evidence that increased schooling levels are outcomes of the mines. Women who were less than 14 years old at the time of mine opening do have insignificantly higher education (0.267 years, Column 1, Table 3.12), whereas women under 19 at mine opening (Column 2) have insignificantly lower education than peers further away. We can rule out that higher educational levels are driving the comparatively large increase in service sector employment and the strong changes in norms regarding female empowerment. Possibly, we note small, insignificant effects on schooling, because there is a time lag in the supply and demand effects of schooling. The data does not permit analysis of long-run changes in equilibrium in schooling attainment (which could of course be an outcome of the observed labor market changes).

The mining sector's traditional use of male labor has made it associated with social concerns regarding sexual services. Narratives from artisanal mining communities show that women seeking job opportunities are at risk of sexual violence (Werthmann, 2009) and that gold mining communities in Tanzania have high HIV incidence (Desmond et al., 2005). On the other hand, a study from Zambia shows that sexual risk-taking behavior among young women decreased in mining communities with the copper boom (Wilson, 2012). The results from Zambia are in line with findings that women's supply of sex and, especially, risky sex is elastic to income shocks, and sometimes a strategy to cope with negative income shocks (Dupas and Robinson 2012; Robinson and Yeh, 2012). Looking at lifetime number of sex partners of all women, and separately for women who were below the age of 14, 19, or 22 when the mine opened, we see no increase in the lifetime number of partners (Table 3.12, Panel B). We find no support for the hypothesis that the service sector jobs created are concentrated to work in prostitution. The effects are negative for the girls who were very young when the mines opened (Column 1) but positive for older women, yet no effects are precisely estimated.

The establishment of a mine could possibly change women's fertility patterns and therefore also the composition of children born and the infant mortality rates. Changes in fertility could also affect labor market outcomes, since pregnancies and young children can decrease labor force participation. A mine may influence fertility patterns by changing the opportunity cost of having children (by increasing income foregone), or by improving access to family planning and healthcare services. Additionally, potential pollution from mining could lead to increased risk of spontaneous abortions. There is no clear indication of this in the medical literature, but both arsenic and cyanide are lethal at high doses and infants are more sensitive than their carrying mothers due to their smaller size. We observe a marginally significant decrease in total fertility in response to mine opening (Table 3.12, Column 4), but the decrease is larger among women who were younger than 14 when the mine opened (Column 1). Table B.6 in the Appendix shows additional results, i.e., lower ideal fertility (Column 3) but no changes in contraceptive use, miscarriage rates, or the sex ratio (as indicated by the probability that the child is male). This indicates that changed fertility patterns due to better access to family planning and/or exposure to pollution are driving the changes in infant mortality. However, we cannot exclude the possibility that the marginally significant change in total fertility behavior is affecting infant survival rates.

While we can think of reasons why a mine would affect marriage behavior, education, engagement in prostitution, and fertility behavior, we cannot find evidence pointing toward changes in these factors being the drivers of our main findings.

Service Sector Jobs, Wealth, and Wages

The effect of a mine opening on female empowerment and infant mortality can be caused by for example changes in economic empowerment (e.g., access to service sector job or cash earnings)and gains in household income and wealth. I test these hypotheses in Table 3.13, where I have included controls for service and sales jobs, cash earnings, and household wealth. The first two of these three control variables are, as we have seen in the previous analysis, themselves outcomes of the mine. Columns 1-4 include controls for service and sales jobs. We learn that having a service sector job is a strong predictor of cash earnings, and that women in the service sector are less likely to be hindered from seeking medical care and to accept domestic violence, while they enjoy more say in the household (note that these are not causal estimates). We also note that the treatment variable active*deposit remains statistically significant for healthcare access and domestic violence, indicating that it is unlikely that a mine affects these variables only by stimulating service sector employment.

In Panel B Column 2, we learn that women who earn cash income have better access to medical care, are less accepting of domestic violence, and enjoy more bargaining power in household decisions. The treatment variable, active*deposit, for barriers to healthcare is no longer significant, and a little smaller in magnitude, possibly indicating that own cash earnings are important in determining a woman's access to medical care, which is intuitive since money is one possible barrier to access.

Similarly for a service sector job, the treatment effect for domestic violence is still significant and negative. So while we see that there is a strong correlation between earning cash and being less accepting of domestic violence, it does not seem like the treatment effect of the mine on domestic violence is working purely through the “cash effect”.

In Panel C, Columns 2 and 3, we learn that women with more household wealth have better access to healthcare and lower acceptance of domestic violence. The effect on bargaining power (Column 4) is very small and marginally significant, however. This could be explained by men’s income being an important determinant of both household wealth and a woman’s bargaining power. Also here, the treatment effects of the mine on healthcare access and domestic violence remain negative, although only the latter is significant. However, we must note that no significant changes are found in household wealth, such as the likelihood that the household is poor or rich, has electricity, owns a radio or is female-headed (results available on request).

The estimated effects for infant mortality (all children, boys, and girls) in Columns 5-7 show that including a control for service sector employment or cash earnings does not change the results significantly, but controlling for household wealth reduces the coefficient for active*deposit significantly.

We learn that it is more common to earn income paid in money in mining communities when there is a mine, but far from all workers earn cash income. Additionally, the DHS data does not tell us anything regarding the wage rate. I complement the study with Living Standard Measurement Survey (LSMS) data for Ghana, collected by the World Bank together with the Ghanaian Bureau of Statistics. I use the rounds for which we have spatial information: 1998, 2005, and 2012.

The LSMS data contains information on whether the individual has worked in the last 12 months (for cash, in-kind payment, or barter), in the last seven days, in what industry (agriculture, mining and services), and wage from main job (defined as the job the person spent most time doing last week, with all non-paid employees having no wage) and number of hours worked per week. Table 3.14 Column 7 shows that wage rate is unchanged for men, but increases for women as indicated by the interaction term active*deposit*woman, although women have lower wage rates to start with (as indicated by the coefficient for woman). We also confirm that men benefit from direct employment effects, i.e., in mining (Column 6), whereas women benefit from indirect job creation in the service sector (Column 5). The results suggest a decrease in work participation on the extensive margin, but an increase on the intensive margin as number of hours worked increases (insignificant). Column 8 indicates that household income increases significantly.

Correlations show that women in service and sales jobs and women earning cash are more empowered (according to our three indexes), and so are women from wealthier households. We have previously found that women in mining communities are more likely to be working in this sector, earn cash, and enjoy higher wage rates. Controlling for these economic empowerment indicators, we find that the effect of the active mine decreases in general. This indicates that the effect of the mine on female empowerment occurs partly through an economic empowerment channel.

The effect of economic empowerment on infant health is less clear, and from the correlations it seems like household wealth is the strongest predictor of infant survival. The mechanisms behind the drop in infant mortality remain unclear. We find that the mine affects (1) household income, women’s income, and healthcare access, which may be predictive of lower infant mortality, but (2) by affecting women’s wages, the opportunity cost of child care may have increased, which may have had negative effects on infant survival. We estimate the composite effect of the mine on infant mortality and find stark evidence that the rate decreases, meaning that we know that the first set of effects dominate the second set, although we cannot say which ones of these matter, and how much.

3.6 Discussion

The large-scale gold mining industry is rapidly expanding in Africa, yet we have a limited understanding of how large-scale mining operations affect local communities. In this analysis, I have attempted to fill the knowledge gap regarding women's welfare in the wake of the mining boom. The analysis contributes to the understanding of a more general question: whether local industrial shocks can empower women.

Using micro data from eight African countries, I show that the gold mining industry brings indirect employment for women by stimulating the demand for services. In mining communities, women are more likely to work in services and sales, in contrast to control communities, where women are more likely to engage in agriculture. Additional welfare increases are noted: Women in mining communities are 23% less likely to state a barrier to healthcare and 24% less likely to accept domestic violence. Infant mortality more than halves and the drop is larger for girls than for boys. We observe stronger effects when the price of gold is high, which can be explained by a high price leading to higher production volumes and/or higher wages to miners, and more trickle down of economic effects into mining communities. I find some support for agglomeration economies, as the effects are stronger in communities close to several mines. These main results are robust to different assumptions about trends, different distance measures, and exclusion of migrants, and withstand a spatial randomization placebo test. I rule out that the expansion in service sector employment and female empowerment observed in connection with the opening of a mine occurred through increased engagement in sexual services, increased schooling attainment, or changes in marriage formation. I find some indication that gains in household welfare could be an important factor in determining child survival, and that urbanization is a likely channel through which the effects of the mine are reinforced. The study shows that norms regarding domestic violence and women's labor market participation (in non-farm activities) can change rapidly with local industrialization, without having to first raise education levels.

I show that local gold mining booms are effective in raising women's employment in modern sectors such as services and sales. RCTs that aim at increasing labor participation rates of (young) women find magnitudes of 2.4 percentage points to 6.8 percentage points, at costs ranging from 12 USD per woman to 812 USD per woman[36]. However, these studies do not discuss the implicit shift from other activities that enabled the increase in time spent on income-generating activities. Women who were previously not working might have engaged in household chores and seasonal subsistence farming, which would not be classified as "work away from home" or "income generating activities." If so, our estimates of a 9-11.5 pp increase in service and sales employment are large compared with the literature and are similar to the effects of a rural electrification program in South Africa, where participation increased by 9 pp (Dinkelman, 2011). The implication is that large-scale mines are effective in stimulating women's engagement in non-farm employment.

Using the Ghana Living Standards Measurement Survey, I look at the worth of a service sector job for a

[36]Magnitudes range from 6.1pp increase in employment (Attanasio et al., 2011) at the cost of 812 USD/person. 6.8pp (72% increase) among teenage women (Bandiera et al., 2014, at the cost of 85 USD per participating woman, or 17.9 USD per woman in the intention-to-treat group). 2.4pp increase women working away from home (11%, at the cost of 12 dollars per woman, Jensen, 2012). The rate of return on all these interventions were positive.

woman. In Ghana, women working in services and sales have a mean daily wage rate roughly 80% higher than women working in agriculture (with at least some cash earnings; note that this excludes women in agriculture who only earn in-kind or nothing at all). Correcting for the longer workdays of women in the service sector (7.5 h compared with 4.7 h in agriculture), there is still a substantial wage gap between agricultural and service sector workers: women in services earn on average 12.3% more per hours. The wage gap is indicative of productivity differences across sectors. Empirical analysis has confirmed this pattern in Africa, with too many workers stuck in low-productivity agriculture (Gollin et al., 2014). By stimulating modern sector employment, large scale mining can thus help decrease the sectoral productivity gap by pulling women from low-productivity agriculture to higher paying service sector jobs.

The estimated gains from mining stretch beyond the labor markets. One pressing issue globally is intimate partner violence. In 2010, it was estimated that 30% of women worldwide had experienced this type of violation (Devries et al., 2013), and the prevalence is among the highest in Sub-Saharan Africa. The global costs of this problem are estimated to 5.18% of world GDP (Fearon and Hoeffler, 2014), and sexual violence against women costs an additional 0.078% of world GDP annually. This includes direct health costs, losses of current and future income, and psychological costs for women and children. In this paper, I estimate that women's acceptance rate of violence decreases from an almost shockingly high mean (almost 1 in 2 women believe that violence is justified) by 24%. Although attitudes to domestic violence may only be weakly correlated with actual violence, changes in attitudes are necessary for a long-run transition to lower equilibrium levels of experienced violence. Women not accepting violence is a first step to a violence-free society. If a 24% reduction in acceptance of domestic violence leads to anything from a 1% to a 24% decrease in the prevalence of violence, the economic gains may be huge. It is beyond the scope of the present study to quantify the monetary gains from such a potential decrease in violence, however.

Despite concerns that revenues from mining are unevenly distributed, both between mining companies and local communities and between men and women, the analysis confirms that mining can change the welfare of women and infants. Although the analysis is not a complete welfare analysis of women's conditions in mining communities, it is the largest, most ambitious, quantitative attempt to date. I welcome further analysis in the future using a richer set of outcomes. The main counterfactual in this study is "no mine," and I estimate the average impact of a large gold mine. Policy makers may want to consider another counterfactual, where policies are in place to stimulate local communities' economies, and to ensure that women benefit from the mining activities. The next step should be to evaluate policies in order to understand how such positive effects can be reinforced and what best-practice really entails.

Tables and Figures

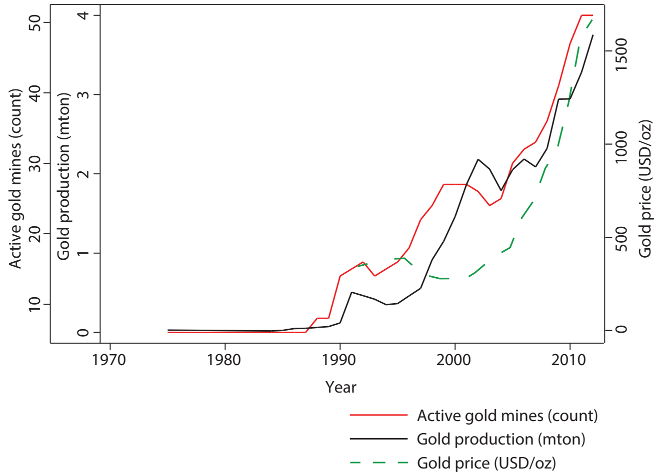


Figure 3.1: The Evolution of the Gold Mines, Production of Gold and the World Price of Gold in Burkina Faso, Cote d'Ivoire, DRC, Ethiopia, Ghana, Guinea, Mali, Senegal and Tanzania

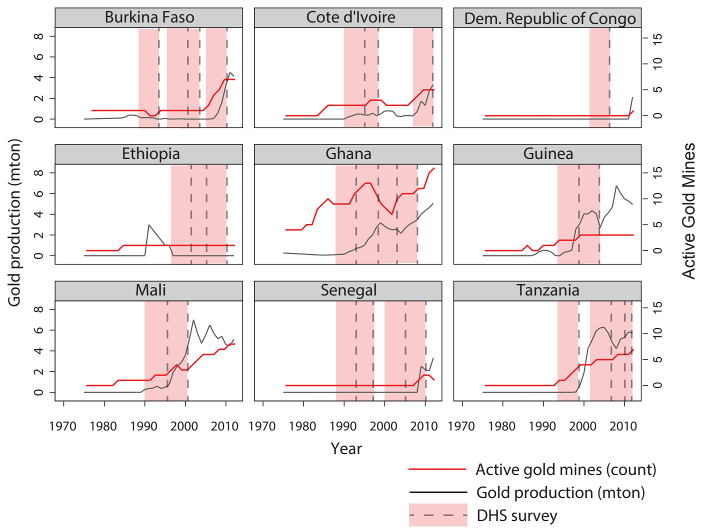


Figure 3.2: The Evolution of the Production of Gold and the Demographic and Health Survey Years by Country

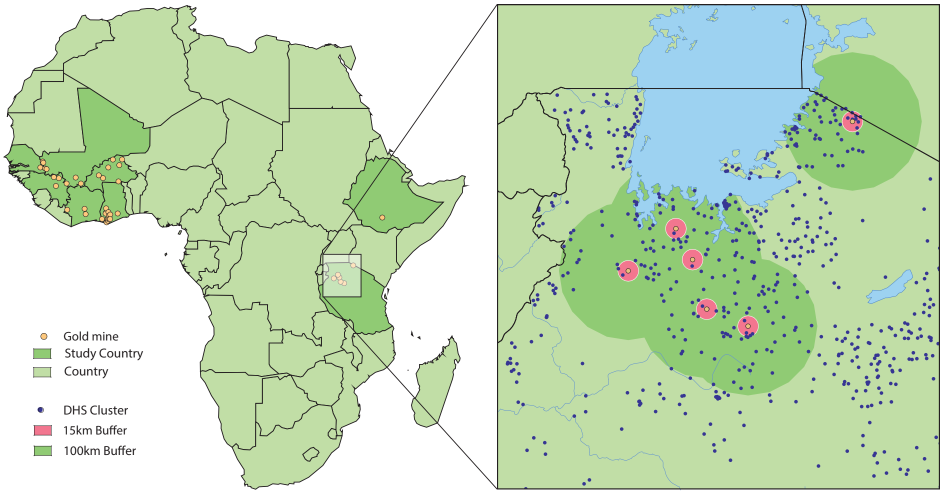


Figure 3.3: Map of Gold Mines and DHS Clusters in North-Western Tanzania

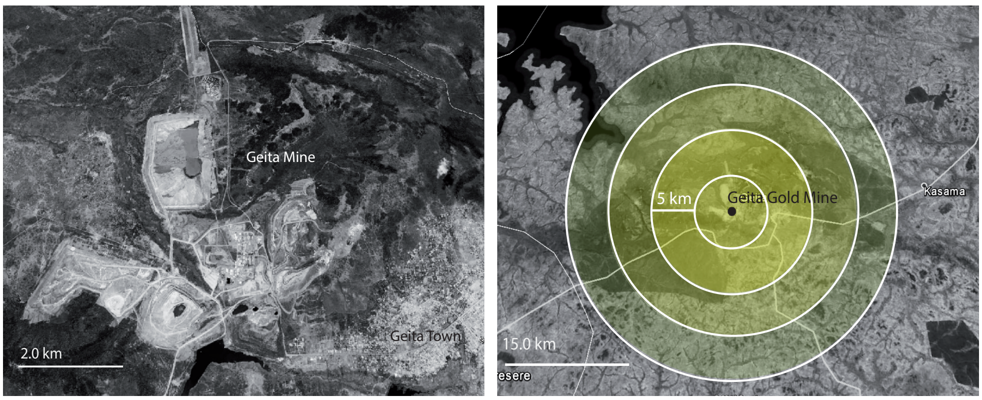


Figure 3.4: Geita Gold Mine and the Lake Victoria Basin

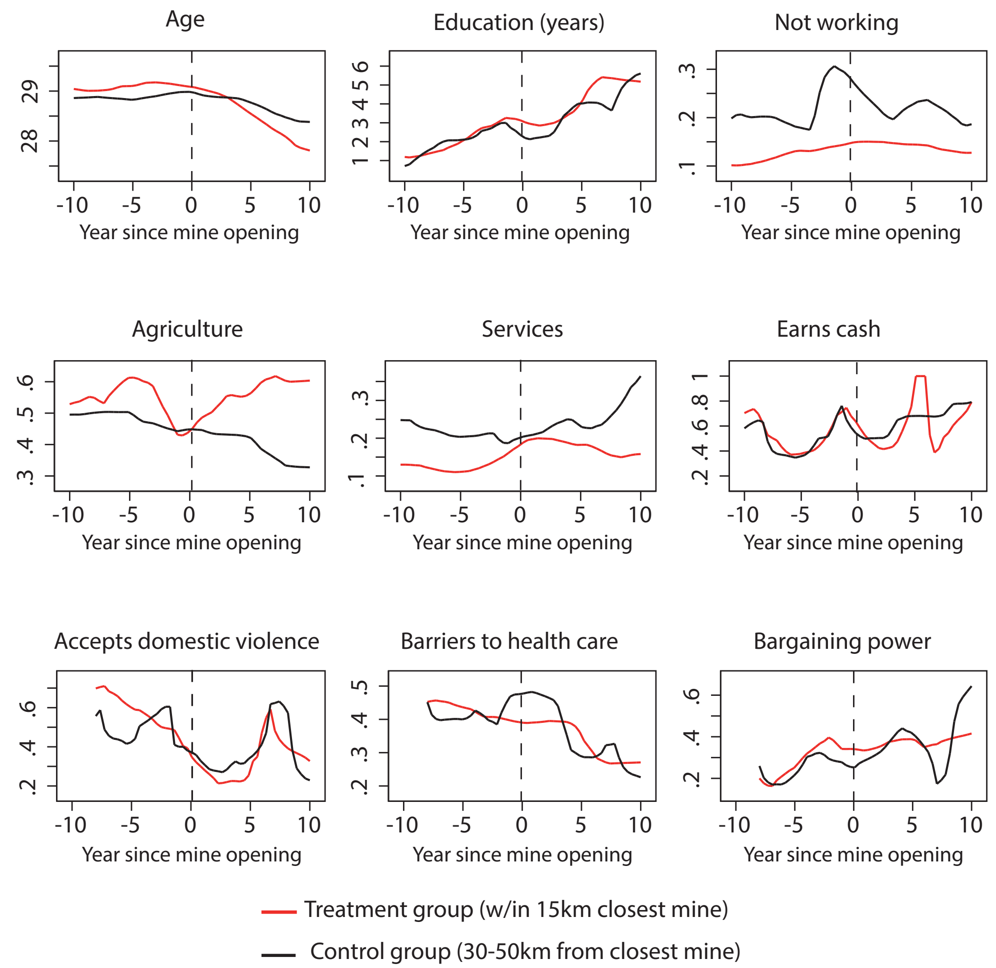


Figure 3.5: Non-parametric Investigation of Trends in Woman Sample

Notes: Local polynomial smooth. Years since mine opening on the horizontal axis, ranging from ten years before to ten years after mine opening. The treatment group is drawn within 15 km from the closest mine, and the control group 30-50 km from the closest mine. The estimates are without control variables, and are not considering if an individual is close to several mines, or if the closest mine closes down production.

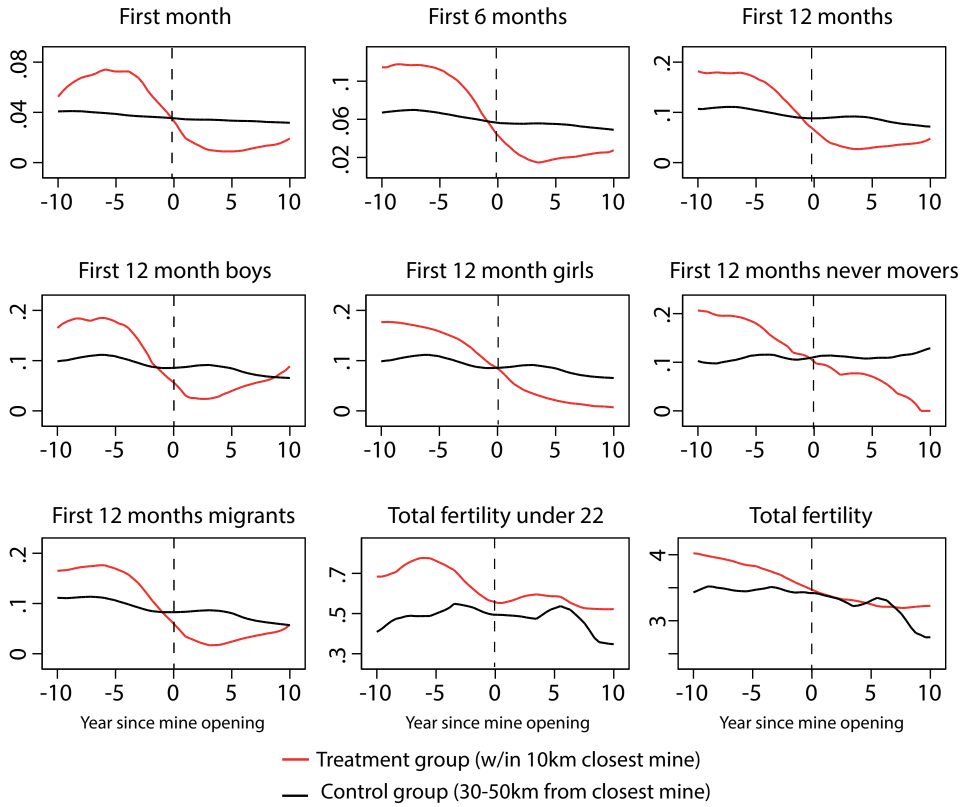


Figure 3.6: Non-parametric Investigation of Trends in Infant Mortality (First month, 6 months, or 12 months) and Fertility in the Child Sample

Notes: Local polynomial smooth for infant mortality rates and fertility rates for mothers. Years since mine opening on the horizontal axis, ranging from ten years before mine opening to ten years after mine opening. Treatment group is drawn within 10km from the closest mine, and the control group 30-50km from the closest mine. The estimates are without control variables, and are not considering if an individual is close to several mines, or if the closest mine closes down production. "Boys" and "girls" refer to male children and female children born. The graph for never-movers refers to children born to mothers who have never moved, and the graph for "migrants" refers to children born to women who have moved. Total fertility under 22 is total fertility for women aged 22 and under at the time of the survey.

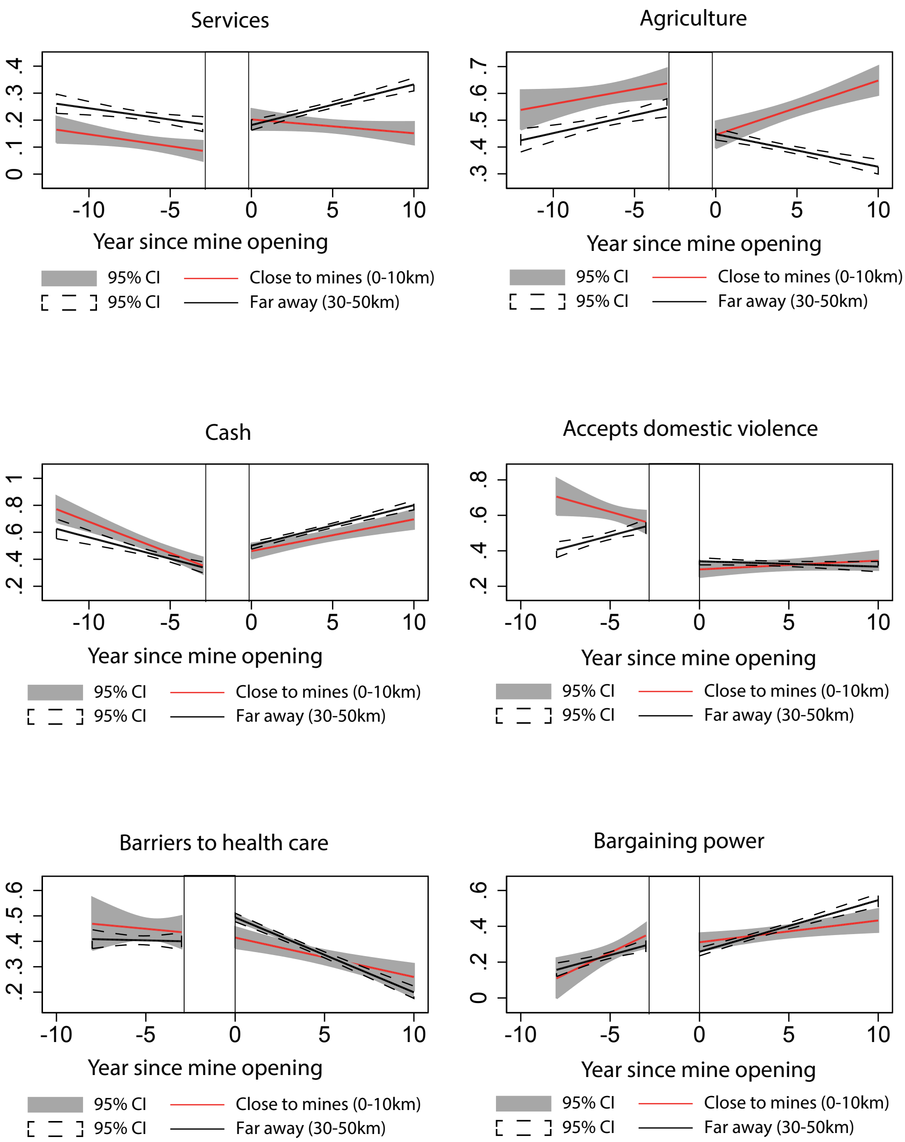


Figure 3.7: Linear Trends in Woman Sample

Notes: Linear trends. Years since mine opening on the horizontal axis, ranging from ten years before mine opening to ten years after mine opening. Treatment group is drawn within 15 km from the closest mine, and the control group 30-50 km from the closest mine. The estimates are without control variables, and are not considering if an individual is close to several mines, or if the closest mine closes down production.

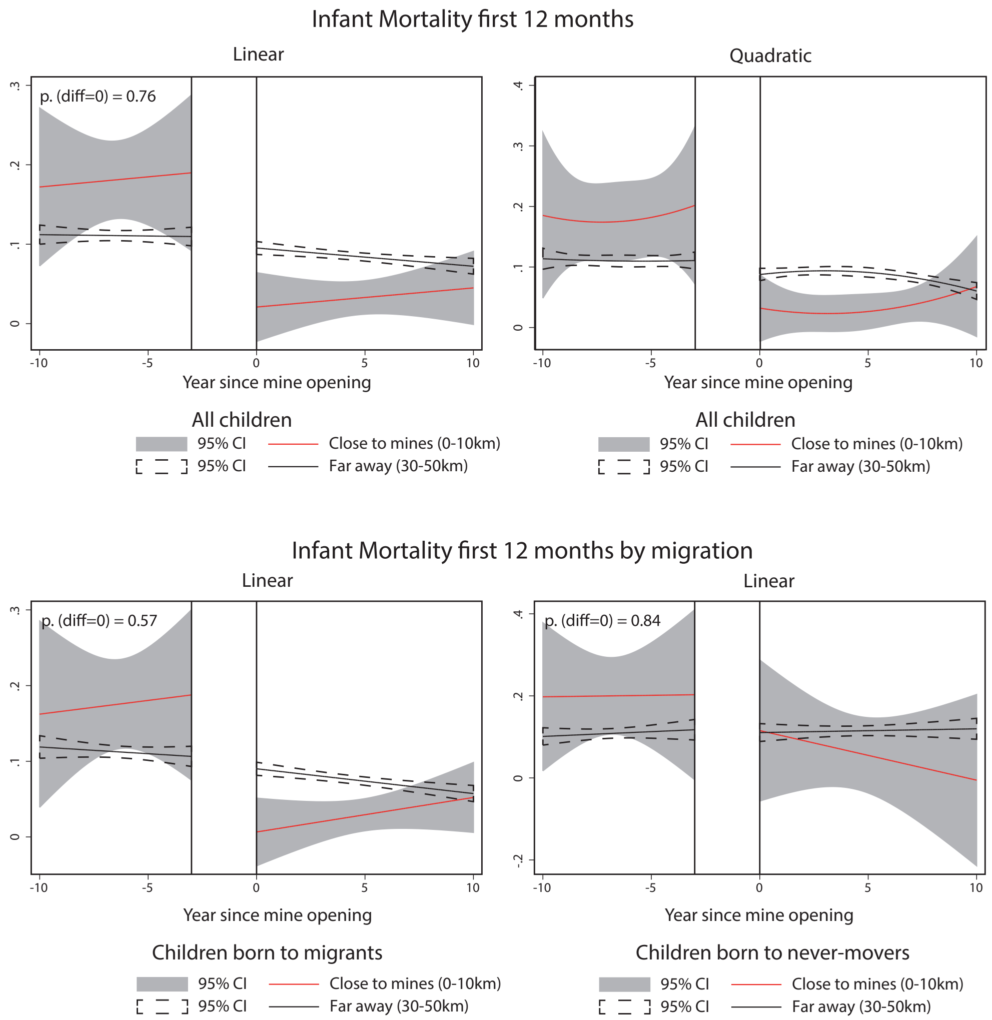


Figure 3.8: Linear and Quadratic Trends in Child Sample

Notes: Linear trends. Years since mine opening on the horizontal axis, ranging from ten years before mine opening to ten years after mine opening. Treatment group is drawn within 10 km from the closest mine, and the control group 30-50 km from the closest mine. The estimates are without control variables, and are not considering if an individual is close to several mines, or if the closest mine closes down production.

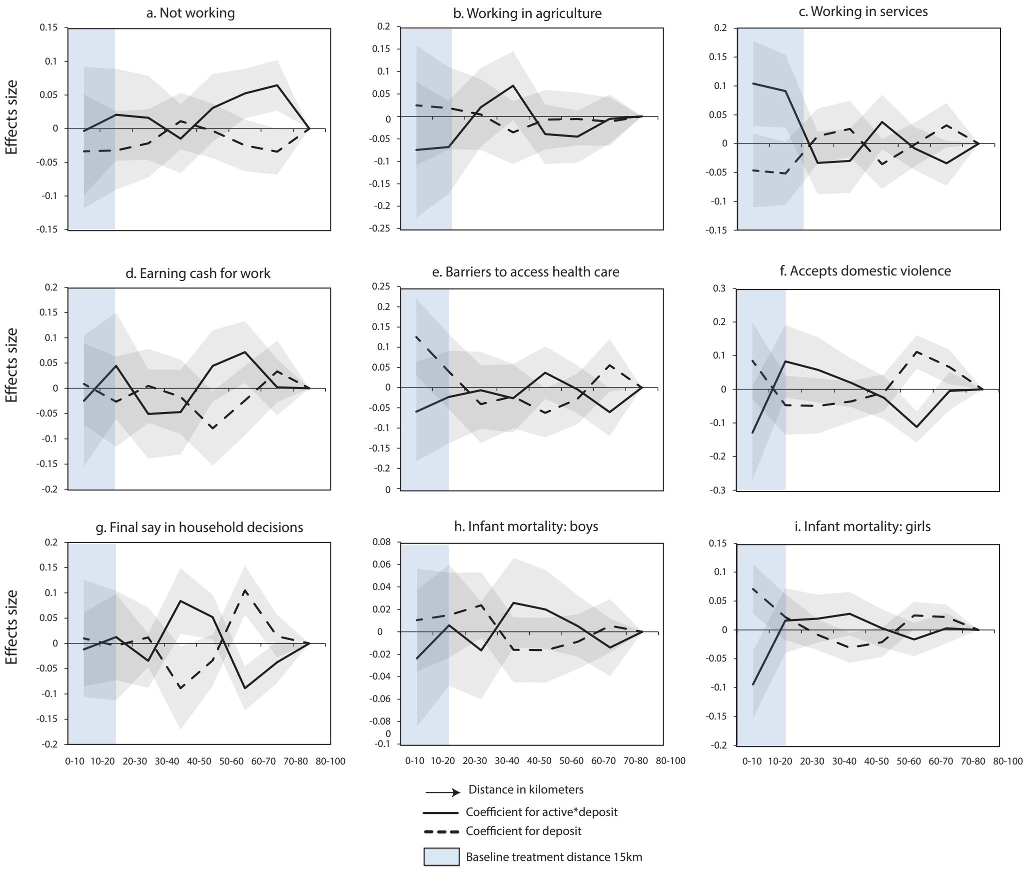


Figure 3.9: Spatial Lag Model: Main outcomes

Notes: The figure shows the coefficients from a spatial lag model by 10km distance bins with 95% confidence intervals. The omitted category is 80-100km away from a mine.

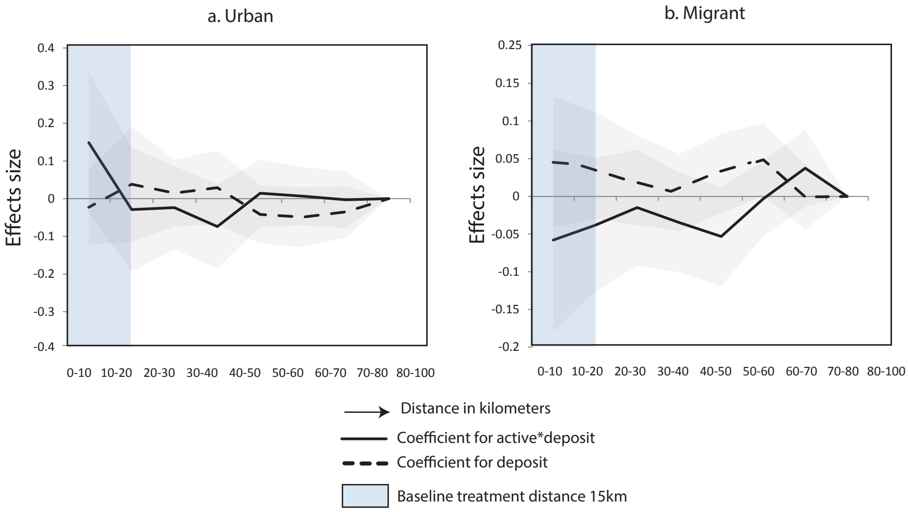


Figure 3.10: Spatial lag model: Urbanization and Migration

Notes: Regression results from two spatial lag models using 10 km bins for the outcomes urban (Figure a) and migrant (Figure b), with 95% confidence intervals.

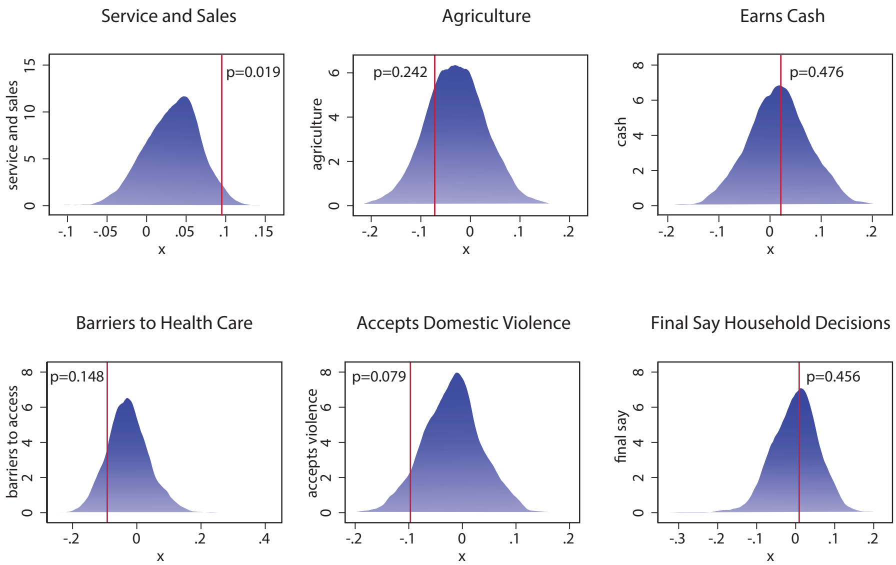


Figure 3.11: Spatial Randomization Placebo Test

Notes: Figure 3.11 shows the density distribution of point estimates from 1,500 re-estimations of the baseline specification with the mine location randomly moved up to 50 km from original mine location. The likelihood of a woman working in the service sector (baseline specification), and the likelihood of a woman accepting domestic violence (count), with the baseline coefficients marked by the red vertical line.

Table 3.1: Summary Statistics for the Women Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean value					Min	Max
Sample	whole sample	control group	treatment group	control group	treatment group		
Time period		pre	pre	post	post		
Woman characteristics							
age	28.7	28.8	28.9	28.6	28.4	15	49
education	2.95	2.45	2.94*	3.26	4.55	0	22
fertility	3.26	3.25	3.60*	3.26	3.05	0	21
never mover	0.407	0.402	0.384	0.420	0.365	0	1
urban	0.27	0.301	0.130*	2.451	0.214	0	1
year	2006	2000	2001*	2005	2006		
Occupational outcomes							
not working	0.201	0.190	0.148*	0.213	0.171	0	1
agriculture	0.438	0.428	0.521*	0.443	0.449	0	1
service and sales	0.233	0.276	0.169*	0.202	0.228	0	1
earns cash	0.563	0.512	0.566*	0.602	0.621	0	1
Empowerment indexes							
barriers to healthcare	0.393	0.395	0.364*	0.395	0.327	0	1
accepts domestic violence	0.404	0.437	0.437	0.386	0.298	0	1
bargaining power	0.318	0.281	0.354*	0.339	0.414	0	1
Treatment variables							
active * deposit (15km)	0.026					0	1
deposit (15km)	0.047					0	1
active (100km)	0.559					0	1
intensity (# mines w/in 15km)	0.031					0	3
gold price (USD/oz)	599.2					270.98	1570.62
N	57,676	24,772	1,052	30,218	1,634		

Note: control group is within 15-100 km from a deposit; treatment group is 0-15 km from deposit
pre-treatment, control group has deposit = 0, and no active mine within 100 km
pre-treatment, treatment group has deposit = 1, but no active mine within 15 km
post-treatment, control group has deposit = 0, and at least 1 active mine within 100 km
post-treatment group has deposit = 1, and at least 1 active mine within 15 km
* p<0.05 for t-test between control group (2) and treatment group (3), pre-treatment

Table 3.2: Summary Statistics for the Child Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean value					Min	Max
Sample	whole sample	control group	treatment group	control group	treatment group		
Time period		pre	pre	post	post		
Mother characteristics							
age	29.17	29.54	28.86*	28.73	28.27	15	49
education	1.88	1.333	1.876*	2.483	4.880	0	21
urban	0.187	0.194	0.044*	0.181	0.236	0	1
Child characteristics							
male	0.506	0.506	0.512	0.506	0.550	0	1
birth number	3.97	3.996	4.290*	3.96	3.676	0	17
birth year of child	2000	1999	1997*	2003	2003	1987	2012
Infant mortality							
1 month	0.038	0.042	0.066*	0.035	0.024	0	1
6 months	0.057	0.070	0.108*	0.057	0.030	0	1
12 months	0.097	0.106	0.151*	0.091	0.048	0	1
12 months boys	0.103	0.110	0.15*	0.097	0.063	0	1
12 months girls	0.093	0.102	0.154*	0.085	0.030	0	1
Treatment variables							
active * deposit (10km)	0.010					0	1
deposit (10km)	0.023					0	1
active (100km)	0.459					0	1
intensity (# mines within 10km)	0.022					0	3
gold price (USD/oz)	536.2					271	1571
gold price* mine	0.118					0	15.71
gold price* active * deposit	0.069					0	15.71
rainfall (trimester)	0.01					0	2.11
N	48,151	25,583	639	21,438	491		

Note: control group is within 10-100km from a deposit; treatment group is 0-10 km from deposit
pre-treatment, control group has deposit = 0, and no active mine within 100 km
pre-treatment, treatment group has deposit = 1, but no active mine within 10 km
post-treatment, control group has deposit = 0, and at least 1 active mine within 100 km
post-treatment group has deposit = 1, and at least 1 active mine within 10 km
* p<0.05 for t-test between control group (2) and treatment group (3), pre-treatment

Table 3.3: Occupation, Empowerment and Infant Mortality

	(1)	(2)	(3)	(4)
	Occupational outcomes			
	not working	agriculture	service and sales	cash
Panel A.				
active*deposit	0.047	-0.072	0.095***	0.021
	(0.031)	(0.049)	(0.026)	(0.045)
deposit	-0.071**	0.021	-0.037	-0.018
	(0.032)	(0.047)	(0.022)	(0.036)
N	55,944	55,944	55,944	35,020
R^2	0.197	0.403	0.164	0.356
controls (age, education, urban)	Y	Y	Y	Y
FE year, country-year, district	Y	Y	Y	Y
mean outcome variable	0.201	0.438	0.233	0.563
	Empowerment indexes			
	barriers to healthcare access	accepts domestic violence	household bargaining power	
Panel B.				
active*deposit	-0.092**	-0.097**	0.009	
	(0.046)	(0.042)	(0.049)	
deposit	0.033	0.055	-0.023	
	(0.035)	(0.039)	(0.038)	
N	31,485	30,693	27,482	
R^2	0.240	0.344	0.286	
controls (age, education, urban)	Y	Y	Y	
FE year, country-year, district	Y	Y	Y	
mean outcome variable	0.393	0.406	0.318	

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. Panels A and B include controls for age, education, urban, and fixed effects for survey year, district, and country-year. Panel A shows results for binary occupational outcomes, (1) if the woman is working (in the last 12 months), (2) if she works in agriculture, (3) services or sales, (4) if she earns cash income for her work (not in-kind or nothing). Panel B shows results for empowerment index variables ranging from 0 to 1. Column (1) "Is money/distance/permission an obstacle to seeking healthcare for yourself?", Column (2): "Is a husband justified to beat his wife if she burns the food/refuses sex/goes out without his permission/neglects the children?" Column (3) "Do you have, alone or together with your partner, a say in healthcare/large purchases/family visits decisions." Active*deposit takes a value of 1 if there is an actively producing mine within 15 km from the household locality in the survey year.

Table 3.4: OLS results for Neonatal Mortality and Infant Mortality at 10km

	(1)	(2)	(3)	(4)	(4)
			infant mortality		
months	1	6	12	12	12
sample	all	all	all	male	female
Panel A: 10 km					
active*deposit (10km)	-0.031***	-0.056***	-0.060***	-0.042	-0.076***
	(0.011)	(0.015)	(0.020)	(0.028)	(0.026)
deposit (10km)	0.024**	0.037***	0.039**	0.024	0.056***
	(0.009)	(0.012)	(0.016)	(0.021)	(0.021)
N	48,107	43,003	37,365	18,982	18,383
R^2	0.018	0.027	0.038	0.047	0.049
Panel B: 15 km					
active*deposit (15km)	-0.013	-0.017	-0.009	0.016	-0.034
	(0.010)	(0.013)	(0.018)	(0.025)	(0.023)
deposit (15km)	0.018**	0.023**	0.025*	0.008	0.041**
	(0.008)	(0.011)	(0.014)	(0.018)	(0.018)
N	48,107	43,003	37,365	18,982	18,383
R^2	0.018	0.027	0.038	0.047	0.049
Panel C: Spatial lag model					
active*deposit (0-10km)	-0.035***	-0.054***	-0.057***	-0.021	-0.091***
	(0.012)	(0.016)	(0.021)	(0.031)	(0.030)
active*deposit (10-20km)	0.002	0.018	0.028	0.030	0.026
	(0.009)	(0.013)	(0.018)	(0.023)	(0.025)
active*deposit (20-30km)	0.005	0.001	0.003	-0.018	0.024
	(0.007)	(0.009)	(0.012)	(0.019)	(0.019)
N	48,107	43,003	37,365	18,982	18,383
R^2	0.018	0.027	0.038	0.047	0.049
mother, child controls	Y	Y	Y	Y	Y
FE birth month, year	Y	Y	Y	Y	Y
FE country-year, district	Y	Y	Y	Y	Y
Mean value	0.038	0.057	0.097	0.103	0.093

Note: *** p<0.01, ** p<0.05, * p<0.1 Clustered standard errors clustered at DHS cluster level. All regressions control for mother's age, age square, mother's education, urban, child's birth number, and fixed effects for birth year, birth month, district, and country-year. Outcomes are infant mortality in first month (column 1), first 6 months (column 2), and first 12 months (Column 3) of life, all with 10 km treatment distance.

Table 3.8: Changing the Control Group: Drop Individuals 15-30 or 10-30 km Away

	(1) service and sales	(2) barriers to healthcare	(3) accepts violence	(4) infant mortality	(5) mortality boys	(6) mortality girls
Panel A. Drop individuals 10/15 - 30 km away						
active*deposit	0.088***	-0.108**	-0.101**	-0.089***	-0.076**	-0.100***
	(0.028)	(0.046)	(0.046)	(0.024)	(0.033)	(0.030)
deposit	-0.039	-0.001	0.042	0.054***	0.042	0.068**
	(0.027)	(0.038)	(0.050)	(0.020)	(0.026)	(0.026)
N	50,523	28,844	28,107	32,898	16,737	16,161
R^2	0.165	0.237	0.349	0.033	0.042	0.044
Panel B: Drop 2 years before opening						
active*deposit	0.103***	-0.093*	-0.084**	-0.066***	-0.050*	-0.082***
	(0.027)	(0.049)	(0.036)	(0.020)	(0.028)	(0.028)
deposit	-0.050**	0.035	0.052	0.044***	0.034	0.057**
	(0.023)	(0.038)	(0.033)	(0.016)	(0.023)	(0.022)
N	54,707	31,393	30,604	33,127	16,814	16,313
R^2	0.165	0.240	0.345	0.035	0.044	0.049
controls	Y	Y	Y	Y	Y	Y
survey year FE	Y	Y	Y			
birth year FE				Y	Y	Y
country-year	Y	Y	Y	Y	Y	Y
district FE	Y	Y	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1 Clustered standard errors clustered at DHS cluster level. All regressions Columns 1-3 control for woman's age, education, urban, and fixed effects for survey year, district, and country-year. All regressions Columns 4-6 control for mother's age, age square, mother's education, birth order, urban, and fixed effects for birth year, birth month, district, and country-year.

Table 3.5: Alternative Specifications: Occupation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	nothing	controls	controls	baseline	FE	FE	FE	trend	cluster
A: Not working									
active * deposit	0.014	-0.006	0.046	0.047	0.016	0.047	0.045	0.064**	0.047
	(0.032)	(0.030)	(0.031)	(0.031)	(0.030)	(0.031)	(0.031)	(0.032)	(0.032)
deposit	-0.046*	-0.045*	-0.068**	-0.071**	-0.044*	-0.071**	-0.066**	-0.082**	-0.071**
	(0.026)	(0.023)	(0.032)	(0.032)	(0.025)	(0.032)	(0.032)	(0.032)	(0.031)
active									
B: Agriculture									
active * deposit	-0.068	-0.018	-0.067	-0.072	-0.072	-0.072	-0.071	-0.048	-0.072
	(0.067)	(0.064)	(0.057)	(0.049)	(0.047)	(0.049)	(0.050)	(0.052)	(0.057)
deposit	0.080	0.081*	0.007	0.021	0.043	0.021	0.007	0.007	0.021
	(0.050)	(0.048)	(0.052)	(0.047)	(0.039)	(0.047)	(0.049)	(0.050)	(0.052)
active									
C: Service and Sales									
active * deposit	0.071**	0.057*	0.092***	0.095***	0.115***	0.095***	0.087***	0.071***	0.095***
	(0.032)	(0.031)	(0.030)	(0.026)	(0.026)	(0.026)	(0.027)	(0.028)	(0.029)
deposit	-0.077***	-0.078***	-0.026	-0.037	-0.069***	-0.037	-0.033	-0.024	-0.037
	(0.021)	(0.019)	(0.026)	(0.022)	(0.020)	(0.022)	(0.023)	(0.023)	(0.023)
active									
D: Cash earnings									
active * deposit	0.034	-0.012	0.005	0.021	0.043	0.021	0.010	0.045	0.021
	(0.068)	(0.060)	(0.046)	(0.045)	(0.042)	(0.045)	(0.047)	(0.048)	(0.051)
deposit	0.026	0.016	-0.009	-0.018	-0.032	-0.018	-0.008	-0.025	-0.018
	(0.049)	(0.042)	(0.038)	(0.036)	(0.030)	(0.036)	(0.037)	(0.036)	(0.043)
active									
age, education		yes	yes	yes	yes	yes	yes	yes	yes
urban				yes	yes	yes	yes	yes	yes
year fe			yes	yes	yes	yes	yes	yes	yes
country fe					yes				
district fe			yes	yes		yes	yes	yes	yes
country * year fe			yes	yes			yes		yes
mine fe							yes		
district time trend								yes	
district clustering									yes

*** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level, except Column 9. Column (1) has no control variables, Column (2) and (3) adds individual controls. The other specifications add fixed effects, linear time trends and vary clustering.

Table 3.6: Alternative Specifications: Female Empowerment

	(1) nothing	(2) controls	(3) controls	(4) baseline	(5) FE	(6) FE	(7) FE	(8) trend	(9) cluster
A: Justifies domestic violence									
active * deposit	-0.253***	-0.221***	-0.089**	-0.097**	-0.118**	-0.097**	-0.087**	-0.098*	-0.097*
	(0.086)	(0.068)	(0.043)	(0.042)	(0.047)	(0.042)	(0.044)	(0.051)	(0.052)
deposit	0.118	0.139**	0.050	0.055	0.039	0.055	0.058	0.045	0.055
	(0.074)	(0.056)	(0.040)	(0.039)	(0.038)	(0.039)	(0.041)	(0.044)	(0.038)
active									
B: Barriers to health care access									
active * deposit	-0.061	-0.041	-0.078	-0.092**	-0.052	-0.092**	-0.101**	-0.110**	-0.092*
	(0.050)	(0.044)	(0.048)	(0.046)	(0.044)	(0.046)	(0.050)	(0.055)	(0.054)
deposit	-0.007	0.005	0.026	0.033	0.021	0.033	0.028	0.037	0.033
	(0.035)	(0.028)	(0.038)	(0.035)	(0.030)	(0.035)	(0.039)	(0.039)	(0.030)
active									
C: Bargaining power)									
active * deposit	0.057	0.035	0.005	0.009	-0.028	0.009	-0.000	-0.001	0.009
	(0.073)	(0.061)	(0.049)	(0.049)	(0.050)	(0.049)	(0.053)	(0.044)	(0.069)
deposit	0.043	0.028	-0.021	-0.023	0.038	-0.023	-0.015	-0.030	-0.023
	(0.061)	(0.050)	(0.038)	(0.038)	(0.041)	(0.038)	(0.041)	(0.034)	(0.045)
active									
age, education		yes	yes	yes	yes	yes	yes	yes	yes
urban				yes	yes	yes	yes	yes	yes
year fe			yes	yes	yes	yes	yes	yes	yes
country fe					yes				
district fe			yes	yes		yes	yes	yes	yes
country * year fe			yes	yes			yes		yes
mine fe							yes		
district time trend								yes	
district clustering									yes

*** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level, except Column 9. Column (1) has no control variables, Column (2) and (3) adds individual controls. The other specifications add fixed effects, linear time trends and vary clustering.

Table 3.7: Alternative Specifications: Infant Mortality in the First 12 Months of Life

	(1) controls	(2) control	(3) control	(4) baseline	(5) FE	(6) FE	(7) FE	(8) trend	(9) cluster
A: All children									
active * deposit	-0.102***	-0.086***	-0.065***	-0.063***	-0.051***	-0.063***	-0.068***	-0.051**	-0.063***
	(0.023)	(0.022)	(0.020)	(0.020)	(0.019)	(0.020)	(0.019)	(0.021)	(0.023)
deposit	0.051**	0.051***	0.042***	0.041***	0.037**	0.041***	0.041***	0.036**	0.041**
	(0.020)	(0.019)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.018)	(0.019)
N	37,402	37,387	37,365	37,365	37,387	37,365	37,365	37,365	37,365
R^2	0.001	0.005	0.033	0.033	0.019	0.033	0.034	0.044	0.033
B: Boys									
active * deposit	-0.085***	-0.071**	-0.046	-0.043	-0.035	-0.043	-0.049*	-0.032	-0.043
	(0.029)	(0.029)	(0.034)	(0.035)	(0.025)	(0.028)	(0.027)	(0.029)	(0.035)
deposit	0.044*	0.044**	0.028	0.027	0.028	0.027	0.028	0.021	0.027
	(0.023)	(0.022)	(0.026)	(0.025)	(0.019)	(0.021)	(0.021)	(0.022)	(0.025)
N	19,007	18,995	18,982	18,982	18,995	18,982	18,982	18,982	18,982
R^2	0.000	0.005	0.042	0.042	0.019	0.042	0.044	0.054	0.042
C: Girls									
active * deposit	-0.124***	-0.105***	-0.081***	-0.080***	-0.072***	-0.080***	-0.082***	-0.071***	-0.080***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.025)	(0.027)	(0.027)	(0.026)	(0.026)
deposit	0.059***	0.059***	0.057***	0.056***	0.046**	0.056***	0.054***	0.051**	0.056**
	(0.023)	(0.022)	(0.022)	(0.021)	(0.020)	(0.021)	(0.021)	(0.024)	(0.025)
N	18,395	18,392	18,383	18,383	18,392	18,383	18,383	18,383	18,383
R^2	0.001	0.005	0.044	0.044	0.021	0.044	0.046	0.058	0.044
age, education		yes	yes	yes	yes	yes	yes	yes	yes
urban				yes	yes	yes	yes	yes	yes
birth year fe			yes	yes	yes	yes	yes	yes	yes
birth month fe			yes	yes	yes	yes	yes	yes	yes
country fe					yes				
district fe			yes	yes		yes	yes	yes	yes
country*year fe			yes	yes			yes		yes
mine fe							yes		
district trend								yes	
dist. cluster									yes

*** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level, except Column 9. Column (1) has no control variables, Column (2) and (3) adds individual controls. The other specifications add fixed effects, linear time trends and vary clustering.

Table 3.9: Using World Price of Gold to Estimate Effects on Occupation, Empowerment, and Infant Mortality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		occupation		earns	accepts	barriers to	bargaining	infant
	no work	agric.	services	cash	violence	healthcare	power	mortality
Panel A. Goldprice I								
goldprice*	0.012*	-0.024**	0.021***	0.005	-0.017**	-0.010	0.002	-0.015***
active*deposit	(0.007)	(0.011)	(0.006)	(0.011)	(0.007)	(0.009)	(0.010)	(0.004)
goldprice*	-0.017**	0.024**	-0.015***	-0.008	0.018**	0.005	-0.003	0.012***
deposit	(0.008)	(0.011)	(0.005)	(0.010)	(0.007)	(0.009)	(0.009)	(0.004)
Panel B. Goldprice II								
goldprice*	-0.005**	0.002	0.004*	-0.002	0.001	-0.004	-0.001	0.001
deposit	(0.002)	(0.004)	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)
means								
dep. var.	0.201	0.438	0.233	0.563	0.394		0.404	0.318
price*deposit	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249
price*active	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179
controls	Y	Y	Y	Y	Y		Y	Y
birth month FE								Y
linear trend	Y	Y	Y	Y	Y		Y	Y
district FE	Y	Y	Y	Y	Y		Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All women's regressions (Column 1-7) include controls for age, education, urban, and fixed effects for district and country, country-year. Column 8 controls for mother's age, age-squared, birth order, mother's education, urban, and fixed effects for birth month, district, and country-year. Annual gold price comes from Raw Minerals Group and is available from 1992 to 2011. Panel A interacts the gold price with the active mine dummy as well as mine location; Panel B predicts gold mine with the annual gold price. Please see Table 3.3 for more information regarding the baseline specification.

Table 3.10: Never-Movers and Migrants

	(1) agri-culture	(2) service sales	(3) earns cash	(4) barriers to healthcare	(5) accepts violence	(6) bargaining power	(7) infant mortality
Panel A. Never Movers							
active*deposit	-0.031	0.099**	0.052	-0.076	-0.124*	-0.006	-0.020
	(0.061)	(0.047)	(0.069)	(0.067)	(0.067)	(0.056)	(0.051)
deposit	0.003	-0.010	-0.020	-0.049	0.034	0.036	0.024
	(0.051)	(0.029)	(0.056)	(0.053)	(0.046)	(0.043)	(0.036)
N	16,288	16,288	10,685	8,801	8,523	8,064	9,366
R^2	0.392	0.167	0.346	0.234	0.359	0.361	0.057
Panel B. Migrants							
active*deposit	-0.100*	0.160***	0.161***	-0.133**	-0.101	0.003	-0.066**
	(0.055)	(0.044)	(0.047)	(0.066)	(0.064)	(0.053)	(0.031)
deposit	0.027	-0.044	-0.074*	0.063	0.038	0.004	0.053***
	(0.046)	(0.027)	(0.040)	(0.039)	(0.039)	(0.038)	(0.020)
N	24,178	24,178	15,685	11,732	11,340	10,851	15,505
R^2	0.441	0.171	0.414	0.216	0.397	0.372	0.053
controls	Y	Y	Y	Y	Y	Y	Y
survey year FE	Y	Y	Y	Y	Y	Y	
birth-year FE							Y
country-year	Y	Y	Y	Y	Y	Y	Y
district FE	Y	Y	Y	Y	Y	Y	Y

*** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions Column 1-6 include controls for age, education, urban, and fixed effects for survey year, district, and country-year. Column 6 controls for mother's age, age squared, mother's education, birth order, urban location, as well as fixed effects for birth year, birth month, country, district, and country-year. Panel A includes subset of sample who have never moved, Panel B only individuals who have ever moved. Please see Table 3.3 for more information.

Table 3.11: Age at Marriage, Age Gap and Partner's Education and Polygamy as Mechanisms

	(1)	(2)	(3)	(4)
Age at mine opening	below 14	below 19	below 22	all women
Panel A. Age at first marriage				
active*deposit	0.168	0.084	-0.141	0.249
	(0.530)	(0.352)	(0.429)	(0.185)
N	5,991	10,723	14,085	46,009
R^2	0.304	0.291	0.281	0.202
mean of outcome variable	17.351	17.36	17.38	17.61
Panel B. Age difference between spouses (years)				
active*deposit	-0.571	0.401	0.940	0.430
	(0.524)	(1.898)	(0.872)	(0.714)
N	32,124	4,778	8,494	11,136
R^2	0.138	0.163	0.174	0.171
mean of outcome variable	9.637	9.784	9.872	10.486
Panel C. Large age difference between spouses				
active*deposit	-0.011	0.062	-0.011	-0.064**
	(0.268)	(0.115)	(0.062)	(0.025)
N	4,757	8,425	11,012	31,499
R^2	0.143	0.146	0.145	0.106
mean of outcome variable	0.619	0.637	0.645	0.690
Panel D. Partner's education in years				
active*deposit	1.538	1.994*	1.825***	0.309
	(1.541)	(1.123)	(0.662)	(0.250)
N	5,013	8,844	11,629	39,181
R^2	0.645	0.655	0.651	0.641
mean of outcome variable	3.879	3.828	3.784	3.018
Panel E. Polygamous marriage				
active*deposit	-0.200	-0.092	-0.128*	-0.012
	(0.169)	(0.077)	(0.068)	(0.030)
N	5,579	9,936	13,033	42,198
R^2	0.195	0.192	0.187	0.178
mean of outcome variable	0.299	0.310	0.316	0.419
controls	Y	Y	Y	Y
survey year FE	Y	Y	Y	Y
country-year	Y	Y	Y	Y
district FE	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions include controls for age, urban, and fixed effects for survey year, district, and country-year. Panel A and Panel C control for years of education.

Table 3.12: Education, Sex Partners, and Fertility as Mechanisms

Age at mine opening	(1) below 14	(2) below 19	(3) below 22	(4) all women
Panel A. Total years of schooling				
active*deposit	0.267	-0.092	-0.393	0.129
	(0.712)	(0.406)	(0.363)	(0.178)
N	11,761	18,477	23,042	57,581
R^2	0.484	0.478	0.476	0.474
mean of outcome variable	4.533	4.242	4.025	2.947
Panel B. Total lifetime sex partners				
active*deposit	-0.415	0.345	0.443	0.103
	(0.355)	(0.323)	(0.272)	(0.305)
N	4,745	7,867	9,726	19,120
R^2	0.111	0.092	0.097	0.119
mean of outcome variable	2.025	2.111	2.16	2.454
Panel C. Total fertility				
active*deposit	0.193**	-0.066	0.035	-0.164*
	(0.083)	(0.127)	(0.098)	(0.092)
N	11,761	18,477	23,042	57,581
R^2	0.672	0.680	0.686	0.672
mean of outcome variable	1.097	1.371	1.534	3.257
controls	Y	Y	Y	Y
survey year FE	Y	Y	Y	Y
country-year	Y	Y	Y	Y
district FE	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions include controls for age, urban, and fixed effects for survey year, district, and country-year. Panel A and Panel C control for years of education.

Table 3.13: Service and Sales, Cash, and Wealth as Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	cash	barriers to	accepts	bargaining		mortality	
	earnings	healthcare	violence	power	kids	boys	girls
A. Services and sales							
active*deposit	-0.042	-0.089*	-0.101**	0.004	-0.066***	-0.044	-0.085***
	(0.041)	(0.046)	(0.042)	(0.049)	(0.020)	(0.028)	(0.027)
deposit	0.004	0.035	0.060	-0.025	0.042***	0.027	0.059***
	(0.034)	(0.035)	(0.038)	(0.038)	(0.016)	(0.021)	(0.022)
service and sales	0.366***	-0.029***	-0.014**	0.082***	0.009	-0.005	0.022
	(0.010)	(0.006)	(0.007)	(0.007)	(0.013)	(0.018)	(0.017)
N	34,587	31,076	30,294	27,264	36,320	18,475	17,845
B. Cash							
active*deposit		-0.062	-0.075**	0.006	-0.090***	-0.069*	-0.110***
		(0.047)	(0.037)	(0.055)	(0.028)	(0.039)	(0.036)
deposit		0.020	0.051	-0.025	0.066***	0.059*	0.074***
		(0.038)	(0.031)	(0.042)	(0.022)	(0.032)	(0.024)
earns cash		-0.035***	-0.017**	0.110***	0.002	0.008	-0.005
		(0.007)	(0.008)	(0.009)	(0.005)	(0.007)	(0.007)
N		25,591	24,867	23,001	25,074	12,742	12,332
C. Household wealth							
active*deposit		-0.043	-0.085**	-0.015	-0.050**	-0.057	-0.039
		(0.048)	(0.040)	(0.067)	(0.024)	(0.040)	(0.038)
deposit		0.017	0.068*	-0.000	0.031	0.032	0.030
		(0.042)	(0.041)	(0.057)	(0.020)	(0.035)	(0.036)
wealth		-0.026***	-0.011***	0.005*	-0.003*	-0.004	-0.003
		(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
N		28,987	27,955	25,005	23,982	11,942	11,523
controls	Y	Y	Y	Y	Y	Y	Y
survey year FE	Y	Y	Y	Y			
birth year FE					Y	Y	Y
country-year	Y	Y	Y	Y	Y	Y	Y
district FE	Y	Y	Y	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions Columns 1-4 include controls for age, education, urban, and fixed effects for survey year, district, and country-year. Columns 5-7 control for mother's age, age-square, mother's education, birth order, urban location, as well as fixed effects for birth year, birth month, district, and country-year. Please see Table 3.3 for more information regarding the baseline specification.

Table 3.14: Occupation on Intensive and Extensive Margin and Wage Rate

	(1) worked (12m) 12 m	(2) worked (7d) 7d	(3) hours (7d) 7d	(4) agri-culture	(5) service sales	(6) miner	(7) ln wage rate	(8) ln hh income
active*deposit	-0.096**	-0.078*	5.160	0.064	-0.053	0.036	-0.099	0.589**
	(0.048)	(0.044)	(3.509)	(0.087)	(0.042)	(0.075)	(0.216)	(0.246)
deposit	-0.001	-0.009	-5.956**	-0.092	-0.010	0.139**	0.090	-0.071
	(0.040)	(0.034)	(2.889)	(0.071)	(0.030)	(0.063)	(0.139)	(0.165)
active*deposit	0.052	0.061	-3.458	-0.054	0.115**	-0.035	0.836**	
*woman	(0.037)	(0.042)	(3.377)	(0.058)	(0.056)	(0.064)	(0.373)	
deposit	-0.009	-0.030	-1.567	0.069*	-0.037	-0.108**	-0.637**	
*woman	(0.032)	(0.036)	(2.632)	(0.039)	(0.041)	(0.050)	(0.267)	
woman	-0.027***	-0.052***	-4.033***	-0.092***	0.140***	-0.012***	-0.315***	
	(0.007)	(0.008)	(0.665)	(0.010)	(0.010)	(0.002)	(0.048)	
N	8,188	8,592	5,423	5,776	5,776	5,776	1,476	6,226
R^2	0.355	0.332	0.123	0.303	0.141	0.081	0.315	0.153
mean dep var	0.585	0.587	41.3	0.514	0.030	0.012	40,363	5,057k
controls	Y	Y	Y	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y	Y	Y	Y
district FE	Y	Y	Y	Y	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at village level. All regressions include controls for age, education, urban, and fixed effects for survey year and district. The outcome variable in Column 8 is annual household income from salaries and wages, and I also control for household size. The data comes from the Living Standards Measurement Survey for Ghana.

3.A Appendix

Intensity of Mining

The baseline results allow us to understand the effects of at least one mine opening. We are interested in knowing how the effects differ with the number of mines, which I will refer to as the "intensity" of mining.

To measure intensity, I calculate the number of mines that are close to the community:

$$Y_{icdt} = \beta_0 + \beta_1 deposit_c + \beta_2 deposit \cdot active_{ct} + \beta_3 intensity_{ct} + \gamma_t + \alpha_d + \delta_{kt} + \varepsilon_{icdt} \quad (3.A.1)$$

Table B.3 shows the results for regressions with an intensity variable. We find that more active mines in an area does not further decrease participation in agriculture, but insignificantly increases service sector employment (Column 2). However, the more active mines the less likely women are to be hindered from seeking healthcare for themselves and to accept domestic violence. The treatment variable for active*deposit is not positive for domestic violence, but the coefficient is smaller than the coefficient for intensity. If there is one active mine, the treatment effect is thus (0.077 - 0.172*1), equivalent to a 10 pp decrease in the violence index. The effect decreases for each additional mine. Note that only a small number of individuals have more than one active mine in the vicinity; the maximum number of mines observed within the threshold distance is three. Infant mortality decreases by 9.4-9.8 pp with one mine. However, the intensity variable indicates that the effect for each additional mine partly offsets the initial decrease.

Multinomial Logit

The occupational outcomes are using the DHS standard classifications, but I have focused on three large groups: not working, working in agriculture, and working in services and sales. The respondent will only belong to one category, which is the category identified as the main occupation in the last 12 months. As a robustness check, I run a multinomial logit since the individual sorts into one of several occupational categories. To ensure that the choices sum to 1, I include "Other," consisting of those smaller categories not included in the main analysis (skilled and unskilled manual labor, professional and clerical categories, in total making up roughly 10% of the labor force).

Table B.2 presents the marginal effects. The effects have the same directionality as the baseline results[37], magnitudes are slightly larger, and all coefficients except "not working" are significant at $\alpha = 0.01$. The coefficients for deposit show that the deposit is associated with higher levels of work participation, mostly in agriculture. Panel B shows that the likelihood of a woman earning cash or a combination of cash and in-kind increases with a mine, whereas the likelihood of not being paid for work decreases.

Multiple Inference Hypothesis Testing

We have analyzed women's empowerment using three clusters of indicators: (1) attitudes to domestic violence, (2) barriers to healthcare, and (3) bargaining power within the household. As discussed earlier, I

[37] The specification includes linear time trend but no country year fixed effects.

constructed the three indexes to avoid issues with multiple inference testing. All original variables with more than 27,000 respondents, which excludes 'final say over daily purchases' and 'final say over husband's salary' from the bargaining power index, are included. These two indicators have 19,072 and 9,516 observations respectively. Limited overlap between the variables when these two indicators are included in the index prohibits analysis of the data. The summary statistics are presented in Table B.1, and the exact questions in Table B.10.

For transparency, the results for all indicators are shown in Table B.4, Panel A, B, and C. The point-estimates in Panel A, exploring effects on bargaining power (final say), are insignificant and fairly small (from negative 2.2 pp to positive 2.7 pp). In Panel B, we find that women are less likely to accept domestic violence for all stated reasons except burning food, which is insignificant. Women are less likely to consider either distance, money, or permission a barrier to seeking healthcare for herself, although these are weakly significant or non-significant (Panel C).

We should be cautious in interpreting these results, as the risk of observing a significant result due to chance increases with the number of hypotheses tested. If $\alpha = 0.05$ and there are five outcomes (like Panel B), the risk of getting a significant result by chance is:

$$P(at\ least\ one\ significant) = \quad 1-(1-0.05)^5 \approx 0.23$$

One solution to this issue is of course to use an index, which is the preferred method in this paper (see Casey et al., 2012 for a longer discussion). An alternative solution is to use the Bonferroni-corrected p-values on the original estimates. The Bonferroni correction redefines the significance cut-off level as $\alpha/n = 0.05/5 = 0.0025$, which is a more conservative level than before. The new significance levels are presented in Table B.4, Panels A, B, and C. Only two coefficients remain significant: whether a husband can beat his wife if she refuses sex (Panel B, Column 2)or neglects the children (Column 4).[38] Given that the point estimates for the independent regressions are mostly significant (with the exception of final say) and in the same direction as for the index regressions, we can feel quite confident that the results are not driven only by chance.

Rainfall

Gold mining can cause acid mine drainage which is the process where heavy metals brought to the surface in the extraction process are set free as water washes off from tailing piles (Almas et al., 2009; Bitala et al., 2009). The geographic spread of pollutants from mines can increase with rainfall (Almas and Makono, 2012), and the concentration of the same pollutants can increase in the dry seasons (Williams, 2001).

In Appendix Table B.7, a rainfall indicator is interacted with the active mine dummy. The rainfall variable is constructed as country averages for the three pregnancy trimesters (trimester 1: months 1-3 from conception; trimester 2: months 4-6; trimester 3: months 7-9 of a pregnancy). Since time of conception is not known, the trimesters are constructed by counting back from the date of birth.

The rainfall data comes from the University of Delaware, which provides reanalyzed grid cell data with monthly averages. The data has been processed to provide country-level population-weighted time series of monthly averages.

[38]Another way of dealing with the same issue is to use principal component analysis. For each of the three sets of clusters, I create a principal component score and use the score as the dependent outcome. The results are presented in Table 3.6 Panels A, B, and C. The results have the same direction as the baseline but with bigger coefficients.

I set out to test whether the child health effects differ with levels of rainfall during pregnancy. Table B.7 shows that the mine area dummy is positively associated with infant mortality, but that this initial characteristic is offset if the mine is actively producing in the birth year. The interaction effects between rainfall in levels and the presence of an active mine are insignificant in all birth trimesters. Further analysis, using more detailed data, is required before we can conclude that there are no heterogeneous effects of exposure to pollution from mining on infant mortality.

3.B Appendix: Tables and Figures

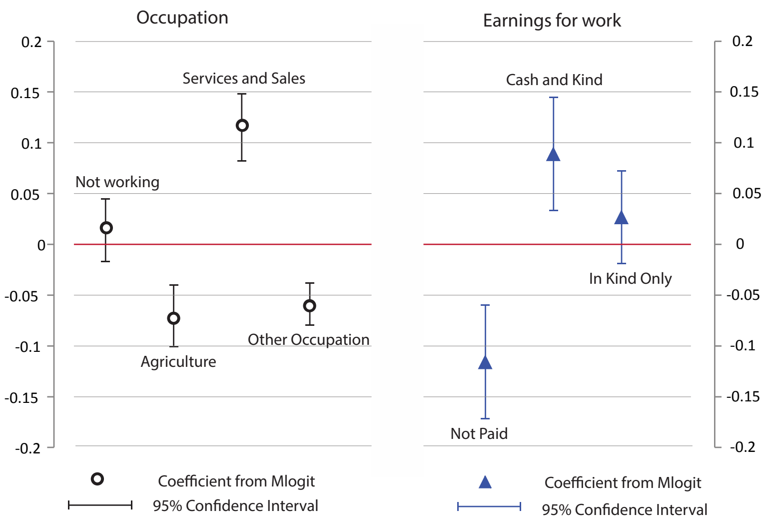


Figure B.1: Marginal Effects from Multinomial Logit

The figure shows marginal effects calculated from two multinomial logit regressions. The first regression is sector of occupation, and the second earnings for work. Both regressions use the baseline specification with 15 km distance dummy. The specification includes controls for urban, education, age, district fixed effects, and year fixed effects. Appendix Table B.2 presents the main coefficients.

Table B.1: Summary Statistics: All Physical Empowerment Outcomes

Variable		Mean	Std. Dev.
barriers to healthcare			
distance	... is a barrier to seek healthcare	0.910	0.285
money	... is a barrier to seek healthcare	0.922	0.268
permission	... is a barrier to seek healthcare	0.877	0.340
domestic violence	*husband has right to beat wife if she....*		
burns the food	... burns food	0.232	0.422
refuses sex	... refuses sex	0.369	0.482
argues	... argues with him	0.454	0.498
neglects children	... neglects the children	0.481	0.500
goes out	... goes out without permission	0.471	0.499
# reasons	average number of stated reasons	2.002	1.928
final say			
healthcare	has final say on healthcare	0.292	0.454
large purchase	has final say on large purchase	0.274	0.446
daily purchase	has final say on daily purchase	0.388	0.487
husband salary	has final say on spending husb. salary	0.171	0.377
family visits	has final say on family visits	0.406	0.491
food	has final say on food	0.543	0.498
N		57.685	

Table B.2: Marginal Effects from Multinomial Logit

	(1)	(2)	(3)	(4)
	Not working	Agriculture	Service and Sales	Other
A. Occupation				
active * deposit (ME)	0.014	-0.070***	0.115***	-0.058***
	(0.016)	(0.016)	(0.017)	(0.011)
deposit (ME)	-0.046***	0.051***	-0.068***	0.013***
	(0.013)	(0.012)	(0.014)	(0.008)
B: Earnings				
	Not paid	Earns cash and in-kind	Only in-kind	
active * deposit (ME)	-0.116***	0.089**	0.027	
	(0.029)	(0.029)	(0.023)	
deposit (ME)	0.100***	-0.06**	-0.041**	
	(0.023)	(0.024)	(0.019)	
controls	Y	Y	Y	Y
country FE	Y	Y	Y	Y
year FE	Y	Y	Y	Y
country*year FE	Y	Y	Y	Y

Average marginal effects (dy/dx) calculated after multinomial logit. Panel A has 56,011 observations, Panel B 25,835 observations. The multinomial logit controls for age, education, and urban and fixed effects for country, year, and country by year.

Table B.3: Intensity of Mining

	(1) agri-culture	(2) service sales	(3) barriers to healthcare	(4) accepts violence	(5) bargaining power	(6) mortality kids	(7) mortality boys	(8) mortality girls
active*deposit	-0.071	0.046	-0.015	0.077	-0.028	-0.097***	-0.098***	-0.094***
	(0.086)	(0.059)	(0.068)	(0.107)	(0.070)	(0.025)	(0.034)	(0.035)
deposit	0.021	-0.036	0.033	0.056	-0.023	0.042***	0.028	0.057***
	(0.047)	(0.022)	(0.035)	(0.038)	(0.038)	(0.016)	(0.021)	(0.021)
intensity	-0.001	0.047	-0.076*	-0.172*	0.037	0.032**	0.051**	0.013
	(0.068)	(0.050)	(0.044)	(0.097)	(0.045)	(0.014)	(0.021)	(0.021)
N	55,944	55,944	31,485	30,693	27,482	37,365	18,982	18,383
controls	Y	Y	Y	Y	Y	Y	Y	Y
survey year FE	Y	Y	Y	Y	Y			
birth year FE						Y	Y	Y
country-year	Y	Y	Y	Y	Y	Y	Y	Y
district FE	Y	Y	Y	Y	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions in Columns 1-5 include controls for age, education, urban, and fixed effects for survey year, district, and country-year. Columns 6-8 control for mother's age, age squared, mother's education, deposit, urban location, as well as fixed effects for birth year, birth month, district, and country-year. Intensity is a count variable indicating how many mines are found nearby.

Table B.4: Female Empowerment Estimated with Initial Variables and Bonferroni p-values

	(1)	(2)	(3)	(4)	(5)
Panel A	she has a final say on (how to spend on)...				
	healthcare	large purchase	daily purchase	family visit	husband wage
active*deposit	-0.003	0.008	0.027	0.017	-0.022
	(0.057)	(0.050)	(0.053)	(0.060)	(0.066)
p-value	0.960	0.870	0.610	0.773	0.740
(Bonferroni sign.)					
N	27,582	27,565	19,072	27,505	9,516
Panel B	a husband has the right to beat the woman if she...				
	burns food	refuses sex	argues	neglects kids	goes out
active*deposit	0.008	-0.123***	-0.099**	-0.110***	-0.083**
	(0.042)	(0.036)	(0.050)	(0.042)	(0.040)
p-value	0.841	0.001***	0.047	0.009**	0.038
(Bonferroni sign.)					
N	31,423	31,038	31,396	31,426	31,455
Panel C	is ... a barrier to seeking healthcare?				
	distance	money	permission		
active*deposit	-0.146*	-0.086*	-0.043		
	(0.079)	(0.050)	(0.047)		
p-value	0.065	0.084	0.353		
(Bonferroni sign.)					
N	31,485	31,488	31,486		
Bonferroni sign. (0.99)	for Panel A, B	0.002, ***	for Panel C	0.0033, ***	
Bonferroni sign. (0.95)	for Panel A, B	0.01, **	for Panel C	0.0016, **	
Bonferroni sign. (0.90)	for Panel A, B	0.02, *	for Panel C	0.033, *	

Note: *** p<0.01, ** p<0.05, * p<0.1, or corrected Bonferroni significance levels as stated above. Clustered standard errors at DHS cluster level. All regressions include controls for age, education, urban, and fixed effects for survey year, district, year and country-year fixed effects. Panel A shows results binary outcomes for seven variables on final say in household decisions. Three of these, with sufficient sample size and overlapping surveying, were used in the household decision but here the whole set are presented. Panel B shows the results from using the outcome variables on domestic violence. The questions are the type: “is a husband justify to beat his wife if she burns the food/refuses sex/goes out without his permission/neglects the children. Panel C shows if the woman thinks that distance, money or getting permission are barriers to access healthcare for herself. The questions are “is money/distance/permission a hinder to seek healthcare for yourself?”

Table B.5: Observable Characteristics of Women and Marital Status

	(1) age	(2) ever married	(3) curr cohab.	(4) divorced
Panel A. All women				
active * deposit	0.507	0.006	0.016	-0.003
	(0.382)	(0.017)	(0.019)	(0.008)
active * deposit at age 14				
deposit	-0.226	0.001	-0.004	-0.001
	(0.345)	(0.015)	(0.017)	(0.007)
N	57,590	57,589	57,589	57,589
R^2	0.038	0.351	0.274	0.041

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions include controls for age, education, urban, and fixed effects for survey year, district and country-year fixed effects. Age is in years, total fertility is the number of children ever born, ever married means the woman had at some point been married regardless of current marital status, curr. cohabiting means the woman currently lives with a partner, married or non-married.

Table B.6: Selective Fertility

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		children			uses...		sex ratio	
	total	alive	ideal	want no more	contra-ception	contra-ception	mis-carriage	male child
active*deposit	-0.180*	-0.099	-0.048	0.014	-0.020	-0.030	0.013	0.010
	(0.092)	(0.091)	(0.075)	(0.024)	(0.020)	(0.022)	(0.018)	(0.024)
deposit	0.026	0.031	0.017	-0.016	0.011	0.019	-0.021	0.000
	(0.084)	(0.082)	(0.057)	(0.020)	(0.017)	(0.018)	(0.020)	(0.020)
want no more						0.056***		
						(0.004)		
N	57,590	56,717	47,453	46,449	52,388	46,449	40,421	48,107
R^2	0.673	0.616	0.302	0.035	0.083	0.099	0.088	0.008
total # kids	N	N	N	Y	N	N	N	N
active at	survey	survey	survey	survey	survey	survey	survey	birth

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions include controls for age, education, urban, and fixed effects for survey year, district and country-year fixed effects. Total: total fertility; alive: number of children born who are alive; ideal: ideal total fertility, i.e. desired fertility; and want no more: the woman feels she doesn't want to have more children. Uses contraception takes a value of one if the woman currently uses any contraceptive method. Sex ratio miscarriage measures whether the woman ever suffered a miscarriage and sex ratio male child the share of children born who are male.

Table B.7: Interacting Rainfall (in Levels) in Pregnancy Trimesters with Active Mine

	(1)	(2)	(3)
	infant mortality	infant mortality	infant mortality
	12m	12m	12m
sample	children	boys	girls
active mine	-0.051	-0.024	-0.082
	(0.096)	(0.094)	(0.181)
rain (trim1) *active	0.009	-0.000	0.024
	(0.049)	(0.048)	(0.085)
rain (trim2) *active	-0.031	-0.017	-0.054
	(0.023)	(0.032)	(0.039)
rain (trim3) *active	0.006	-0.003	0.028
	(0.047)	(0.043)	(0.097)
deposit	0.042**	0.025	0.060***
	(0.017)	(0.023)	(0.023)
N	31,105	15,755	15,350
R^2	0.032	0.045	0.041
mean of infant mortality	0.097	0.103	0.093
mean of rain (trim)*active	0.001	0.001	0.001
birth year FE	Y	Y	Y
birth month FE	Y	Y	Y
country-year FE	Y	Y	Y
district FE	Y	Y	Y
birth trimester rainfall	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1 Clustered standard errors clustered at DHS cluster level. All regressions control for mother's age, mother's education, urban location, as well as fixed effects for birth year, birth month, district, and country-year. All regressions control for birth trimester levels of rainfall; coefficients not reported here.

Table B.8: Sample Size and Survey Rounds by Country

Country	Year	Type	Observations all	Observations w/in 100km	Clusters w/in 100km	Active Mines
Burkina Faso	1993	Standard	5,599	2,808	73	1
	1998-1999	Standard	5,779	3,818	67	1
	2003	Standard	10,468	6,813	68	1
	2010	Standard	14,898	8,752	67	7
Cote d'Ivoire	1994	Standard	3,714	3,073	81	2
	1998-1999	Standard	1,836	704	54	2
Ethiopia	2000	Standard	10,513	331	30	1
	2005	Standard	9,767	273	36	1
	2011	Standard	11,385	329	35	1
Ghana	1993	Standard	2,168	3,180	32	9
	1998	Standard	3,233	3,577	33	13
	2003	Standard	3,805	4,012	31	7
	2008	Standard	2,968	3,425	24	11
Guinea	1999	Standard	5,650	799	45	2
	2005	Standard	6,165	882	45	3
Mali	1996	Standard	5,841	1,796	66	1
	2001	Standard	12,839	2,501	56	3
Senegal	1992-1993	Standard	5,419	114	43	0
	1997	Standard	6,997	233	32	0
	2005	Standard	10,569	216	44	0
	2010	Standard	12,008	479	60	2
Tanzania	1999	Standard	2,975	451	34	1
	2007	Standard	7,104	1,918	55	5
	2010	Standard	7,672	1,292	40	6
	2012	AIS	8,273	3,284	73	7
N	-	-	208,223	57,676	1,224	-

Notes: Standard refers to Standard DHS survey. AIS refers to AIDS Indicator Survey, also collected by the DHS Program. More information about the survey types can be found at: http://www.dhsprogram.com/What-We-Do/Survey-Types/index.cfm

Table B.9: Main Results by Country

	(1) not working	(2) agri-culture	(3) service sales	(4) earns cash	(5) barriers to healthcare	(6) accepts violence	(7) bargaining power	(8) infant mortality
Burkina Faso								
active*deposit	0.003	-0.012	0.066	-0.064	0.039	-0.093*	0.028	-0.063***
	(0.054)	(0.094)	(0.058)	(0.078)	(0.092)	(0.053)	(0.118)	(0.017)
Observations	20,784	20,784	20,784	14,911	15,553	14,937	13,799	16,173
R^2	0.240	0.389	0.199	0.346	0.218	0.275	0.171	0.088
Cote d'Ivoire								
active*deposit	-0.177*	0.011	0.166*	0.094				
	(0.094)	(0.173)	(0.091)	(0.159)				
Observations	3,770	3,770	3,770	751				
R^2	0.163	0.411	0.151	0.363				
Ghana								
active*deposit	0.019	-0.131***	0.108***	0.041	-0.012	-0.028	-0.096	
	(0.028)	(0.047)	(0.032)	(0.034)	(0.059)	(0.041)	(0.067)	
Observations	14,058	14,058	14,058	10,728	7,368	7,186	5,849	
R^2	0.223	0.345	0.120	0.114	0.196	0.194	0.288	
Guinea								
active*deposit								-0.060*
								(0.031)
Observations								6,219
R^2								0.135
Mali								
active*deposit	0.194*	0.047	0.223**	0.269***	-0.337***	-0.113	0.084*	
	(0.108)	(0.102)	(0.105)	(0.099)	(0.060)	(0.085)	(0.050)	
Observations	6,833	6,833	6,833	5,469	5,098	4,947	5,069	
R^2	0.114	0.394	0.104	0.132	0.086	0.095	0.152	
Senegal								
active*deposit	0.082	-0.022	-0.286***					-0.078**
	(0.098)	(0.095)	(0.048)					(0.035)
Observations	1,040	1,040	1,040					5,105
R^2	0.170	0.249	0.135					0.070
Tanzania								
active*deposit	-0.116**	0.058	-0.016	0.132*				-0.106***
	(0.049)	(0.108)	(0.021)	(0.070)				(0.036)
Observations	6,872	6,872	6,872	1,582				763
R^2	0.180	0.362	0.116	0.372				0.115
controls	Y	Y	Y	Y	Y	Y	Y	Y
survey year FE	Y	Y	Y	Y	Y	Y	Y	
birth year FE								Y
birth month FE								Y
district FE	Y	Y	Y	Y	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors at DHS cluster level. All regressions include controls for age, education, urban, and fixed effects for survey year and district fixed effects. Ethiopia is excluded, as well as certain results for countries, as the sample size of treated individuals was too small to run the full model.

Table B.10: DHS Survey Questionnaire

Survey question	**answer**
Barriers to healthcare access	
Many different factors can prevent women from getting medical advice or treatment for themselves. When you are sick and want to get medical advice or treatment, is each of the following a big problem or not?	
1. Getting permission to go?	big problem/not a big problem
2. Getting money needed for treatment?	big problem/not a big problem
3. The distance to the health facility?	big problem/not a big problem
4. Having to take transport?	big problem/not a big problem
5. Not wanting to go alone?	big problem/not a big problem
6. Concern that there may not be a female healthcare provider?	big problem/not a big problem
Attitudes toward domestic violence	
(Sometimes a husband is annoyed or angered by things that his wife does). In your opinion, is a husband justified in hitting or beating his wife in the following situations:	
1. If she burns the food?	yes/no/dk
2. If she refuses to have sex with him?	yes/no/dk
3. If she argues with him?	yes/no/dk
4. If she neglects the children	yes/no/dk
5. If she goes out without telling him?	yes/no/dk
Earnings and decision making	
6. Who usually decides how the money you earn will be used: mainly you, mainly your husband/partner, or you and your husband/partner jointly?	respondent/partner/jointly/other
7. Who usually decides how your husband's/partner's earnings will be used: you, your husband/partner, or you and your husband/partner jointly?	respondent/partner/jointly/ husband has no earnings/other
8. Who usually makes decisions about your healthcare: you, your husband/partner, you and your husband/partner jointly, or someone else?	respondent/partner/jointly/ somebody else/other
9. Who usually makes decisions about major household purchases? you, your husband/partner, you and your husband/partner jointly, or someone else?	respondent/partner/jointly/ somebody else/other
10. Who usually makes decisions about purchases for daily household needs? you, your husband/partner, you and your husband/partner jointly, or someone else?	respondent/partner/jointly/ somebody else/other
11. Who usually makes decisions about visits to your family or relatives? you, your husband/partner, you and your husband/partner jointly, or someone else?	respondent/partner/jointly/ somebody else/other

Table B.11: Health Effects of Toxic Waste from Gold Mining

	(1)	(2)
Heavy metal	Arsenic	Cyanide
Characteristics		
compounds	organic and inorganic	e.g. hydrogen CN, sodium CN
natural in	soil, mineral	food, plants
spreads with	air, water, soil	air, water, soil
through	dust, runoff, leakage	natural and industry processes
decompose	cannot be destroyed	hydrogen CN half-life is 1-3 years
Health issues		
inhaling	lung issues	chest pain, coma, death
ingestion	nausea, death	chest pain, coma, death
skin exposure	warts, darkening, swelling	skin sores
carcinogenic	yes	no
in childhood	lower IQ	rapid breathing, coma, death
in utero	fetal loss, premature delivery	inconclusive
Sources:	ATSDR 2007: Arsenic; Kapaj et al. (2006)	ATSDR 2006: Cyanide

Chapter 4

Extractive Industries, Production Shocks, and Criminality: Evidence from South Africa

Abstract

Extractive industries are key to development in many countries, accounting for large shares of government revenue and GDP. However, a vast and growing literature links extractive industries to conflicts and war in countries with weak institutions. This study is, to our knowledge, the first to investigate whether extractive industries can cause property and violent crime in a middle-income country. We focus on South Africa, a country with a significant mining industry and high crime levels, similar to Botswana, Brazil, and Mexico. Our empirical strategy exploits temporal and spatial variation in mining, in addition to fluctuations in international mineral prices, to estimate the effect of mining activity on crime. In contrast to studies in lower income countries focusing on conflict and war, we find that the start of natural resource extraction is not linked to higher levels of crime. However, the closure of a mine leads to a large and significant increase in both property and violent crime. Subsequently, we show that the migration flows and income opportunities created by the mining industry are two important channels through which mining affects criminality. The findings illustrate that the volatile nature of the sector can be a threat to social stability and security.

Keywords: Extractive Industries, Mining, Crime, Violence

JEL classification: K42, D74, O13

4.1 Introduction

Extractive industries are key to economic development in many countries. Mineral resources, in particular, play a dominant role in 81 countries that collectively account for nearly 70 per cent of those in extreme poverty (World Bank 2014). Many have discussed this association in terms of the resource curse[1], but fewer have looked at the extractive industries as an inherent feature of many developing economies that presents both potential harms and potential benefits. Mining is economically important in developing countries, and approximately one percent of the global labor force works in mining (ILO 2010). Mining has been found to spur local structural change, benefiting local labor markets (Aragon and Rud 2013; Kotsadam and Tolonen 2013), and the industry has been crucial for countries such as Botswana and Namibia in the transition from poor to middle income.

However, a growing body of evidence links extractive industries, such as the mining industry, to conflict and civil war in contexts with weak institutions.[2] The main mechanism emphasized in this literature is that a shock to an extractive industry might alter the incentives for appropriation since the increase in potential rents can drive social conflict (see, e.g., Dal Bó and Dal Bó 2011). However, extractive industries also generate job opportunities which could affect the opportunity cost of illegal activity, as outlined by Becker (1968). The latter of these two mechanisms could potentially play a more dominant role in countries with stronger institutions where social conflict mainly comprises violent and property crime, rather than civil war. A number of countries have both considerable natural resource endowments as well as high crime rates, including South Africa, Botswana, Brazil, and Mexico, which highlights the need to empirically investigate this relationship in such a setting. Thus, in this paper we explore the effect of mining activity on crime rates in South Africa.

We argue that the South African setting is of particular importance. Crime, and violent crime in particular, is a serious threat to development in the country. For example, our data shows that 13,123 men, 2,266 women and 827 children were murdered in 2012/13, making it one of the most murder dense regions of the world.Violent crime is a major factor behind the emigration of skilled labor, emergence of gated communities, and flourishing private security sector. At the same time, South Africa has the fifth largest mining industry in the world, contributing to around 8 per cent of GDP (Chamber of Mines 2014). Recently, the link between mining and violence has received both media and government attention , not least since the 2012 Marikana massacre where 44 miners were killed. A *New York Times* report (NYT 2013) suggests that violent crime has risen as townships have "fallen on hard times as gold mines have closed". In addition, previous studies have claimed that the conditions in the mining industry have spurred criminality in South Africa in a historical context (Kynoch 1999, 2005). Several factors inherent to the industry have been argued to spur criminal behavior: a predominantly male workforce, living in single-sex hostels, away for their families[3].

The empirical analysis exploits several different estimation strategies to examine the causal effect of mining activity on crime rates in South African police precincts from 2003 to 2012. Specifically, we explore the effect of mining activity and production shocks on crime rates at different spatial scales, as well as what

[1] see van der Ploeg 2011 for an overview

[2] Collier and Hoeffler (2004 & 2005) were pioneers of the literature examining links between natural resources and civil war. Recent works include Berman, Couttenier, Rohner and Thoenig (2014), Buonanno et al. (2012) and Maystadt et al. (2014).

[3] Both property crime and violent crime may decrease because of the increasing opportunity costs of time that come with a mining boom. However, violent crime may also increase if the mining boom leads to increasing interactions between miners in close quarters. Previous studies have found support for this hypothesis when exploring anti-social behavior of juveniles in U.S. schools (Jacob and Lefgren 2003)

types of crime are affected, and lastly we try to disentangle the mechanisms behind our findings. Using the panel data on crime rates and a fixed effects approach, we estimate a negative association between the number of active mines in a police precinct and local crime rates. These results are not robust to the inclusion of province or precinct linear trends. One concern when estimating the impact of mining activity is that mine production could be affected by crime levels in the proximity of a mine. To overcome this potential reverse causation, we employ an instrumental variable approach where we instrument the number of actively-producing mines of a specific mineral in a given location by the international price of that mineral. Other papers (cf. Allcott and Keniston 2014; Berman et al. 2014; Tolonen 2015) have used international prices as exogenous variation in mining production, but we instrument mining activity with prices rather than rely on the reduced-form relationship. The first-stage coefficient is positive and highly statistically significant: The higher the international price of a given mineral, the larger the number of mines actively producing such minerals. In the second-stage analysis, we investigate how a change in mining activity affects the crime rate in police precincts.[4] We find a negative and significant effect of mining production on both property and violent crime. In particular, as mining activity increases, induced by a higher international mineral price, crime rates fall by approximately seven percent for each additional mine. We estimate that mining decreases both violent and economic crime, which speaks for an opportunity cost channel. To capture effects at a higher aggregate level we replicate the results at the larger municipality level and find similar effects.

Subsequently, we make an additional contribution to the literature by investigating the dynamic effects of production shocks by allowing for asymmetric effects of starts and stops in mining production. We find that when a mine stops actively producing, crime rates increase substantially. This finding argues for the opportunity-cost channel: When a mine closes, direct and indirect income opportunities decrease locally and the incentives to commit crime increase. Similarly, we find suggestive evidence that as a mine starts producing, crime rates fall. Poor availability of mining employment numbers and labor market information at a sufficiently disaggregated geographic level makes it difficult to further assess the viability of the income channel. However, following recent economic literature (Bleakley and Lin 2012; Henderson et al. 2012; Michalopoulos and Papaioannou 2013; Lowe 2014; Pinkovskiy and Sala-i-Martin, 2014), we proxy economic activity in police precincts using satellite data on lights at night. Doing so, we find that the number of active mines has a positive effect on light density. However, when a mine closes, local economic activity falls. These findings support the hypothesis that the causal effect of mine closure on crime goes through an income channel. Furthermore, following the theory outlined by Dal Bó and Dal Bó (2011), we show that our results seem to be driven by relatively more labor intensive mining, a finding that also speaks for the income channel.

In addition, we consider to what extent labor migration to mining areas can be a mechanism through which crime rates are affected. Prior to democratization, the labor in South African mines was supplied by domestic and international migrants. Mine workers did not have the right to permanently settle in the mining towns according to apartheid policy (Cox et al. 2004). However, labor migration remains important in the mining sector also today.[5] There are two main reasons why we believe migration to be important. First, the migrant-labor system[6] is associated with serious social concerns, such as single-sex hostels and informal settlements,

[4]Police precincts are South African administrative areas that are smaller than municipalities.

[5]In 1997, a few years after the advent of democracy, 95 per cent of all mine workers were still migrants, most from rural South Africa, Lesotho and Mozambique.

[6]The system has even been called a "scar on the face of democratic South Africa" by Deputy President Motlanthe (Financial Times, April 2014). Policies have aimed at improving the social situation and single-sex hostels have become less common. However, oftentimes the hostels have been replaced by informal settlements where mine workers live.

characterized by lack of social services, high crime rates and unemployment (Aliber 2003; Hamann and Kapelus 2004). From a historical perspective, the association between the migrant-labor system and crime has been emphasized (Kynoch 1999, 2005).[7] Second, the size of the mine-induced migration flow will determine whether the employment rate increases or decreases, as well as the local wage rate.

We establish that the number of active mines in a municipality increases the share of migrants in the population by 23 percent for each additional mine. In fact, when a mine starts producing (a positive shock in mining activity), migration increases by 18 per cent. Thereafter, we compare the effect of mining activity on crime in municipalities with high and low average migration rates. The results from this analysis are imprecisely estimated but provide suggestive evidence for migration patterns being one determinant of the relationship between mining and crime. We find that production starts in low-migration areas are associated with lower crime rates and that there are typically small and insignificant effects on crime when a mine stops producing. However, in high migration areas, both production starts and stops are associated with higher crime rates. We see two potential explanations for this: first, inward migration increases competition over jobs, and second, production shocks in high migration areas affect individuals with weaker ties to the local labor market. Hence, the income opportunities provided by the mine may be more important for this group.

Previous research on extractive industries find detrimental effects on social conflict. Likewise, looking at the effect of mining activity on public violence (the outcome most closely associated to that used in related studies), we display suggestive evidence that earlier findings also apply to South Africa. However, we find that extractive industries affect overall criminality in a different way. Increases in mining activity lead to lower crime rates, whereas a cessation in production has the opposite effect. This is in contrast to a country at risk of conflict, where mining wealth coupled with poor mineral property rights can increase the risk of conflict by providing funding for rebel groups (Bellows and Miguel 2009). We show that in South Africa, a thriving mining sector can lead to lower local crime rates, presumably by affecting local income opportunities. The dynamic long-run effect of a mining sector can, however, be more criminality as we find that mine closures lead to increases in criminal activity. The non-renewable character of the extractive sector thus makes us cautious in recommending extractive industries as a policy strategy to tackle criminality.

Section 2 looks at previous literature on extractive industries and violence. Section 3 gives a background on the mining industry and crime in South Africa. Section 4 describes the data used in the estimations, and Section 5 goes through the empirical strategies. The results from our main specifications, mechanism checks, and robustness tests are given in Section 6. Section 7 concludes the paper.

4.2 Previous Literature

In this paper, we use production changes in mineral and coal mines to identify the effects of mining activity on crime. This is, to our knowledge, the first attempt to investigate the effect of extractive industries on various types of crime using official police records. We add to the literature on the "resource curse", focusing on the link between natural-resource extraction and social conflict[8].

There is a growing empirical literature on the effects of extractive industries and violence. Recent papers have explored the links between extractive industries and violence at a sub-national level (see, e.g., Caselli et al. 2013; Maystadt et al. 2013; Rohner 2006). Couttenier et al. (2014) find that minerals play a role both

[7] See Appendix A for a description of the historical relationship between mining, migration and criminality.

[8] For an overview of the resource curse, see van der Ploeg 2011)

historically and presently for U.S. homicide rates, and Buonanno et al. (2012) find a relationship between natural resource endowments and the emergence of the Sicilian mafia. Bellows and Miguel (2009) show that diamond mining increased armed clashes during the civil war in Sierra Leone. Aragon and Rud (2013), however, find that household members in mining communities in Peru are no more likely to report having been affected by a criminal act than surveyed households further away.

The paper most similar in spirit to ours is Berman et al. (2014), who explore the impact of mining on conflict in all African countries from 1997 to 2010. The authors exploit within-mining area panel variation in violence due to changes in the world price of the relevant mineral and find that mining activity increases local area conflict, as collected by the ACLED dataset. Similarly, we explore the effect of changes in mining activity induced by changes in mineral prices, but focus on South African crime rates. We investigate whether the above described patterns of detrimental effects stemming from extractive industries are also true for a middle-income country, using official police records of economic and violent crime rather than multi-origin datasets on conflict. Thus, apart from public violence which we have data on, we test the predictions from the relevant literature regarding violent crimes, e.g., murder and assault, and property crimes, e.g., burglary. An additional contribution of this paper is that we can instrument mining production with international prices, in contrast to Berman et al. (2014) who look at the reduced-form relationship between prices and conflict.

A first stepping stone for understanding the aforementioned research question and earlier empirical work is Dal Bó and Dal Bó (2011), who provide a theoretical investigation of how economic shocks and policies affect the intensity of conflict and crime. In particular, the authors show how positive productivity shocks to labor-intensive industries in less-developed countries (e.g., agriculture in Sub-Saharan Africa) diminish conflict, while positive shocks to capital-intensive industries (e.g., the oil industry) do the opposite. The intuition is that a positive shock will cause a capital-intensive industry to expand and a labor-intensive industry to contract, making labor relatively more abundant and therefore reducing wages. Since wages decrease relative to the value of appropriable resources, appropriation will increase. That is, the incentives for social conflict will increase. For example, this intuition is supported by Dube and Vargas (2013), who find that conflict in Colombia increased following a fall in the prices of coffee, which might be considered a labor-intensive product, and an increase in the prices of oil, which might be considered a capital-intensive product. Similarly, we test this channel by splitting mining into open-pit (more capital intensive) and underground (more labor intensive).[9]

Another stepping stone in understanding the link between mining and crime is the theory of the economics of crime developed in Becker (1968). The intuition is similar to that of Dal Bó and Dal Bó (2011). In this model, crime is a type of job chosen in competition with regular wage work. An increase in mining activity will lead to an increase in the opportunity cost of crime if certain requirements are fulfilled.[10] In other words, the closure of a mine or lower production will lead to lower incomes among mine workers and societies that are dependent on the mine, in turn strengthening the driving forces behind for example burglary, robbery, and carjackings.

[9]The mining industry in South Africa employs around half a million people directly, and many more indirectly (Chamber of Mines, 2014). The relatively high number of direct employment is foremost due to the depths of South African mines that makes mechanization less common. The South African mining industry is therefore relatively more labor intensive compared to other mining countries, including its African neighbors.

[10]Specifically that mining increases the supply of jobs, and/or the market-clearing wage. If inward migration exceeds the new jobs created, total employment or market wages need not increase. Furthermore, in the case of a mine leading to local "Dutch disease" effects (cf. Allcott and Keniston 2014) and the crowding out of other industries, such as manufacturing, these two relationships need not hold.

4.3 Background

4.3.1 Crime in South Africa

Although South Africa has seen a huge increase in the number of private security guards as well as a tripling of government spending on crime prevention since the mid-1990's, the country is one of the most crime stricken in the world. *The Economist* (2010) notes that "a staggering 50 murders, 100 rapes, 330 armed robberies and 550 violent assaults are recorded every day". The recorded crime levels increased during the last decade of apartheid rule and peaked in the early 1990s. The hope that the levels would decrease after 1994 was not met. Rather, in the period from 1994 to 2000, crime increased. For example, the annual increase in the number of crimes was higher in 1999 than in any previous years after 1994. These changes were mainly driven by huge rises in common robbery (121 percent), residential burglary (25 percent), assault (22 percent), rape (21 percent), and carjackings (20 percent). In general, violent crime stands out as the one category where South Africa saw a steady increase from 1994. In 2001, the country was considered to have the highest per capita murder and rape rates and the second highest rate of robbery and violent theft in the world (Louw and Schönteich 2001). It should however be noted that South African crime follows a geographic pattern. Burglaries, for example, are more common in police precincts (police station jurisdictions) that are wealthier than neighboring precincts, pointing toward migratory criminal behavior (Demombynes and Özler 2005)

Poverty, unemployment, and labor migration are common in South Africa and the unemployment is high (Aliber 2003). In 2004, the beginning of our study period, unemployment was 41 percent (broad definition) or 30 percent (narrow definition) (Kingdon and Knight 2004). By 2012, the unemployment rate had decreased somewhat, to an average of 25.2 percent. Thus, many South Africans lack income opportunities, which could potentially be a partial explanation for the high crime rates.

4.3.2 The Mining Industry

Large-scale mining is a notable element in South Africa's history, having begun in 1867 when alluvial diamonds were found along the Orange River. This was soon followed by the Kimberley diamond discovery and the Witwatersrand Gold Rush in the 1880s. The gold rush led to the onset of the Mineral Revolution, the rapid mineral-driven economic growth that laid the foundations for South Africa's economic capital Johannesburg[11]. Today the South African mining industry is the fifth largest in the world (Chamber of Mines 2014), and the country may still have the largest mineral endowment worldwide despite a long history of extraction. South Africa is a producer of many different metals and minerals, with the most important being platinum (platinum group metals, PGMs), gold, coal and iron ore.[12] The country is the biggest global producer of PGMs, gold, manganese, and chromium, although the latter two contribute less to the South African economy than the PGMs and gold (Antin 2013).

525,000 people were employed in mining in 2012, an increase from 436,000 in 2003 (Chamber of Mines 2014). Only roughly 15 percent of the workforce in 2013 were women (StatsSA 2014). The employment opportunities are concentrated to certain regions; at the top of the list are the North West (141,000 miners in 2012), Mpumalanga (79,000), Limpopo (73,000), and Gauteng (32,000), but significant mining employment

[11] See Appendix A for a detailed account of the history of mining in South Africa and its relationship with migration and criminality.
[12] These are the largest mineral groups in terms of employment and sales (Antin, 2013).

can also be found in Free State, KwaZulu-Natal, and Northern Cape (StatsSA 2014).

Despite its generation of many employment opportunities, the sector's economic importance relative to GDP exceeds its importance in terms of employment. In 2011, the sector employed 0.7 percent of the workforce. However, while in recent years the sector has contributed on average 8 percent of GDP, it constitutes as much as 18 percent of all economic activity if upstream and downstream industries are included (StatsSA 2014).

Despite the small share of employment to value created, labor constitutes a significant share of the production costs, at roughly 40 percent. There is significant heterogeneity, however: For deep-level mines the figure can be over 60 percent, and for open cast mines about 30 percent, a fact we make use of in the subsequent analysis. The wage burden has increased over time. From 2007 to 2012, negotiated wage increases have exceeded inflation, putting more pressure on the industry and leading to staff reductions (Antin 2013).

4.4 Data

4.4.1 Mining

Our study uses data on all large-scale mining operations across South Africa from 1975 to 2012. The data is licensed and provided by IntierraRMG.[13] For each mine we know the minerals produced during the sample period, the exact geographic location as well as the ownership structure.[14] The panel dataset consists of 320 mines across South Africa that produce 23 different minerals. The majority of mines produce either coal or gold (as many as 245 of the mines at least partly produce one of these two minerals). A large number of mines also produce minerals palladium, platinum, and rhodium. The geographic locations of all mines in South Africa are illustrated in Figure 4.1. The aggregate annual production in these mines fluctuates substantially over time as depicted in Figure 4.3. As can be seen from the figure, the industry is both expanding and contracting at the same time. The production of gold, copper, silver, and zinc decreased during the sample period, whereas the production of iron ore, cobalt, and platinum increased.

However, the production levels reported are not always comparable, since reporting standards differ across mineral types and companies. To deal with this dilemma, we define our main variable of interest as a dummy variable indicating whether a mine is an active producer of a particular mineral in a given year. In a sense, this variable captures the extensive margin of mining activity. Similar strategies have previously been employed within the economic geography literature by Currie et al. (2013), who examine U.S. plants that produce toxic waste, and by Kotsadam and Tolonen (2013).

The mining data from IntierraRMG has previously been employed in a few recent papers: Berman, Couttenier, Rohner, and Thoenig (2014) use it to explore the links between mineral deposits and conflict in Africa; von der Goltz and Barnwal (2014) explore the effects of polluting mining industries on child health in developing countries; and Kotsadam and Tolonen (2013) and Tolonen (2015) focus on local economic development and structural shifts in Africa.

[13] `http://www.intierrarmg.com/Products/SNL_MnM_Databases.aspx`

[14] The geographic location provided is double-checked against information available from http://mining-atlas.com.

4.4.2 Crime and Police Expenditure

The crime data used in this paper is for the years 2003 to 2012 and is provided by the South African Police Service. The data set includes recorded crimes from all 1083 police stations in South Africa.[15] The geographic locations of these police stations are illustrated in Figure 4.2. Crimes are reported for each financial year (April to March) divided into 29 different categories. Highlighting some of the variables, there were 177,593 recorded murders, 125,759 carjackings, 29,839 kidnappings, and 668,038 sex crimes over the course of the ten year period. Comparing 2003 and 2012, reported murders and carjackings, for example, went down, while kidnappings and sex crimes increased. However, the overall crime rates went down, as illustrated in Figure 4.6. Theft, residential burglary and assault show the greatest number of reported incidents.

We create three main outcome variables: property[16], violent[17], and total crime[18].[19] These categories have been defined ex-ante to avoid the multiple testing concerns of investigating a large group of similar outcomes.

Crime data in South Africa, as in many other countries, is likely to suffer from under-reporting. However, previous validations comparing the police data with information from the Victims of Crime Survey conducted by Statistics South Africa have shown that this does not seem to be a major problem (such validations have been carried out by Demombynes and Özler (2005) and the Institute for Security Studies). Since we use the data as the outcome variable, our results should be unbiased as long as reporting of crime is uncorrelated with mining activity. This might not be the case if mining activity affects the amount of resources dedicated to the police. To investigate this potential concern and to be sure that our results are not explained by higher investments in local policing as mining intensity increases, we collect data on crime-prevention expenditure. This data is from the National Treasury's yearly budget reports and is available at provincial level (National Treasury 2015). More subtle changes in police reporting might stem from changes in reporting behavior, unrelated to police expenditure. Norms regarding and prevalence of bribe taking behavior of the police in mining districts could affect the number of crimes reported. Crime syndicates involved in illegal trading of gold and diamond have been found to bribe police men (Gastrow 2001). Illegal extraction (such as outside of the concession, on someone else's concession, or more than allowed in the mining contract, Le Billon, 2014, p.49), theft from mines, and illegal trading of raw materials are not per se threats to our identification. The natural resource curse literature hypothesizes that an increase in value of the natural resources stemming from an increase in the commodity price, increases the competition over the resource, resulting in more social conflict. However, while such a mechanism would result in more criminal behavior, police bribing would decrease the reporting of such crimes. To fully disentangle these two effects might be problematic.

[15] A crime enters the official statistics through two mechanisms: first, a victim or witness report an incident to the police. Second, the police record it in their records.

[16] Property crime consists of theft, burglary at non-residential premises, burglary at residential premises, common robbery, robbery at non-residential premises, robbery at residential premises, shoplifting, stock theft, theft of motor vehicle and motorcycle, and theft out of or from motor vehicle.

[17] Violent crime consists of arson, assault with the intent to inflict grievous bodily harm, attempted murder, common assault, culpable homicide, malicious damage to property, murder, public violence, robbery with aggravating circumstances, and sex crimes.

[18] In addition to property and violent crime, total crime also includes carjacking, crimen injuria, driving under the influence of alcohol or drugs, drug-related crime, illegal possession of firearms and ammunition, kidnapping, neglect and ill-treatment of children and truck hijacking.

[19] In the context of South Africa, violence might not be a specific case of criminality, but rather a phenomenon of its own, that at times overlaps with criminality. Research has found that violence is ingrained in South African society and that it is often both legal and socially acceptable, such as in childrearing and in intimate relationships (Collins 2013), which further motivates analyzing this as a separate category.

4.4.3 Population, Migration, Night Lights, and Mineral Prices

The population data comes from Statistics South Africa's 2001 and 2011 censuses.[20] Since the crime data covers the years 2003-2012, we need to extrapolate the population estimates to be able to create a per capita outcome variable for each year. Although this proceeding is of course not ideal, the census data is the most reliable and, to our knowledge, most commonly used source on the size of the South African population. We assume a constant growth rate for each geographical unit from 2003 to 2012 based on the average annual growth rate according to the two censuses for that particular unit.[21] These growth rates are then used to obtain estimates of the annual population level. In the subsequent results section, we also show that our results are robust to not taking the local population size into account.

From the 2011 census, we also construct an annual measure of international migration to a municipality. This is possible since respondents in the census need to provide information on how long they have lived in their current municipality and from what country they moved[22]. The question is only asked to persons who were born outside South Africa. We can reconstruct migration inflows, but will unfortunately not have information on migration outflows. That is, we only capture immigrants for 2011 and thus not, for example, a person who migrated to South Africa in 2004 and then moved out of the country in 2007. Subsequently, to deal with the fact that areas with a high population also tend to have higher migration flows, we combine this information with the aforementioned population data to construct the share of migrants in a given municipality and year.

As with the population data, reliable employment and income data is only available from the South African census (Statistics South Africa). Unfortunately, this data is only available for 2011 and is not provided at a sufficiently disaggregated level to enable us to match it with police precincts[23]. To understand employment and income over time we make use of estimates of light density measured by satellites at night as a proxy for economic activity, in line with several recent studies (Bleakley and Lin 2012; Henderson et al. 2012; Lowe 2014b; and Michalopoulos and Papaioannou 2013). This high-resolution data comes from the National Oceanic and Atmospheric Administration and is suitable for estimation of localized effects (Lowe 2014), such as in this paper.

Finally, the data on mineral prices is available for 20 different minerals[24] comes from two different sources: the U.S. Geological Survey[25] and IntierraRMG[26]. The price data covers the same years as those for which we have crime data (2003-2012) and is measured in U.S. dollars per gram. The price trend per mineral is shown in Figure 4.5.

[20] An interim census was collected in 2007, and the population estimates from the 2007 census will be incorporated in later versions of the paper.

[21] For the precincts we only have information about the population in 2011. To calculate the population figures for the other years we use the population growth rate in the municipality.

[22] Respondents answer the following question: "In which year did [you] move to South Africa?"

[23] Quarterly Labor Force Surveys are available 2008-2012 with enumeration area information. A later version will include robustness analysis using this data.

[24] In the instrumental variable analysis, we only make use of the main mineral of each mine, which leaves us with 15 minerals.

[25] USGS gives us price data for antimony, cobalt, manganese ore, phosphate rock, titanium, vanadium, zirconium, chromite and iron ore.

[26] IntierraRMG gives us price data for gold, silver, platinum, aluminum, copper, lead, nickel, tin and zinc.

4.4.4 Sample Construction

Since the above data is provided at different geographical levels, it is necessary to aggregate the information in order to carry out the analysis. Administrative areas (police precincts and the larger municipalities) are matched to all mines within 20 km from their borders. The matching procedure is illustrated in Figure 4.7 and has been designed to take potential spillover effects into account. Previous studies on mining in Africa have found that both local labor markets and agricultural productivity are affected within 20km from the mine (e.g., both Aragon and Rud, 2013 and Kotsadam and Tolonen, 2013 use a 20 km radius around the mine as their main specification[27]). Since a number of mines are located close to administrative borders in South Africa, this matching strategy is important in order to capture the full effect of mining activity on criminality.

Using this approach, three different samples are constructed. Two samples use the police precincts as the geographical unit of observation and one sample uses the municipalities. Summary statistics for all samples are presented in Table 4.1. The sample in Panel A is constrained by the availability of international mineral price data and only includes precincts with mines that are main producers of any of these minerals. This sample is used for the IV analysis described below. The samples presented in Panels B and C are used in the fixed effect strategy and include all mines and minerals as well as all administrative units. Overall, we see that crime rates are high, with total crimes ranging from 39.8 to 88.9 per 1,000 inhabitants, with a majority of these crimes being classified as property crime. Crime levels are notably higher in precincts with mines, reflecting the positive correlation between number of mines and crime rate.

4.5 Empirical Strategy

4.5.1 Fixed Effects Approach

The baseline estimation strategy is a fixed effects (FE) model using the panel version of the dataset. The FE approach relies on the timing of mine opening being orthogonal to local changes in crime levels. We use the following equation:

$$ln(y_{jt}) = \theta a_{jt} + \gamma_j + \lambda_t + \varepsilon_{jt}, \tag{4.5.1}$$

where $ln(y_{jt})$ is the log of the crime rate and a_{jt} the number of active mines in precinct/municipality j and year t. Time and location fixed effects are captured by λ_t and γ_j, respectively. The parameter of interest is θ, which captures the effect of the number of active mines on the local crime rate. We estimate the same equation (at municipal level) when analyzing the effect of mining activity on migration. Table 4.2 shows that there is substantial variation in the data. Fifty-four precincts move from zero to one mine, 48 move from one mine to zero mines, 46 move from one mine to two mines, and 43 move from two mines to three mines, etc. These are net flows: If a precinct sees one mine close and one mine open between year t-1 and year t, it will have a net effect of zero and place along the diagonal.

There may be selection into becoming a mining precinct, however the strategy relies on within-precinct variation in crime levels stemming from the production status of mines. South African police precincts can

[27] Other studies have used shorter baseline distances, ranging from 5 km in von der Goltz and Barnwal (2014) to 15km in Tolonen (2015). In this analysis, we consider as a mining district any precinct with a border within 20 km from a mine. The treatment area is thus larger than in aforementioned analyses. We argue that South Africa has a more extensively developed infrastructure network, which allows for longer commuting distances as well as economic integration of larger geographic areas.

become mining areas if they have a mineral deposit that is profitable to exploit[28]. The decision to extract minerals from the deposit will however depend on local institutions. The police precincts, which are smaller geographic areas than the municipalities or provinces, are only related to the work of the police force and fills no other administrative role. Institutions that might influence the mining industry, such as rules regarding mining licenses, will be determined at higher administrative levels. The FE strategy, however, relies upon mine opening and closing years being exogenous to other changes in a police precinct. Additionally, we use an instrumental variables (IV) approach, explained below.

4.5.2 Instrumental Variable Approach

To estimate the causal effect of mining activity on the local crime rate, we need to overcome a potential reverse causation problem: that mine production could be affected by changes in crime in the proximity of the mine. In other words, we risk misinterpreting our effects if lower crime rates lead to higher mineral production, rather than higher mineral production leading to lower crime rates. Although we do not have any evidence that this is the case in South Africa, it seems likely that investment decisions, including foreign direct investment decisions, are affected by local and regional security issues and corruption. It can be assumed that multinational mining companies prefer stable political environments with low corruption, as has been shown for investment in the gold sector (Tole and Koop 2011). Contrary to this assumption, however, the cross-sectional results illustrate that mines are located in police precincts with higher crime levels (see Table 4.5 OLS).

We use an IV approach where we instrument mining production with international mineral prices[29]. The idea is that production decisions are largely influenced by the exogenously determined possibility of profitably selling the minerals on the international market.[30] The exogeneity of international mineral prices is motivated by the fact that demand elasticities are typically low since minerals are generally inputs in industrial production and only constitute a small share of the consumer price. At the same time, the income elasticity of demand is often high, and hence changes in economic activities in other countries, such as among large Asian manufacturers, can have significant effects on mineral prices (Slade 1982). Similar identification strategies have been used previously by, for example Sanchez de la Sierra (2014) and Berman, Couttenier, Rohner and Thoenig (2014), and are particularly suitable for South Africa with its large mineral exports (CoM 2014). The main identification assumption is that international mineral prices affect crime through mine production and not through any other channels (the exclusion restriction). We have no reason to believe that South African crime levels are directly affected by international mineral prices. However, a potential concern is that South Africa influences the international market price for those minerals where it has market power. In order to rule this out, we exclude all such minerals in the robustness section.[31]

We estimate the following first stage regression:

$$a_{ijt} = \delta p_{it} + \gamma_{ij} + \lambda_t + u_{ijt}, \tag{4.5.2}$$

[28] Mineral deposits are known to be geological anomalies and random across space.

[29] One limitation of the IV strategy is that we do not have world prices for all minerals, which means that we do not use all the variation we have in mining activities in the data set. However, all variation is used in the FE approach.

[30] We mainly expect price changes to affect production stops or fluctuations rather than the openings of new mines considering the large investment costs and time required to start up a new mine. However, in the subsequent analysis we test whether our results change for starts in production by excluding new mines.

[31] South Africa has significant market power for palladium, platinum, zirconium, vanadium, manganese ore and titanium.

where a_{ijt} is the number of active mineral i mines in precinct j, year t. The regression controls for mineral by precinct (γ_{ij}) as well as year (λ_t) fixed effects. The main variable of interest is p_{it} which captures the world market price of mineral i in year t in USD per gram. In the second stage analysis we regress the log of the total, property and violent crime rate in precinct j and year t on the instrumented number of mineral i mines in the precinct:[32]

$$ln(y_{ijt}) = \beta a_{ijt} + \gamma_{ij} + \lambda_t + \varepsilon_{ijt}. \tag{4.5.3}$$

The parameter of interest is β, which captures the local average treatment effect (LATE) of price-induced changes in mining activity on the crime rate under the identification assumptions discussed above. Standard errors are clustered at the precinct level in order to account for serial correlation of the errors over time.[33] The same equations are estimated when we investigate the effect of mining activity on economic activity, proxied by light density.

4.5.3 Production Shocks

In order to understand the dynamics of how mining activity affects crime, we investigate how production shocks affect crime rates. We implement this analysis using both an IV and an FE strategy. We implement a fixed effect strategy using the following regression:

$$ln(y_{jt}) = \beta_1 start_{jt} + \beta_2 stop_{jt} + \gamma_j + \lambda_t + \varepsilon_{jt} \tag{4.5.4}$$

where $start_{jt}$ / $stop_{jt}$ is the net number of mines that start/stop producing in year t (in relation to whether they were producing in year $t-1$) in precinct/municipality j. As in all previous specifications all mines within 20 km from the geographical unit of observation are considered. Time and location fixed effects are captured by λ_t and γ_j, respectively. Moreover, to investigate the possibility that mining affects crime both before and after production shocks (e.g., through linkages and changes in production volume), we allow for leads and lags in this specification.

The IV strategy estimates the following equations:

$$shock_{ijt} = \kappa p_{it} + \gamma_{ij} + \lambda_t + u_{ijt}, \tag{4.5.5}$$

$$ln(y_{ijt}) = \pi shock_{ijt} + \gamma_{ij} + \lambda_t + \varepsilon_{ijt}. \tag{4.5.6}$$

where $shock_{ijt}$ is the net number of mines that either start or stop producing the mineral i in year t (in relation to whether they produced the mineral in year $t-1$) within 20 km from precinct j. The start and stop regressions are estimated separately to allow for non-symmetric effects. All other variables are the same as in the IV specification above. We expect κ to be positive when estimating the impact on production starts (i.e., that a higher international mineral price leads a larger number of mines to start producing that mineral), whereas we expect κ to be negative when estimating the effect on production stops (i.e., if the international price

[32]Note that the local crime rate varies by precinct j and year t and not by the mineral type i. Hence, the mineral i subscript for the outcome variable is only used to show that the same crime rate is used for all mineral i observations in precinct j and year t.

[33]However, to deal with mineral-time specific shocks, two-way clustered standard errors on the precinct and mineral-time dimension are also reported for the main specifications.

becomes sufficiently low, a larger number of mines will stop producing that mineral). The effect of production starts/stops on the log of the crime rate is captured by π.

4.6 Results

4.6.1 Main Effects

Table 4.3 and Table 4.4 display the results from the FE specification, while Table 4.5 shows the corresponding results from the IV strategy. Table 4.8 reports the results of production shocks on crime rates in an FE setting.

As stated earlier, we implement an FE strategy at both police precinct and municipality level. Since crime statistics are given at precinct level, we need to aggregate them to match with the larger municipalities, the level at which we have information on migration flows from the censuses. The effects of mining activity on crime in a municipality are then based on an area approximately five times as large as the precinct on average. Thus, we view such estimations as the effect of mining activity on crime at an aggregate level. Tables 4.3[34] and 4.4 display negative results. The estimated effects of mining activity on total crime rate are quite similar in size at both levels (1.5-2 percent), but the effects differ for property and violent crime. Specifically, violent crime is significantly negatively affected by mining activity at the precinct level, while property crime is negative but insignificant. The reverse holds true at the municipal level.

The top panel in Table 4.5 show the unadjusted correlation between mining and crime using the sample with prices. We see a strong positive association between the number of active mines in a police precinct and the crime level. As discussed above, there are a number of reasons why we should not trust such an estimate, e.g. that mining activity may be affected by crime levels and that the industry has historically been a catalyst behind the growth of towns and cities, which today are the major crime hubs. To overcome potential reversed-causation and omitted variable problems, we implement our IV strategy. The same table show that the first-stage estimate is positive and highly significant: as world market mineral prices increase, so does the number of active mines producing those particular minerals in a police precinct.[35] More specifically, we find that as the mineral price increases by ten dollars per gram, the number of active mines increases by about nine per cent of the mean number of active mines. Contrary to previous literature investigating the effect of extractive industries on social conflict, the resulting second-stage analysis displays a big and significant *negative* effect from mining. In particular, as the number of active mines increases, induced by higher international prices, total crime rates decrease by around seven percent for each additional active mine. The effect is somewhat bigger for property crimes than for violent crimes but is highly statistically significant in both cases.

Comparing the IV results and the FE results, it is clear that the estimated effects are larger using the IV approach. This discrepancy might stem from the fact that the IV results rely on price shocks and thus could be considered the local effects of a mining-production shock on crime. That is, in the IV specification we

[34] Column 1 shows the unadjusted correlation in the data, revealing that mining districts have higher total crime rates. However, the fixed effects model show that the association between more active mines and criminality is negative. The main treatment variable *Active Mine 20 km* is zero in 88%, but can be as high as 10 active mines, in a given year and precinct. The high levels of zeros mean that we do not want to use the log of this variable. To test the constant semi-elasticity of the model assumed here, we include the square of this term in Appendix Table C.5. We note that in the cross section, the positive association between the number of active mines and criminality is concave. However, in the fixed effects model the square terms are very small and insignificant, which increases our belief in the assumption of constant semi-elasticity.

[35] These results are robust to logging the price variable.

capture the effect of less expected production changes, compared with the FE specification[36].

The above results are supported by Figure 4.6, which shows how the number of active mines has increased during our period of study while criminality in mining precincts has fallen.[37] In fact, crime rates have been on a negative trend overall in South Africa, with property crimes falling more than violent crime, and mining districts seeing larger reductions than non-mining areas. Crime levels converged for mining districts and non-mining districts around 2011 and 2012. For total crime, which contains more crime categories than property and violent crimes, non-mining areas have even surpassed mining areas in crime levels.

Next, we delve further into the dynamics of how mining activity affects crime by investigating the effect of production shocks. Here, we define a production shock as a start or a stop in mining production. We display support for this result in Table 4.7 which gives the estimates for an FE strategy, also looking at the effect of starts/stops in mining activity. Here, however, violent crime is not significant and we find no significant effect from starts in mining production. In turn, Table 4.8 shows that the positive effect of a stop in production on crime is stronger for the current year than if the mine stops producing in $t-1$ or $t+1$. However, we find significant effects of mining stops with both leads and lags on criminality. Mines that are about to close may phase out production over time, especially if they are closing down because of depletion of the mineral source. Hence, this is likely a consequence of the fact that we are only capturing the extensive margin effect of mining activity. Similar patterns are seen for a start in production, but here the results are insignificant.

Lastly, Tables C.6, C.7 and C.8 in the Appendix give the results for all subcategories of crime using the IV approach. As would be expected given the results on the compiled variables (total, property and violent), most crimes have a negative coefficient. It is however interesting to note in Table C.1 that the effect of mining activity on public violence tends to be positive, albeit insignificant using the IV approach. This subcategory of crime is much like what has been explored in earlier papers on extractive industries and social conflict. To investigate this further we run regressions with this outcome also using the FE strategy for both the municipality and the precinct sample. Using this strategy, we find positive and a highly statistically significant impact on public violence. Hence, we seem to, at least suggestively, find similar effects as previous studies also for South Africa. This implies that extractive industries may have differing effects dependent on the type of crime investigated.

4.6.2 Potential Mechanisms

Income Opportunities

We have found that mining activity has a negative effect on crime rates and that crime rates go up as mining activity stops. These results are in line with economic theories saying that income opportunities determine crime rates. In other words, when mining activity increases, economic opportunities are likely to increase as a consequence. This in turn lowers the incentives to commit crimes. Likewise, when a mine stops producing, income opportunities may fall and crime incentives increase. Ideally, we would want to test these channels with yearly data on employment and incomes at police precinct level, but such data does not exist for our

[36] If precinct level decreases in crime rates caused mines to open, the FE estimates would suffer from bias and more negative. We notice however the IV estimates are in fact more negative than the FE estimates.

[37] We take the fact that mining and non-mining police precincts seem to have very similar time trends in criminality during the time period when mining is relatively low as support for the way we implement the FE strategy, i.e. that we include non-mining precincts in the sample to estimate our time fixed effects.

period of analysis. Thus, we make use of the light density at night as a proxy for economic activity. Table 4.12 reports the results.

As expected, we find that an increase in the number of active mines leads to increased economic activity, proxied by night lights. More specifically, the results from a precinct FE analysis show that one additional active mine increases the mean light density by about five percent of the mean value. Likewise, when a mine stops producing, economic activity decreases by about 2.6 percent. Using the IV strategy we find effects in the same direction that are substantially larger, especially for production shocks. Again, we see no significant effects for a start in mining activity with the FE strategy, but when using the IV approach and excluding new mines in Panel B, we find a positive and significant effect. Furthermore, in the third column of Panel A in Table 4.12, we show that the effect of mining activity also is present in precincts without a mine, but with a mine 20 km from its borders. Thus, there are clear economic spillover effects from mining activity that underline the importance of the 20 km radius used in this paper. The estimate is larger in the third column than in the fourth column, but so is the mean light density, a result of the fact that cities are usually situated in precincts neighboring mining areas. Further, this analysis ensures that the results in this section are not driven by lights emitted from the mine.

In Table 4.13 we split the sample and explore the effect of mining on crime for open-pit mining and underground mining respectively. The idea is that open-pit mining and underground mining differ in capital and labor intensity, with underground mining being more labor intensive. Looking at these heterogeneity results, we are thus able to say something about how our setting relates to the theory developed by Dal Bó and Dal Bó (2011). In line with the theory, we find that our results seem to be driven by positive shocks to labor-intensive mines (Panel B). For capital-intensive mining, the results are not significant, but it is interesting to note that the signs are positive for all crime categories.

In summary, this analysis suggests that mining activity does significantly affect local economic opportunities. In turn, since much of the South African mining industry is labor intensive, a positive shock to the industry reduces the incentives to commit crimes.

Migration

Migration plays a paramount role in the South African mining industry and the size of the migratory influx determines whether employment rates increase or decrease. Moreover, the migrant-labor system and the informal settlements that it is associated with, have historically been linked high unemployment, lack of services and high crime rates and are thus a potential mechanism behind our findings.

In Table 4.14, we start out by showing that total and male migration as well as migration from SADC[38] countries increase due to mining activity. In particular, when the number of active mines increases by one, migration as a share of the municipality's population increases by approximately 23 per cent of the mean. It thus seems to be the case that the mining industry is still seen as a potential employer by migrant workers from countries such as Mozambique and Lesotho. In turn, this finding might be driven by the increase of around 18 percent that comes from a start in mining production (second panel). The fact that we do not find significant estimates from stops in production is not too surprising since the data does not allow us to capture migration outflows (see data section above).

[38]SADC stands for the Southern African Development Community and includes Angola, Botswana, Democratic Republic of the Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

Geography, such as distance from border and persistence of migration movements may determine migration patterns in the wake of a mining boom. We explore if effects are different in precincts with higher than median rate of migration from precincts with lower than median rates of migration. Migration rates are possibly endogenous to present and historic mining, so the results should be interpreted with care. Table 4.15 shows the results.[39] The results for municipalities with migration shares below the median are reported in Panel A. There are no significant effects of the number of active mines within 20 km on the log crime rate in these municipalities, but point estimates are positive. However, looking at production shocks we see that production starts in low migration areas are associated with lower crime rates (total crimes go down by about 2.45 percent) and typically small and insignificant effects on crime when a mine stops producing. Panel B shows the results for municipalities with above-median migration shares. These results indicate that an increase in the number of active mines leads to lower crime rates, while both starts and stops in production are associated with higher crime rates. Notably, the increase in crime when a mine stops producing is statistically significant for both total and property crime. A potential explanation for these results is that production shocks in high migration areas affect individuals with weaker ties to the local labor market and weaker network ties, hence the income opportunities provided by the mine are more important for this group. The positive (but mostly insignificant) estimates when the mine starts production could potentially be driven by an over-supply of migrant workers.

4.6.3 Robustness Checks

The main specification uses year fixed effects. In Table 4.9 and Table 4.10 we show the sensitivity to the inclusion of linear and quadratic trends and different geographic level fixed effects. Figure 4.9 shows that the year dummies capture a quadratic trend, and that the inclusion of a linear and a quadratic time trend (Table 4.9, Column 4) or linear and quadratic price trend (Table 4.9, Column 4) result in comparable results to the main specification with year fixed effects. Appendix Figures C.1, C.2, C.3 show non-linear trends in crime rates across the nine South African provinces, motivating the inclusion of quadratic trends or year fixed effects.

However, the fixed effects model is not robust to inclusion of province time trends (Table 4.9, Column 5), province-year fixed effects (Column 6), or precinct time trends (Column 7 and Column 8). This is worrying, since we cannot exclude that the main results in the fixed effects model are driven by local time trends in criminality. Nonetheless, the IV model (Table 4.10) estimates results in similar direction to the baseline results using year fixed effects and province specific time trends (Column 5), province specific year fixed effects (Column 6), or year fixed effects and a precinct-specific linear time trend (Column 7). The coefficient size is smaller for these estimates and for Columns 6 only significant at the 90 percent confidence level. Table 4.11 shows that the results from the instrumental variable model are robust also to a log-log specification, where the log of mineral price is used as an instrument.

As discussed earlier, we use international mineral prices as an instrument for mining production. Table 4.5 reports results using prices of all minerals. In Table C.2 we deal with the potential concern that South African production may affect international prices since the country has a high share of the world production for some minerals. If that is the case, local crime levels could affect production, which in turn would affect international prices and thus invalidate the instrument. We thus drop minerals for which South Africa contributed more than

[39] The median migrant share of the population in the sample is about 0.1 per cent.

20 percent of the world production in the period of analysis.[40] We still find strong negative and significant effects of mining activity on crime. Although we drop 1,500 observation with this specification, the estimates are very similar in size with a nearly identical first-stage estimate of the effect of international prices on mining production.

Another potential concern is that the price instrument is reflecting overall changes in the global economy, rather than shocks to a specific mineral mine. If this is the case, then our strategy might capture changes in general economic trends that could affect criminal activity directly, which would invalidate our identification assumptions. To investigate this potential concern, we follow Hsiang and Jina (2014) and randomly match our mineral price data (preserving the time-ordering of the data) to the mineral-precinct units and re-estimate our first stage equation on this new sample. This procedure is then carried out 10,000 times with the purpose of testing whether temporal trends in our data are generating spurious correlations. Panel A of Figure 4.10 shows the density of first stage coefficients using this randomization strategy. As can be seen from the figure, the randomization procedure produces a distribution of coefficients centered at zero, indicating that the model is unlikely to generate biased results. Further, the figure show a vertical line indicating the coefficient obtained when using the true data. An exact test show that the probability that our estimate is generated by chance is less than 0.01. The concern that our results are driven by economic trends also applies to the FE specification. In order to check this we employ a similar randomization strategy as above but instead randomize the mining activity variable in equation (3). Panel B of Figure 4.10 shows the results from this test. Also in this case are we able to reject that our estimate is from the randomly generated distribution of coefficients, indicating that the results are not driven by economic trends.

We also investigate the importance of the strategy employed to deal with spillovers in Table C.3, where we run the same regression as earlier, but without a 20 km radius around each mine. This means that if, for example, a mine closes in a municipality near the border of another municipality, we do not take into account that the mine closing could affect the neighboring municipality's crime rate. Even with this restriction we find a negative significant effect on total crime with a point estimate similar in size to when a 20 km radius was used, but less precisely estimated.

As mentioned in Section 4.3, we need to extrapolate the population estimates from StatSA's censuses to be able to create per capita outcome variables for each year. To test the concern that this data issue is somehow affecting our results, we show that the negative and significant estimates hold also for count data in Table C.4.

There is a possibility that the negative effect of mining activity on crime found in this paper stems from the fact that the mining industry makes use of private security companies. An increased mining activity would then result in more private security forces which in turn would result in lower crime rates. However, we do not have any indications of mining security working outside the immediate mining facilities. Rather, as outlined by the director of the global security company G4S when discussing South Africa, "the priority is to control access in order to counter external criminal threats against the company's equipment and infrastructure, while maintaining order among the large workforce" (Mining Technology 2013). Thus, since this paper explores the effect of mining activity on crime in a larger area around a mine, we do not expect private mining security to be driving the results.

Lastly, and similar to the aforementioned, a potential concerns is that our results are explained by higher crime-prevention expenditures as mining activity increases (or lower expenditures when they close down). If

[40]For our period of analysis, these minerals are palladium, chromite, platinum, zirconium, vanadium, manganese ore and titanium.

so, we cannot say with certainty that the negative effects of mining on crime actually stems from mining in itself. In Table 4.16, the first two columns explore the effect of the number of active mines on crime-prevention expenditure in a fixed effect setting. Unfortunately, to our knowledge, this data is only available at province level, which leaves us with very few observations. This is due to the fact that the policing responsibility lies at this administrative level. We find no significant effects of mining activity on police expenditure. If anything, the estimates are negative, regardless of whether the outcome is logarithmized or not. The third column shows the main (negative) result from instrumenting the number of active mines with international mineral prices. The last column gives the same estimation, but here we include provincial crime-prevention expenditure per capita as a control variable. Apparent from the column, the main estimate remains virtually the same in terms of both size and significance (and even increases somewhat) while the coefficient on police expenditure is negative and significant. Bearing in mind the limitations of these tests, we do not find any evidence for the concern that our results are driven by crime-prevention expenditure. Police activity directly related to local mining is restricted to the so called Diamond and Gold Branch of the South African Police Service (ISS 2015). Since their main responsibility is to investigate cases where mining materials are suspected to be stolen, rather than crimes as defined in this paper, our findings from this analysis might not be too surprising.

4.7 Discussion

It is a much studied question whether natural resource economies are more vulnerable to social conflict and civil war. To our knowledge, this is the first paper to look at social instability at another level: criminality. We explore the link between South Africa's mining sector and crime rates. The question is of particular interest in this context: first because South Africa is one of the world's most important mining countries and one of the most crime-ridden countries in the world and second because South Africa is a middle-income country with relatively stable political institutions. Previous hypotheses are mostly applicable to low-income countries or countries with political volatility, and are therefore not informative regarding the relationship between criminality and mining in this context. Since many natural-resource rich economies are middle-income countries, for example Botswana, Brazil, Mexico, and Romania, this is an issue of great relevance.

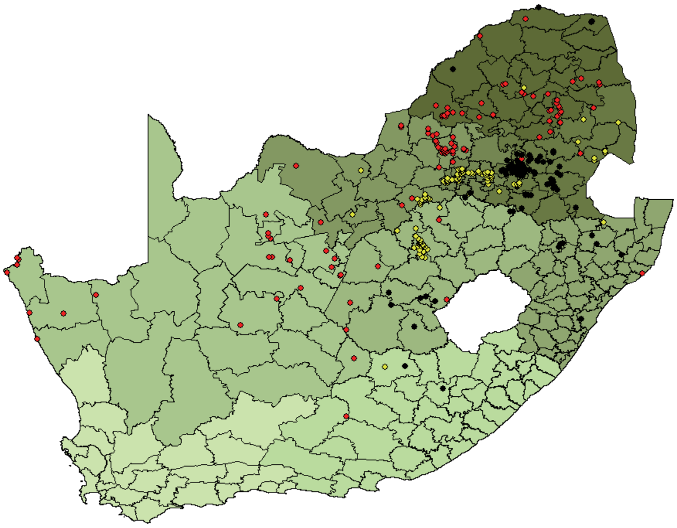
In this paper we explore the causal link between large-scale mining activities and criminality using different definitions of mining areas and two different identification strategies: a fixed-effects approach and an instrumental variable approach. With these strategies we explore how criminality changes with the number of active mines of a certain mineral within a precinct or at the larger municipality level, and how criminality changes with stops and starts in mining production. To overcome concerns regarding reversed causality, where companies choose to invest or disinvest in certain areas because of crime rates, we instrument the number of active mines and the start and stop in production with international mineral prices. We have detailed information on various types of criminality, but to limit the risks of drawing the wrong conclusions due to multiple hypothesis testing, we focus on a pre-determined set of outcomes: total crime, property crime, and violent crime.

In contrast to the general conclusion of the literature, we find an overall negative and significant relationship between mining and criminality for total, property and violent crime. Total crime rates decrease by around seven percent with each additional mine. However, the analysis shows that mining areas may be at risk of suffering from increased levels of criminality when a mine stops producing. This indicates that the negative relationship that we see between mining and criminality could be driven by the positive shocks on criminality that mine closures could have. Such an effect could be explained through an income opportunity channel, as income opportunities likely decrease when a mine stops producing (both from the mine itself and from other industries that rely on incomes from the mining industry).

We explore two main channels: income opportunities and migration. Using night lights data, we find supportive evidence that the local economies contract when mines stop producing, leading to higher levels of unemployment and a substitution of income from wage labor with income from crime. In line with predictions from Dal Bó and Dal Bó (2011), our results seem to be driven by labor-intensive underground mining. We also note that mining causes inward migration, as the migrant share increases by 18 percent with a mine opening. Subsequently, we try to understand how migration rates may affect criminality. In this analysis we split the sample into municipalities with high and low shares of migrants in their population, respectively. The results indicate that in areas with high migration, the relationship between mines and criminality is stronger. We see this as an indicator that created job opportunities matter relatively more for crime rates in high migration areas.

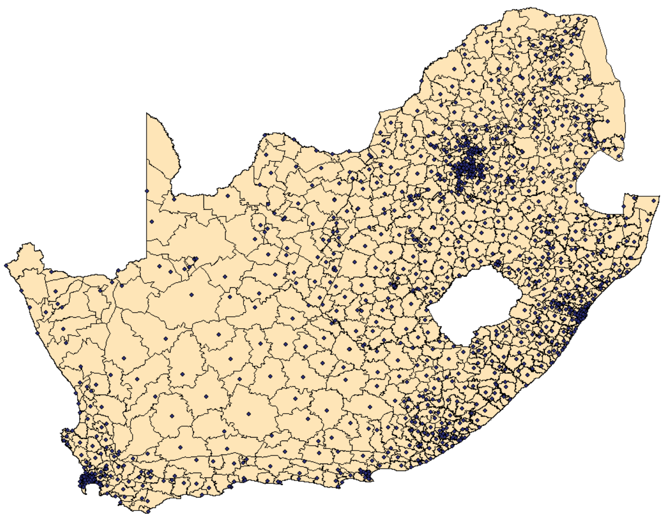
Despite the overall negative relationship between mining and criminality, we want to highlight two caveats. First, in line with previous literature, we note a positive relationship between mining and public violence. Second, the dynamic relationship between criminality and mining needs further analysis. Mining could change the local demographic structure and labor markets, which could result in higher crime rates when a local mining bust materializes. In the case of South African mining, we might expect the mining sector to cause inward migration of young men to informal settlements around mines. If the job opportunities within the sector are suddenly withdrawn, it could spur a criminality shock. Given the sector's volatile nature, in that it is dependent on depletable resources and sensitive to commodity price shocks, this is potentially of high relevance.

Figure 4.1: Mines in South Africa



Notes: This map shows the location of all mines in South Africa for which data is available. Gold mines are illustrated with yellow points and coal mines with black points, whereas all other mines are illustrated with red points. The map also shows municipality borders as defined in the 2011 census and provinces are color coded.

Figure 4.2: Police Stations in South Africa



Notes: This map shows the geographical location of all police stations in South Africa. The map also shows the borders of the police precincts in 2003.

Figure 4.3: Production of Minerals in South Africa

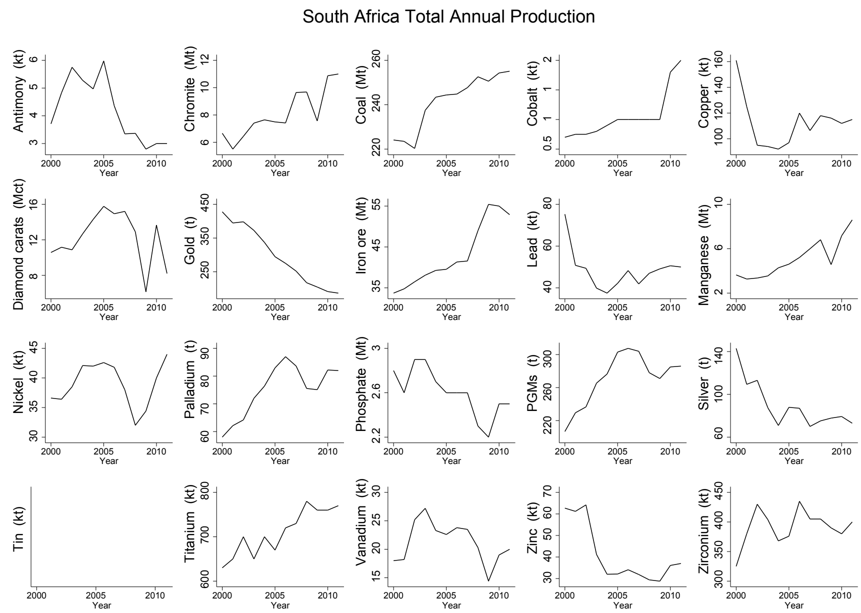


Figure 4.4: South Africa Share of World Production

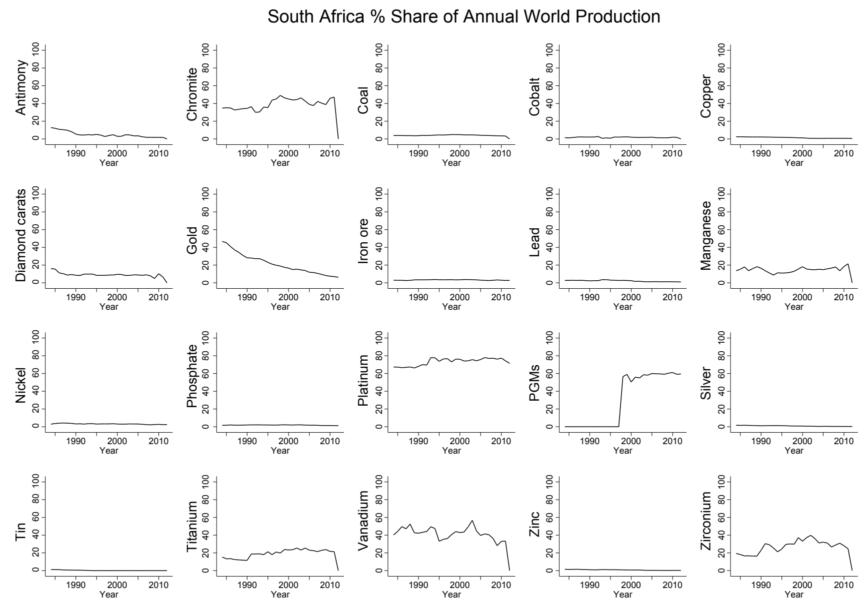
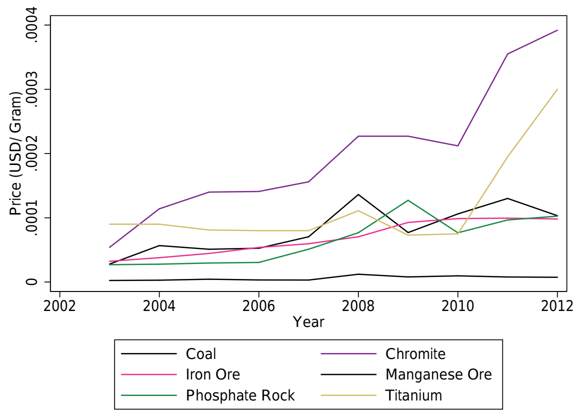
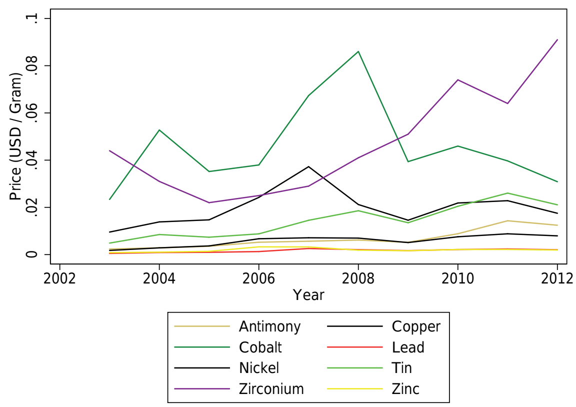


Figure 4.5: International Mineral Price Trends

(a) Low Price Minerals



(b) Medium Price Minerals



(c) High Price Minerals

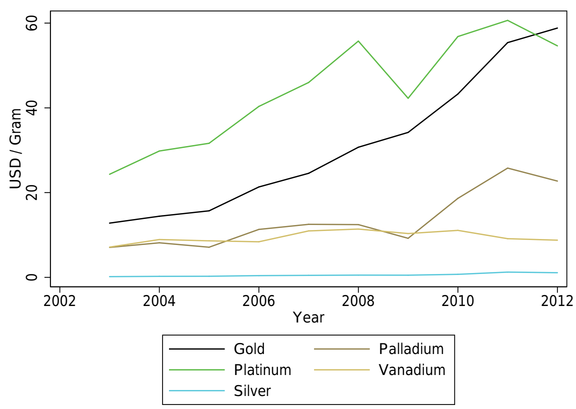
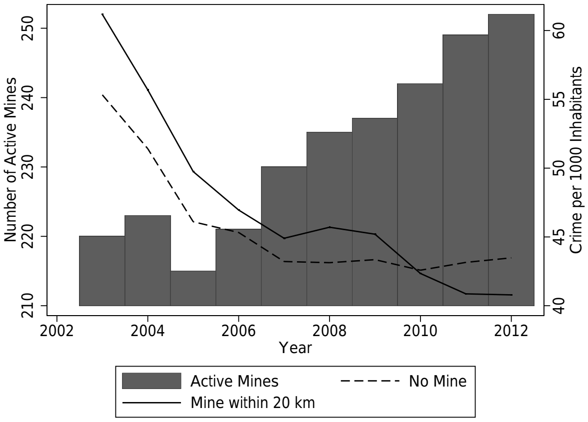
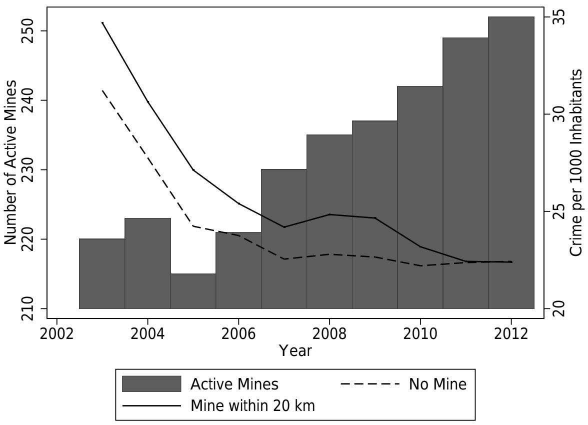


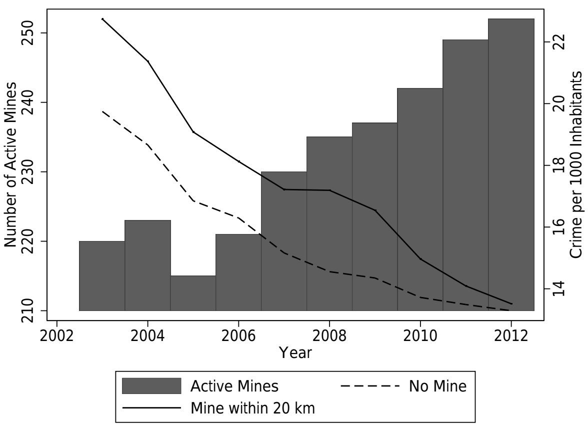
Figure 4.6: Active Mines and Crime Rates in Mine and Non-mine Precincts



(a) Total Crime



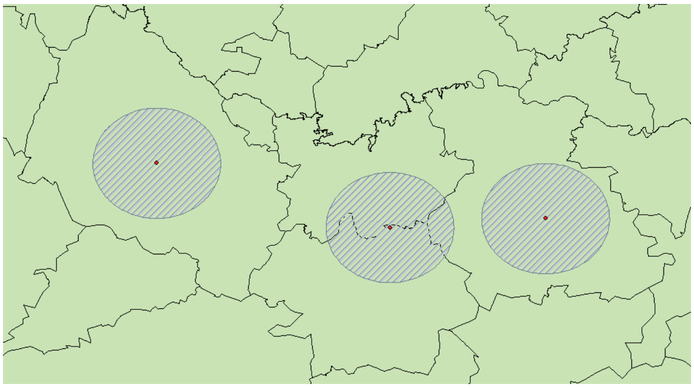
(b) Property Crime



(c) Violent Crime

Notes: Sample is split by precincts that never have a mine, or have at least one mine in the sample period.

Figure 4.7: Matching Mines and Police Precincts



Notes: This map shows how administrative areas are matched to all mines that lie within 20 km from their borders. For example, the mine shown in the middle will be matched to three precincts while the other two only maps to the same precinct as they are situated in.

Figure 4.8: Mine Location and Night Lights in 2012

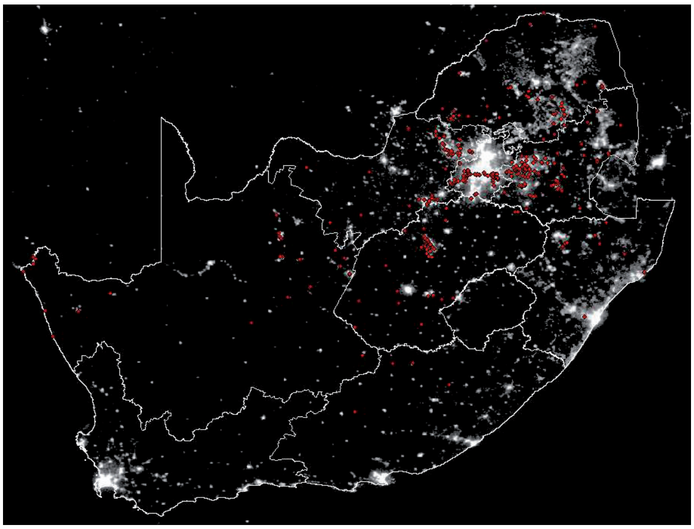
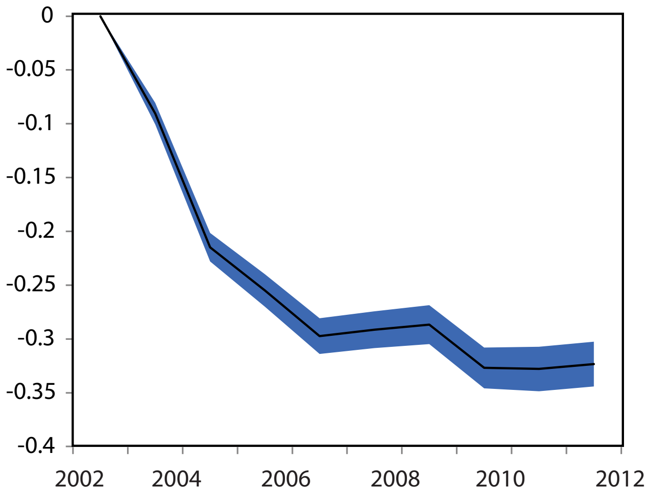
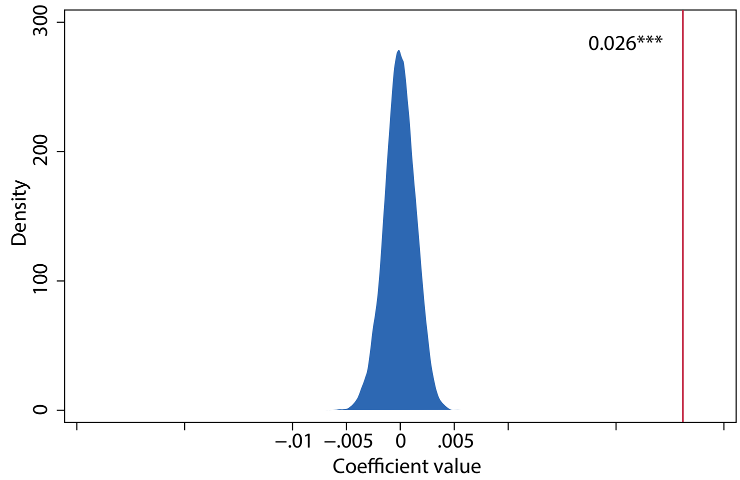


Figure 4.9: Year Fixed Effects

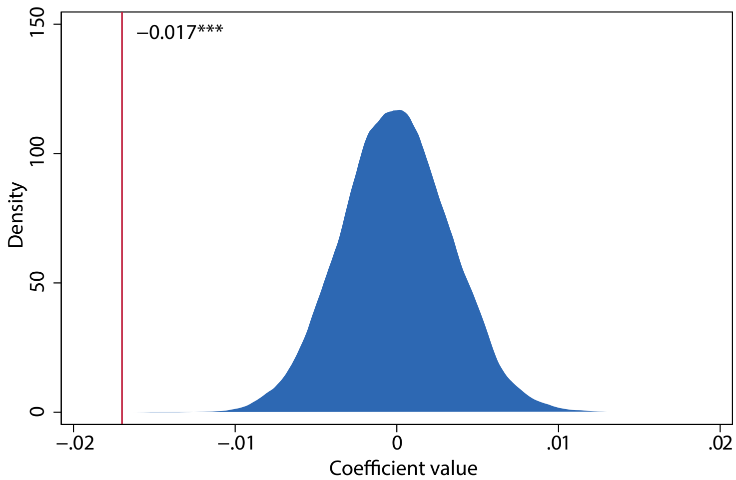


Notes: This figure plots the year fixed effects coefficients estimated in the baseline model (see Table 10, Column 2).

Figure 4.10: Coefficient Densities from Randomization Tests



(a) First Stage Coefficient



(b) Fixed Effect Coefficient

Notes: These density plots show the distribution of coefficients from running the main specification with randomly assigning data between panel units. The first figure shows the distribution of the first stage coefficients (the effect of the mineral price on mining activity) from estimating equation (1) with randomly matched price data to a mineral-precinct pair (preserving the time structure of the data). Panel B shows the distribution of the fixed effect coefficient (the effect of mining activity on the log of the total crime rate) from estimating equation (3) with randomly matched mining activity data to a precinct (preserving the time structure of the data). Both randomizations have been carried out 10,000 times. *** indicate that exact p-values are < 0.01.

Table 4.1: Summary Statistics

	MEAN	SD	MIN	MAX	OBS
A: Price Sample					
International Mineral Price (USD/gram)	16.6	20.1	0.0000024	60.6	5260
Lights at Night	15.4	20.6	0	63	5260
Population (1000')	55.1	58.6	0.14	592.3	5260
Active Mine 20km	2.89	4.04	0	35	5260
# Start Producing 20km	0.12	0.42	0	5	4733
# Stop Producing 20km	0.061	0.28	0	3	4733
Total Crime per 1000	88.9	914.5	3.49	24794.3	5260
Property Crime per 1000	59.6	740.7	1.22	21531.7	5260
Violent Crime per 1000	19.9	56.2	1.39	1544.7	5260
Log(Total Crime per 1000)	3.71	0.70	1.25	10.1	5260
Log(Property Crime per 1000)	3.02	0.86	0.20	9.98	5260
Log(Violent Crime per 1000)	2.73	0.59	0.33	7.34	5260
Expenditure per capita (Rand)	7.11	9.08	0.062	43.4	5260
B: Precinct Sample					
	mean	sd	min	max	count
Lights at Night	13.3	20.8	0	63	10830
Population (1000')	45.5	53.6	0.14	592.3	10830
Active Mine 20km	1.66	3.77	0	36	10830
# Start Producing 20km	0.062	0.29	0	5	9747
# Stop Producing 20km	0.030	0.19	0	3	9747
Total Crime per 1000	72.2	641.8	2.24	24794.3	10830
Economic Crime per 1000	44.5	519.6	0.58	21531.7	10830
Violent Crime per 1000	19.1	41.3	0	1544.7	10830
Log(Total Crime per 1000)	3.66	0.77	0.80	10.1	10830
Log(Economic Crime per 1000)	2.90	0.93	-0.54	9.98	10830
Log(Violent Crime per 1000)	2.69	0.64	0.18	7.34	10825
C: Municipality Sample					
Migrants' Share of Pop	0.0015	0.0026	0	0.062	2106
SADC Male Migrants' Share of Pop	0.00056	0.0011	0	0.026	2106
Male Migrants' Share of Pop	0.0010	0.0015	0	0.035	2106
Population (1000')	210.8	482.0	6.98	4555.7	2340
Active Mine 20km	2.86	5.93	0	44	2340
# Start Producing 20km	0.097	0.36	0	4	2340
# Stop Producing 20km	0.059	0.27	0	3	2340
Total Crime per 1000	39.8	22.3	4.50	145.1	2340
Property Crime per 1000	19.2	12.0	1.44	90.1	2340
Violent Crime per 1000	15.7	8.50	2.19	55.4	2340
Log(Total Crime per 1000)	3.50	0.64	1.50	4.98	2340
Log(Property Crime per 1000)	2.74	0.70	0.37	4.50	2340
Log(Violent Crime per 1000)	2.59	0.60	0.79	4.01	2340

Notes: This table reports summary statistics for the three main samples used in the analysis. Columns (1) through (4) reports the mean, standard deviation, minimum and maximum values of the listed variables, whereas column (5) show the number of observations. The construction of these variables are explained in sections 4.4.

Table 4.2: Transition Matrix

t-1/ t	0	1	2	3	4	5	6	7	8	9	10	Total
0	6,227	54	7	0	0	0	0	0	0	0	0	6,288
1	48	984	46	1	0	0	0	0	0	0	0	1,079
2	5	29	481	43	0	0	0	0	0	0	0	558
3	0	0	32	334	35	3	0	0	0	0	0	404
4	0	0	3	13	208	31	4	0	0	0	0	259
5	0	0	0	2	12	111	28	3	0	1	0	157
6	0	0	0	0	0	15	110	26	4	1	0	156
7	0	0	0	0	0	0	15	113	27	5	2	162
8	0	0	0	0	0	0	2	10	58	27	6	103
9	0	0	0	0	0	0	0	1	17	76	35	129
10	0	0	0	0	0	0	0	1	1	16	443	461
Total	6,280	1,067	569	393	255	160	159	154	107	126	486	9,756

Notes: This table reports the frequencies of transition for the main independent variable amine (20km) year t-1 to year t for each precincts. The reported values are net values of openings of closings that are happening in the same year. Values are censored at 10 and the maximum is 36.

Table 4.3: Precinct Fixed Effects

	OLS	FE		
	Total Crime	Total Crime	Property Crime	Violent Crime
Active Mine 20 km	0.0239***	-0.0171**	-0.0124	-0.0184**
	(0.00484)	(0.00713)	(0.00798)	(0.00786)
Observations	10830	10830	10830	10825
R-Squared	0.0136	0.955	0.952	0.905
Mean of Outcome	3.665	3.665	2.898	2.694
Precinct FE	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes

Notes: Column 1 presents the OLS cross-sectional results. Column 2-4 report the results of a fixed effect regression of the log of the local crime rate in a precinct on the number of active mines within 20 km from the precinct, with controls for precinct and year fixed effects. Standard errors in parenthesis are clustered at the precinct. For inclusion of the square term of the treatment variable, see Table C.5.

Table 4.4: Municipality Fixed Effects

	OLS	FE		
	Total Crime	Total Crime	Property Crime	Violent Crime
Active Mine 20 km	0.0193***	-0.0157**	-0.0157**	-0.0139
	(0.00398)	(0.00732)	(0.00758)	(0.00960)
Observations	2340	2340	2340	2340
R-Squared	0.0314	0.969	0.959	0.957
Mean of Outcome	3.501	3.501	2.737	2.593
Municipality FE	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes

Notes: This table reports the results from a fixed effect regression of the log of the local crime rate in a municipality on the number of active mines within 20 km from the precinct. All regressions control for municipality and year fixed effects. Standard errors in parenthesis are clustered at the precinct.

Table 4.5: Precinct IV

	Total Crime	Property Crime	Violent Crime
OLS	0.0284***	0.0351***	0.0212***
	(0.00604)	(0.00722)	(0.00478)
2SLS	-0.073***	-0.088***	-0.066***
	(0.020)	(0.022)	(0.024)
	[0.024]	[0.027]	[0.027]
Reduced Form	-0.00192***	-0.00230***	-0.00174***
	(0.000504)	(0.000551)	(0.000615)
First Stage	0.026***		
	(0.0018)		
	[0.0024]		
F Statistic (one way cluster)	206.9		
F Statistic (two way cluster)	121.1		
Observations	5260		
Mineral by Precinct FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the result of an IV regression using the world market price to instrument the number of mines that produce a given mineral within 20 km from a precinct. The IV estimate for each of the three crime categories (log of crime per capita in the precinct) is presented in the first row and the corresponding reduced form estimates in the second row. The first stage relationship is reported in the final row. All these regressions are carried out at the mineral-precinct level and include mineral by precinct fixed effects as well as year fixed effects, with the exception of the OLS results that show the cross-sectional pattern in the data. Standard errors in parenthesis are clustered at the precinct and standard errors in brackets are clustered at the precinct and the mineral-year level.

Table 4.6: Start & Stop Producing Precinct FE

	Total Crime	Property Crime	Violent Crime
Start Producing 20 km (excl. new)	-0.00182	0.00659	-0.0138
	(0.0101)	(0.0115)	(0.0137)
Stop Producing 20 km	0.0232**	0.0280**	0.0106
	(0.00999)	(0.0113)	(0.0124)
Observations	9747	9747	9742
R-Squared	0.957	0.954	0.907
Mean of Outcome	3.638	2.864	2.664
Precinct FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the result from a fixed effect regression of the log crime rate in a precinct on the number of mines that start and stops producing within 20 km from that precinct. All regressions include precinct fixed effect as well as year fixed effects. Standard errors clustered at the precinct level are reported in parenthesis.

Table 4.7: Start & Stop Producing Precinct FE

	Total Crime	Property Crime	Violent Crime
Start Producing 20 km (excl. new)	-0.00367	0.00382	-0.00645
	(0.00982)	(0.0115)	(0.0129)
Stop Producing 20 km	0.0133	0.0198*	0.00645
	(0.00928)	(0.0108)	(0.0116)
Observations	9747	9747	9742
R-Squared	0.960	0.956	0.911
Mean of Outcome	3.638	2.864	2.664
Precinct FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the result from a fixed effect regression of the log crime rate in a precinct on the number of mines that start and stops producing within 20 km from that precinct. All regressions include precinct fixed effect as well as year fixed effects. Standard errors clustered at the precinct level are reported in parenthesis.

Table 4.8: Start & Stop Producing Precinct FE with Lags and Leads

	Total Crime	Property Crime	Violent Crime
Stop 20 km t-1	0.0243**	0.0319**	0.0159
	(0.0114)	(0.0132)	(0.0149)
Stop 20 km	0.0300**	0.0354***	0.0193
	(0.0122)	(0.0133)	(0.0147)
Stop 20 km t+1	0.0209	0.0325**	-0.00399
	(0.0129)	(0.0145)	(0.0203)
Start 20 km t-1 (excl. new)	0.00126	-0.00491	-0.00220
	(0.0125)	(0.0139)	(0.0164)
Start 20 km (excl. new)	-0.0181	-0.0146	-0.0258
	(0.0134)	(0.0144)	(0.0180)
Start 20 km t+1 (excl. new)	-0.00681	0.00380	-0.0215
	(0.0127)	(0.0157)	(0.0156)
Observations	7581	7581	7576
R-Squared	0.964	0.961	0.919
Mean of Outcome	3.620	2.845	2.652
Precinct FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the result from a fixed effect regression of the log crime rate in a precinct on the lags and leads of the number of mines that start and stops producing within 20 km from that precinct. All regressions include precinct fixed effect as well as year fixed effects. Standard errors clustered at the precinct level are reported in parenthesis.

Table 4.9: Fixed Effects Model: Trends and Fixed Effects

	1	2	3	4	5	6	7	8
				Total Crime				
Active Mine 20 km	-0.063***	-0.017**	-0.0102	-0.016**	0.0009	0.0044	-0.0019	0.007
	(0.00856)	(0.0071)	(0.007)	(0.0071)	(0.0072)	(0.0074)	(0.0073)	(0.005)
Observations	10830	10830	10830	10830	10830	10830	10830	10830
R-Squared	0.937	0.955	0.950	0.954	0.957	0.959	0.976	0.984
Mean of Outcome	3.665	3.665	3.665	3.665	3.665	3.665	3.665	3.665
Precinct FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	N	Yes	N	N	Yes	N	Yes	Yes
Linear time trend	N	N	Yes	Yes	N	N	N	N
Quadratic time trend	N	N	N	Yes	N	N	N	N
Province time trend	N	N	N	N	Yes	N	N	N
Province year FE	N	N	N	N	N	Yes	N	N
Precinct time trend	N	N	N	N	N	N	Yes	Yes
Precinct quadratic trend	N	N	N	N	N	N	N	Yes

Notes: This table reports the results from a fixed effects regression of the log of the local crime rate in a municipality on the number of active mines within 20 km from the precinct. Standard errors in parenthesis are clustered at the precinct.

Table 4.10: IV Model: Trends and Fixed Effects

	1	2	3	4	5	6	7
				Total Crime			
2SLS	-0.29***	-0.073***	-0.075***	-0.073***	-0.054**	-0.045*	-0.066***
	(0.026)	(0.020)	(0.020)	(0.020)	(0.025)	(0.027)	(0.013)
	[0.025]	[0.022]	[0.022]	[0.022]	[0.029]	[0.031]	[0.012]
	1	2	3	4	5	6	7
				First Stage			
First Stage	0.027***	0.026***	0.026***	0.026***	0.020***	0.019***	0.025***
	(0.0019)	(0.0018)	(0.0018)	(0.0018)	(0.0018)	(0.0019)	(0.0030)
	[0.0019]	[0.0018]	[0.0018]	[0.0018]	[0.0018]	[0.0019]	[0.0023]
F Statistic (one way)	208.2	206.9	207.4	206.9	123.3	106.2	69.0
F Statistic (two way)	213.2	202.1	202.6	202.1	124.9	110.5	116.9
Observations	5260	5260	5260	5260	5260	5260	5260
Precinct FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	N	Yes	Yes	N	Yes	N	Yes
Linear price trend	N	N	Yes	Yes	N	N	N
Quadratic price trend	N	N	N	Yes	N	N	N
Province-time trend	N	N	N	N	Yes	N	N
Province-year FE	N	N	N	N	N	Yes	N
Precinct linear trend	N	N	N	N	N	N	Yes
Precinct-quad. trend	N	N	N	N	N	N	Yes

Notes: This table reports the results from an IV regression of the log of the local crime rate in a municipality on the number of active mines within 20 km from the precinct. The instrument is mineral price. Clustered standard errors at precinct level or mineral-precinct.

Table 4.11: IV Model: Trends and Fixed Effects using Log Price

	1	2	3	4	5	6	7
				Total Crime			
2SLS	-0.55***	-0.22***	-0.25***	-0.22***	-0.35**	-0.36**	-2.20**
	(0.053)	(0.069)	(0.074)	(0.069)	(0.14)	(0.18)	(1.07)
	[0.050]	[0.075]	[0.081]	[0.075]	[0.16]	[0.20]	[1.02]
	1	2	3	4	5	6	7
				First Stage			
First Stage	0.41***	0.28***	0.27***	0.28***	0.14***	0.13**	0.071**
	(0.035)	(0.060)	(0.059)	(0.060)	(0.044)	(0.051)	(0.035)
	[0.035]	[0.061]	[0.061]	[0.061]	[0.049]	[0.055]	[0.034]
F Statistic (one way)	139.2	22.6	21.6	22.6	10.7	6.13	4.13
F Statistic (two way)	140.5	21.2	20.1	21.2	8.77	5.18	4.43
Observations	5260	5260	5260	5260	5260	5260	5260
Precinct FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	N	Yes	Yes	N	Yes	N	Yes
Linear price trend	N	N	Yes	Yes	N	N	N
Quadratic price trend	N	N	N	Yes	N	N	N
Province-time trend	N	N	N	N	Yes	N	N
Province-year FE	N	N	N	N	N	Yes	N
Precinct linear trend	N	N	N	N	N	N	Yes
Precinct-quad. trend	N	N	N	N	N	N	Yes

Notes: This table reports the results from an IV regression of the log of the local crime rate in a municipality on the number of active mines within 20 km from the precinct. The instrument is log mineral price. Clustered standard errors at precinct level or mineral-precinct.

Table 4.12: Night Lights

	(1)	(2)	(3)	(4)
A: Precinct Fixed Effects				
Active Mine 20 km	0.648***		0.649***	0.603***
	(0.106)		(0.168)	(0.132)
Start Producing 20 km		0.00701		
		(0.0839)		
Stop Producing 20 km		-0.358**		
		(0.173)		
Observations	10840	9756	2640	1410
R-Squared	0.992	0.992	0.993	0.990
Mean of Outcome	13.36	13.52	20.20	9.951
Sample	Full	Full	No mine	$\geq$ 1 mine
B: Precinct IV				
Active Mine 20 km	0.987***			
	(0.260)			
Start Producing (all mines)		-29.51		
		(23.86)		
Start Producing (excl. new)			26.49**	
			(13.07)	
Stop Producing				-10.95***
				(3.493)
F Statistic	206.9	1.748	4.594	24.77
Observations	5260	4733	4733	4733

Notes: This table reports the result from a set of regression of the average light intensity at night in a precinct on mining activity. Panel A reports results from fixed effects regressions. Column (1) estimates the effect for the number of active mines within 20 km from the precinct, whereas column (2) estimates the effect for the number of mines that starts and stops producing within 20 km from the precinct. Column (3) estimates the same effect as in column (1), but excludes all precincts with a mine within the precinct; i.e. only mines within 20 km that are not located within the precinct are included. Column (4) limit the sample to precincts with a mine within the borders of the precinct. All regressions in Panel A include precinct fixed effect as well as year fixed effects. Panel B reports results from IV regressions and all include precinct by mineral fixed effects as well as year fixed effects. Standard errors clustered at the precinct level are reported in parenthesis.

Table 4.13: Precinct IV Heterogeneous Effects by Mine Type

	Total Crime	Property Crime	Violent Crime
A: Open-pit mining (capital intensive)			
2SLS	0.132	0.0690	0.143
	(0.313)	(0.305)	(0.385)
First Stage	0.00993***		
	(0.00329)		
F Statistic	9.142		
Observations	1105		
B: Underground mining (labor intensive)			
2SLS	-0.0923***	-0.116***	-0.0548*
	(0.0251)	(0.0293)	(0.0305)
First Stage	0.0275***		
	(0.00216)		
F Statistic	162.9		
Observations	3169		
Mineral by Precinct FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the result from splitting the sample into precincts with primarily (defined as at least half) open-pit mines and precincts with primarily underground mines. Precincts with an equal number of open-pit and underground mines have been excluded from the analysis. All regressions include mineral by precinct fixed effect as well as year fixed effects. Standard errors clustered at the precinct level are reported in parenthesis.

Table 4.14: Effects on Migration

	Total Migration	Male Migration	SADC Male Migration
A: Number of Active Mines			
Active Mine within 20 km	0.000360**	0.000180**	0.000134**
	(0.000146)	(0.0000770)	(0.0000573)
Observations	2106	2106	2106
R-Squared	0.775	0.772	0.761
Mean of Outcome	0.00154	0.00100	0.000563
B: Start and Stop Producing			
Start Producing 20 km	0.000275***	0.000148**	0.000102**
	(0.000106)	(0.0000582)	(0.0000441)
Stop Producing 20 km	0.000263	0.000144	0.000109
	(0.000340)	(0.000193)	(0.000146)
Observations	2106	2106	2106
R-Squared	0.771	0.770	0.758
Mean of Outcome	0.00154	0.00100	0.000563
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the results from a fixed effects regression of the share of migrants in a municipality on the mining activity within 20 km from a municipality. The sample covers all years for which migration data is available (2003-2011). Panel A report the results for the total number of active mines, whereas Panel B report the results for the number of mines that starts or stops producing in a given year. Column (1) reports the effect on the total migrants' share of the population, column (2) on male migrants and column (3) on male migrants from the SADC countries. Standard errors clustered at the municipality level are reported in parenthesis.

Table 4.15: Heterogenous Effects by Average Migration

	Number of Active Mines			**Start and Stop Producing**		
	Total Crime	Property Crime	Violent Crime	Total Crime	Property Crime	Violent Crime
A: Below Median Migration						
Active Mine 20km	0.0188	0.0177	0.0313			
	(0.0211)	(0.0228)	(0.0202)			
Start Producing 20 km				-0.0245**	-0.0152	-0.0199
				(0.0115)	(0.0156)	(0.0134)
Stop Producing 20 km				0.0105	0.00495	-0.00371
				(0.0171)	(0.0184)	(0.0204)
Observations	1230	1230	1230	1230	1230	1230
R-Squared	0.964	0.949	0.960	0.964	0.949	0.960
Mean of Outcome	3.303	2.471	2.462	3.303	2.471	2.462
B: Above Median Migration						
Active Mine 20km	-0.0190**	-0.0219***	-0.0155			
	(0.00815)	(0.00814)	(0.0113)			
Start Producing 20 km				0.0111	0.0140*	0.00787
				(0.00702)	(0.00827)	(0.00897)
Stop Producing 20 km				0.0275***	0.0298**	0.0186
				(0.0105)	(0.0117)	(0.0144)
Observations	1110	1110	1110	1110	1110	1110
R-Squared	0.966	0.957	0.949	0.966	0.956	0.949
Mean of Outcome	3.720	3.033	2.738	3.720	3.033	2.738
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports the results from carrying out the municipality fixed effect analysis in Table 4.4 on two different samples. Panel A reports the results for municipalities with below median migration during the sample period. Panel B reports the results for municipalities with above median migration. Standard errors clustered at the municipality level are reported in parenthesis.

Table 4.16: Crime Prevention Expenditure

	Expenditure		Log Total Crime Per Capita	
	Per Capita	Log Per Capita		
Active Mines	-0.529	-0.137	-0.0731***	-0.0889***
	(0.561)	(0.0789)	(0.0196)	(0.0199)
Expenditure per capita (Rand)				-0.00495***
				(0.00125)
Observations	90	90	5260	5260
R-Squared	0.752	0.857	0.345	0.341
Mean of Outcome	7.987	1.355	3.707	3.707
Province FE	Yes	Yes	No	No
Mineral by Precinct FE	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes: This table reports the results using province data on crime prevention expenditure. Columns (1) and (2) regress per capita crime prevention expenditure on the number of active mines within a province in a given year using a fixed effect setup similar to equation (3). Column (3) replicates the main IV specification and column (4) add expenditure per capita as a control to this specification. Standard errors in parenthesis are clustered at the province level in the first two columns and at the precinct in columns (3) -(4).

4.A Appendix: South African history of mining, migration and criminality

Recently, media has focused on uprisings in South African mining communities. A demonstration for wage increases in the Marikana platinum mine in 2012 led to violent clashes and the death of 34 workers. The incident was one of the most violent ever in the democratic South Africa. NGO's have pointed to the clash as a result of the widespread poverty and grievances among migrant mine workers (Human Rights Watch 2013). Such a narrative of grievances is far from new in the South African mining industry. The history of mining dates long back and so does its history of violence and criminality. In fact, to some extent they may be interconnected.

The gold deposits in present-day Johannesburg were long the destinations of fortune seekers from Europe and other parts of the African continent. The migration movement was sudden and strong: from a mining camp worthy of 3,000 individuals in 1887, Johannesburg grew to a city of 100,000 in only 22 years. Migrant gangs formed in the mining communities during the early 20th century, and defined what was to be the criminal landscape of Johannesburg (Kynoch 2005). Social exclusion of migrants is thought to be part of the reason why migrants on the fringe of the mining communities turned to criminality: migrant workers were the lowest on the hierarchical social ladder, confined to the roughest and most menial jobs (Kynoch 1999). Moreover, the migrant workers employed in the mine were kept aside from the rest of the urban South Africa, as part of British colonial policy (Antin 2013), and later of apartheid policy. Gang activity became prevalent within the mining compounds and in adjacent urban living spaces open for black South Africans and migrants, such as townships and squatter camps (Kynoch 1999).

After first relying on imported Australian, British, and Chinese mine workers, the industry became reliant on black migrant workers from rural South Africa and neighboring countries such as Lesotho, Mozambique, Malawi, and as far away as Tanzania (Bezuidenhout and Buhlungu 2011). During apartheid, the influx control policy forced black migrant workers to settle in peri-urban areas in Bantustans (homelands) and commute to mines and industries (Cox et al. 2004), instead of in the industrial areas. Arguably that was to ensure that industries were not responsible for workers' welfare, rather than to give them local autonomy, which was the official reason behind the creation of homelands. The threat of urbanization of blacks might have been part of the appeal of apartheid among white South Africans since the National Party promised to stop the development. However, the policy was also supported by the gold industry, in whose interest it also was to stop the burgeoning urbanization movement (Cox et al. 2004).

One result of the influx control policy was the single-sex hostel system. The hostels served as temporary housing for black migrant workers, who did not have the right to settle permanently in the area (Bezuidenhout and Buhlungu 2011). At the advent of democracy, attempts were made to diminish the reliance on the migrant system. Such attempts were partly motivated by the risks of spread of HIV/AIDS and labor unrest associated with the single-sex hostel systems (Hamann and Kapelus 2004). However, the process away from migrant-labor was slow, especially in the mining industry. In 1991, over 97 percent of the mining workforce (about half a million people) lived in single-sex hostels (Crush and James 1991), but in 1997 the figure had dropped by only two percentage points to 95 percent (Campbell 1997).

4.B Appendix: Additional Figures and Tables

Figure C.1: Province Trend in Total Criminality

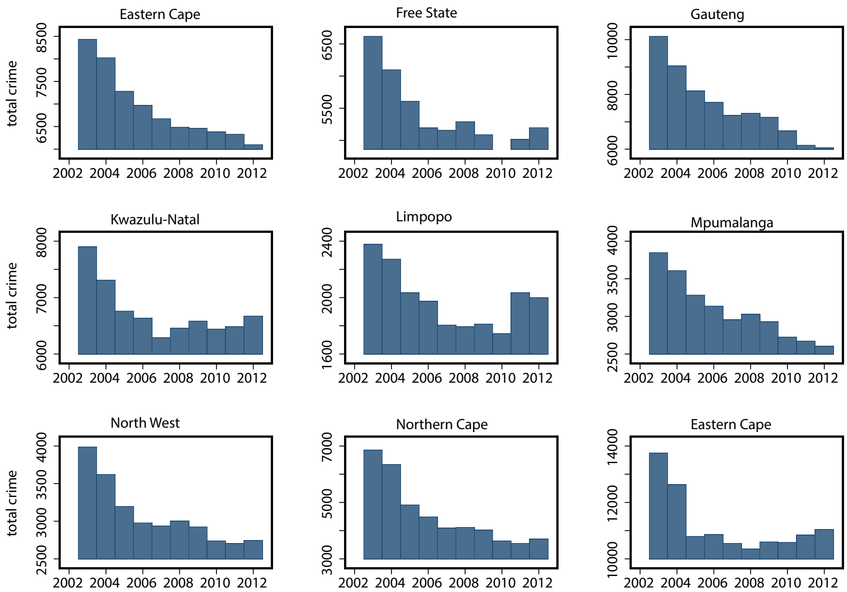


Table C.1: Public Violence

	Municipality FE	Precinct FE	IV
Active Mine 20km	0.00387***	0.00510***	0.00203
	(0.00120)	(0.00178)	(0.00672)
Observations	2340	10830	5260
R-Squared	0.304	0.190	0.0221
Mean of Outcome	0.0243	0.0246	0.0243
Location FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports the results on the log of public violence per capita using the three different samples. Columns (1) and (2) report the results from the fixed effect strategy, whereas column (3) reports the results from the IV strategy. All regressions include location and year fixed effects. Standard errors clustered at the geographical unit of observation are reported in parenthesis.

Figure C.2: Province Trend in Economic Criminality

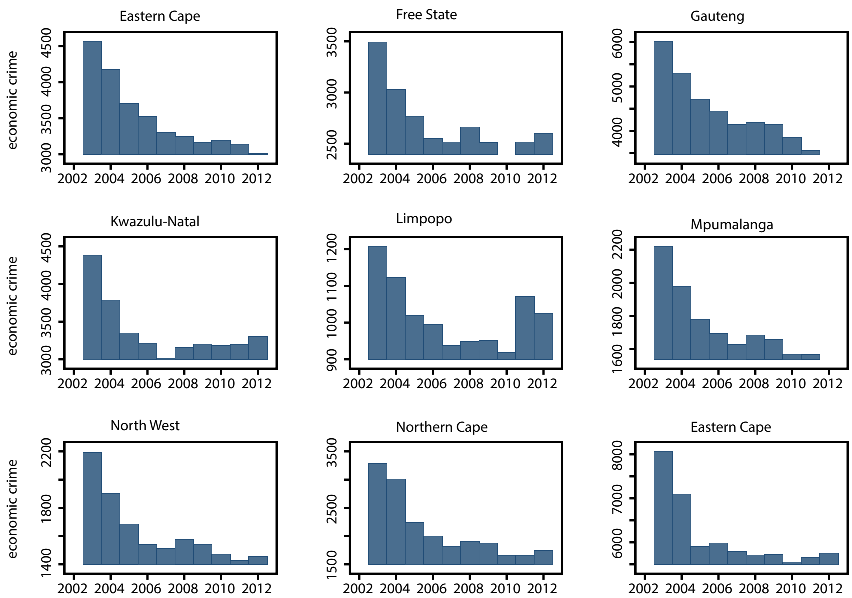


Figure C.3: Province Trend in Violent Criminality

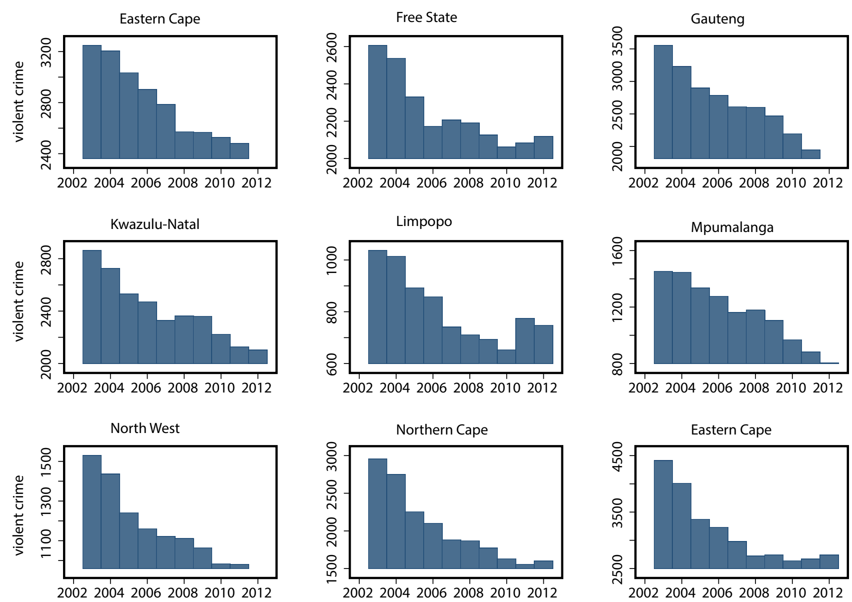


Table C.2: IV Excluding Minerals where SA is a Large Producer

	Total Crime	Property Crime	Violent Crime
2SLS	-0.0841***	-0.0956***	-0.0774***
	(0.0218)	(0.0246)	(0.0266)
Reduced Form	-0.00219***	-0.00249***	-0.00201***
	(0.000550)	(0.000615)	(0.000679)
First Stage	0.0260***		
	(0.00207)		
F Statistic	158.5		
Observations	3760		
Mineral by Mine FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: The results in this table corresponds to those reported in Table 4.5, but exclude minerals for which South Africa is a major producer. The minerals excluded are palladium, platinum, zirconium, vanadium, chromite, manganese ore and titanium.

Table C.3: FE: Only Mines within Municipality Borders

	Total Crime	Property Crime	Violent Crime
Active Mine	-0.0182*	-0.0178	-0.0132
	(0.00952)	(0.0110)	(0.0128)
Observations	2340	2340	2340
R-Squared	0.968	0.959	0.957
Mean of Outcome	3.501	2.737	2.593
Municipality FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: The results in this table corresponds to those reported in Table 4.4, but only considers mines that are located within the municipality. All regressions include location and year fixed effects. Standard errors clustered at the municipality are reported in parenthesis.

Table C.4: IV: Crime in Levels as Outcome

	Total Crime	Property Crime	Violent Crime
Active Mine 20 km	-0.0493***	-0.0639***	-0.0424**
	(0.0180)	(0.0209)	(0.0215)
Observations	5260	5260	5260
R-Squared	0.170	0.129	0.281
Mean of Outcome	7.134	6.450	6.153

Notes: This table reports the results from IV strategy using the number of crimes as the outcome variable. All regressions include the same fixed effects as the baseline specifications and standard errors are clustered at the precinct level.

Table C.5: FE: Nonlinear Effects of Mining

	OLS	FE		
	Total Crime	Total Crime	Property Crime	Violent Crime
Active Mine 20 km	0.0403***	-0.0250**	-0.0259*	-0.0249*
	(0.0114)	(0.0122)	(0.0138)	(0.0149)
Active Mine 20 km square	-0.000907**	0.000432	0.000735	0.000355
	(0.000447)	(0.000493)	(0.000580)	(0.000612)
Observations	10830	10830	10830	10825
R-Squared	0.0157	0.955	0.952	0.905
Mean of Outcome	3.665	3.665	2.898	2.694
Precinct FE	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes

Notes: Column 1 presents the OLS cross-sectional results. Column 2-4 report the results of a fixed effect regression of the log of the local crime rate in a precinct on the number of active mines within 20 km from the precinct, with controls for precinct and year fixed effects. Standard errors in parenthesis are clustered at the precinct.

Table C.6: IV: Property Subcategories

All theft not mentioned elsewhere	-0.0724***
	(0.0228)
Burglary at non-residential premises	-0.0178
	(0.0217)
Burglary at residential premises	-0.0719***
	(0.0240)
Commercial crime	-0.0384*
	(0.0232)
Common robbery	-0.135***
	(0.0221)
Robbery at non-residential premises	-0.0250*
	(0.0151)
Robbery at residential premises	-0.0383***
	(0.0131)
Shoplifting	0.0221
	(0.0230)
Stock-theft	0.0187
	(0.0183)
Theft of motor vehicle and motorcycle	-0.0910***
	(0.0233)
Theft out of or from motor vehicle	-0.0811***
	(0.0222)

Notes: This table reports coefficients from estimating the IV strategy for all subcategories of property crime. Each row represent a separate regression with the outcome listed in the left column. The outcome is defined as the log of the crime rate plus one to avoid dropping data with no crime for that particular category. All regressions control for time and municipality fixed effects. Standard errors clustered at the precinct are reported in parenthesis.

Table C.7: IV: Violent Subcategories

Arson	-0.0425***
	(0.00892)
Assault with grievous bodily harm	-0.0274
	(0.0234)
Attempted murder	-0.0403**
	(0.0160)
Common assault	-0.0112
	(0.0267)
Culpable homicide	-0.0164*
	(0.00896)
Malicious damage to property	-0.0762***
	(0.0220)
Murder	-0.0355***
	(0.00912)
Public violence	0.00203
	(0.00672)
Robbery with aggravating circumstances	-0.189***
	(0.0277)
Total Sexual Crimes	-0.0520***
	(0.0176)

Notes: This table reports coefficients from estimating the IV strategy for all subcategories of violent crime. Each row represent a separate regression with the outcome listed in the left column. The outcome is defined as the log of the crime rate plus one to avoid dropping data with no crime for that particular category. All regressions control for time and municipality fixed effects. Standard errors clustered at the precinct are reported in parenthesis.

Table C.8: IV: Other Subcategories

Carjacking	-0.0912***
	(0.0152)
Crimen injuria	0.000493
	(0.0282)
Driving under the influence of alcohol or drugs	0.0859***
	(0.0323)
Drug-related crime	0.0102
	(0.0290)
Illegal possession of firearms and ammunition	-0.0260**
	(0.0110)
Kidnapping	0.00969**
	(0.00482)
Neglect and ill-treatment of children	-0.00809
	(0.00709)
Truck hijacking	-0.00164
	(0.00483)

Notes: This table reports coefficients from estimating the IV strategy for all other subcategories of crime (not included in violent or property crime). Each row represent a separate regression with the outcome listed in the left column. The outcome is defined as the log of the crime rate plus one to avoid dropping data with no crime for that particular category. All regressions control for time and municipality fixed effects. Standard errors clustered at the precinct are reported in parenthesis.

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