Mines, Migration and Households' Welfare in Ghana:

A Structural Gravity Model Approach

Job market paper

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Abstract

Natural resources, and most specifically extractives industries, have long played an important role in the development of many emerging countries. For example in 2008, gold mining rents represented 33% of the government's revenue in Mali, 27.4% in Peru or 16.3% in Tanzania. In this paper, I estimate the change in household welfare and agricultural land prices following a mine opening in Ghana. More specifically, I elaborate and calibrate a spatial general equilibrium model to study subnational migration and trade flows generated by mine openings. First, I use Ghana's large gold mining sector and improvement in road network between 1960 and 2013 to establish if the cost of distance on gross migration flows between districts is smaller for active mining districts. I then estimate a migration gravity equation with a Poisson Pseudo-Maximum Likelihood method to assess if mining destination districts have lower migration costs. Finally, I use the spatial general equilibrium model to compute the change in welfare and agricultural land prices following a mine opening (represented by a shock in mining districts' productivity, production function's parameters and travel distance to other districts on the road network). Welfare increases by 1.3% on average in the treated district due to outward migration flows, which mitigate the decrease in wages and the large increase in land rental rates of 11.5%. Our results indicate a significant change in indirect utility and land rental rates up to 200kms from the treated district and shed a new light on the mechanisms through which a mining boom can spread to nearby regions.

JEL codes: D50, J61, N57, O13, O18

Keywords: Mining; Natural Resources; Ghana; Sub-Saharan Africa; Migrations; Labor; Spatial General Equilibrium, Gravity Models.

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I. Introduction

Extractives industries have long played a relatively important role in the economic development of emerging countries. In 2016, mineral rents represented almost 1.95% of GDP in Sub-Saharan Africa, following a peak at 4.3% in 1980[2]. In some countries, minerals production amount to a large share of the government's revenue through direct ownership, taxation or royalties (for example, gold mining rents represented 33% of government's revenue in Mali in 2008, 27.4% in Peru or 16.3% in Tanzania[3]). However, overly relying on economic rents (difference between value and cost of production) from extractive industries can endanger national financial stability because of volatile world commodity prices (UNCTAD, 2012[4]), the risk of a sharp currency appreciation (commonly referred to as the Dutch Disease) and the low direct employment impact (enclave industries).

In Marlet (2018), I studied the gender-specific labor effects of large-scale mining in Sub-Sahara Africa. Following Kotsadam & Tolonen (2016), I exploited spatial and temporal variation in minerals production using Demographic and Health Surveys and mines location from Berman et al. (2017)[5] for 29 Sub-Saharan countries. Decomposing survey clusters into two treated groups (located near an active or a soon-to-be-active mine) and one control group (located far away from any mine) allowed me to implement a difference-in-difference strategy which revealed that women seemed more vulnerable than men to labor market disruptions from mine openings. After a mine opens, labor force participation significantly decreases for female workers but increases for men. However, while overall employment significantly decreases in agriculture, some women are able to transfer to services while some men transfer to manual labor (skilled and unskilled).

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[2] The World Bank data.
[3] "Excessive Commodity Price Volatility: Macroeconomic Effects on Growth and Policy Options", UNCTAD, 2012.
[4] "Excessive Commodity Price Volatility: Macroeconomic Effects on Growth and Policy Options", UNCTAD, 2012.
[5] Berman et al. (2017) obtained large-scale mines data from the Raw Material Data (RMD) from S&P Global.

Additionally, I provided evidence that mine openings seemed to disrupt local labor markets up to 200kms away as male labor force participation appears to decrease farther away from the mine and to increase closer to the extraction site. The percentage of migrants was also significantly higher in active mining areas (70%) than in soon-to-be-active mining areas (56%). These results are indicative of migration flows which could be explained by several factors: first, there is evidence in the literature that mines improve local infrastructure to facilitate merchandises' transport (Söderholm & Svahn (2015)[6], Cust & Poelhekke (2015)[7]), but also migration journeys. Second, mine openings create a male labor demand shock which acts as a pull factor, attracting workers from other regions. These observations only give a partial understanding of how mining impacts regional migration. Does mining significantly impact migration patterns? What is the change in households' welfare or in land value resulting from this migration? To my knowledge, no paper formally studied how minerals extraction attracts workers from afar and what are the impacts of this change in the labor market on households' welfare and land markets.

This paper contributes to the literature in several ways. I use Ghana's relatively large gold mining sector and improvement in road network between 1960 and 2016 (using Geographic Information System (GIS) data from Jedwab & Moradi (2016)[8] and ESRI) to first establish whether mine openings had a significant effect on local transportation infrastructure (using roads density as a proxy). Then I analyze if the cost of distance on gross migration flows between districts (taken from the 2000 Population and Housing Census) is smaller for active mining destination districts. This could not only indicate that mining locations have access to more nearby roads but also that their specific characteristics (average consumption, price level, comparative advantage and amenities) increase the indirect utility households derive from migrating to that mining location. Finally, I estimate the change in households' indirect utility and in agricultural land price (using land rents per acre) following a shock in mining activity simulated in three

[6] Söderholm, P. and N. Svahn (2015), "Mining, regional development and benefit-sharing in developed countries", Resources Policy, vol. 45, p. 78-91.
[7] Cust, J. and S. Poelhekke (2015), "The Local Economic Impacts of Natural Resource Extraction", Annu. Rev. Resour. Econ., vol. 7, p. 251-268.
[8] Jedwab, R. and A. Moradi, (2016), "The Permanent Effects of Transportation Revolutions in Poor Countries: Evidence from Africa", The Review of Economics and Statistics, vol. 98, no. 2, pp. 268–284.

different ways: 1) a 5% increase in the treated district's productivity, 2) a decrease in the distance traveled on roads to the treated district, and 3) a change in the treated district's production function's parameters. To conduct this last analysis I draw on Morten & Oliveira (2017), Donaldson & Hornbeck (2016) and Monte et al. (2018) and build a spatial general equilibrium trade model demonstrating how districts are affected, directly or indirectly, by mining activity and by the expansion in the road network. In that model, trade and migration between districts are costly, depend on the distance between two locations, and impact districts' "market access". Following Morten & Oliveira (2017), I distinguish two different market access expressed as reduced-form expressions: the trade market access (TMA), which represents a district's ease to exchange goods with other districts, and the labor market access (LMA), which represents the pool of available workers in and around a district. As the road network becomes relatively denser in mining districts and the male labor's wage increases, migration and trade costs to these mining districts are expected to fall and both their trade and labor market access should increase. Equilibrium prices, wages, labor, agricultural land prices, and indirect utility are expressed as a function of TMA and LMA.

I calibrate and estimate the model with data from Population and Housing Census (2000), Living Standard Surveys (1987 to 2013), Enterprise Surveys from the World Bank (2007 and 2013), and Demographic and Health Surveys (1998-2003). I first construct migration flows and distance matrices between districts to estimate the migration gravity equation, and then retrieve the baseline endogenous variables and parameters from the surveys (district level wages, agricultural land prices, weight of consumption and land in utility, and Cobb-Douglas production function parameters). This allows me to compute the change in indirect utility and agricultural land prices following a shock in mining productivity, and to compare these elasticities between mining and non-mining districts. As districts' trade and labor market access improve thanks to the expansion in the road network and increase in male wages, agricultural rents and indirect utility will evolve in opposite directions: land prices increase a lot as labor supply expands and land becomes less available (due to increased competition between workers and mines for plots). Inversely, indirect utility decreases with the number of workers (as it drags down wages) but increases with trade market access as consumers have access to a wider variety of goods.

Ghana's relatively developed gold mining sector and data availability made it a good candidate for this case study. The country is the second largest gold producer in Sub-Saharan Africa and the mineral represented 52% of its exports (a bit less than $10 billion) in 2016[9]. Furthermore, the artisanal and small scale gold mining directly employs an estimated one million people in the country and supports approximately 4.5 million more[10]. In 2013, the Ghanaian government set up the Minerals Development Fund Act (MDF) to provide additional financial resources to mining communities as well as to entice mining companies to enhance their involvement in local communities' development. The MDF allocates 20% of all mining royalties received by the Ghana Revenue Authority from holders of mining leases towards the five following goals: mitigating any negative impact of mining on local communities, funding local development and alternative livelihood projects, promoting minerals research and training mines' human capital workforce, promoting mining projects, and supporting the ministry's monitoring of mining activities. Additionally, the Ghanaian road network has been praised for its quality (74% of unpaved roads are considered to be in good or fair condition[11]) and its backbone covers the entire country, helping to better integrate peripheral regions.

This paper contributes to the strand of literature studying the effects of mining on local communities as well as the literature on gravity equations and migration patterns. On the macroeconomic level, mineral resources production represents an important source of revenues for resource-rich countries' governments but has also been documented to increase the risk of Dutch Disease. Khan & Gottschalk (2017) used a computable general equilibrium model with Mongolian data and found that the mining sector demand for domestic factor inputs explains two-thirds of the appreciation of the real exchange rate. In their seminal paper, Benjamin, Devarajan & Weiner (1989) also built an eleven-sector

[9] The World Bank data.
[10] McQuilken, J. and G. Hilson (2016), "Artisanal and Small-Scale Gold Mining in Ghana – Evidence to Inform "Action Dialogue"", IIED, Sustainable Markets Group, Country Report.
[11] "Ghana's Infrastructure: A Continental Perspective", The World Bank, 2010.

CGE calibrated with Cameroon data which revealed that because of the Dutch Disease, the agricultural sector is the most likely to be hurt but some manufacturing sectors will expand (those which are the least substitutable to imports). Additionally, rural-urban inequality as long as real wage increase in general. Positive microeconomic effects of extractive industries include increased households' assets wealth (Von der Goltz & Barnwal (2018)), increased and diversified consumption (Zabsonré, Agbo & Somé (2018), Bozigar, Gray & Bilsborrow (2016), Loayza & Rigolini (2016), Fisher et al. (2009)), and decreased poverty (Zabsonré, Agbo & Somé (2018)). However, local households are exposed to increased inequality (Zabsonré, Agbo & Somé (2018), Loayza & Rigolini (2016)), decreased availability of agricultural lands (Hausermann, et al. (2018), Bozigar, Gray & Bilsborrow (2016), Rudel (2013)) as mines monopolize nearby plots and pollute fields and water sources (Von der Goltz & Barnwal (2018), Hausermann et al. (2018), Bozigar, Gray & Bilsborrow (2016)).

The negative effects on inequality and land availability are made worse by migration. Mines act as a pull factor for workers located far away because of new employment opportunities: mines generate direct jobs in skilled and unskilled manual labor but also some indirect employment in services, construction or healthcare (Loayza & Rigolini (2016), Bryceson & Jønsson (2010), Fisher et al. (2009)). New infrastructure and more public goods also help attract workers. In fact multiple countries passed laws requiring foreign mining companies to invest in public goods in nearby communities. As a result, mines have been linked to improved public infrastructure such as roads, bridges and ports (Bonfatti & Poelhekke (2017), Bunte et al. (2018)), agglomeration and faster local growth (Bunte et al. (2018)). Finally, thanks to these private investments in public infrastructure, the mining sector participates in roads construction which helps the country achieve greater and faster regional connection. Indeed, roads have been found to improve access to labor markets by decreasing migration costs, and to ease commercial exchanges by decreasing trade costs (Aggarwal (2018), Morten & Oliveira (2017)). Finally, locals have access to cheaper and more varied goods.

The aggregate impact of transport network (roads, railways, etc.) has often been studied using gravity models. Anderson (2010, 2016) and Head & Mayer (2014) provide an extensive survey of how gravity models changed over the years. Originally, the simplest gravity models predicted economic flows between two regions as inversely related to the squared distance between these two regions. However, these models couldn't fit the data very well and are slowly being replaced by structural gravity models that provide stronger economic foundations to the analysis. For example, Morten & Oliveira (2017) use a structural gravity model of economic interaction to analyze the effects of a shock in the road network on migration and internal trade. They use the construction of Brazilia and adjacent roads in Brazil in 1960 as a study case. The expansion in road network is found to increase households' welfare by 16%, 88% of which is due to decreased trade costs and 12% to lower migration costs. Donaldson & Hornbeck (2016) follow a similar approach to quantify the aggregate impact on agriculture of the American railroad network expansion in the 1890s. Railroads were found to have substantially increased agricultural land prices. Morten & Oliveira (2017) and Donaldson & Hornbeck (2016) both expressed the impact on labor and wage in a given region with market access, a reduced-form expression derived from general equilibrium trade theory. I use a similar approach in this paper to assess the effects of mines and nearby roads on households' welfare and agricultural land prices.

This paper is organized as follows: section II reviews the literature's results concerning the socioeconomic effects of mines, how they can foster migration and the evolution of gravity models. I describe the Ghanaian mining industry in section III, and then explore the first research question concerning mining activity, roads density and migration in section IV. I then lay out the theoretical foundation for the structural gravity model in section V. The calibration strategy is explained in section VI. Section VII gives the change in households' welfare and agricultural land prices following a shock in mining activity. Section VIII presents some factors explaining the heterogeneity across districts in utility and land prices' elasticities. Finally, section IX concludes.

II – Literature review

a) Socioeconomic outcomes of mining

Long confined to macroeconomic studies, the topic of natural resources extraction, such as mining or oil production, has recently gathered some attention from micro-economists. The variety of potential topics combined with the great diversity of resource-rich countries allowed for a number of interesting studies, bringing mixed results on the effects of natural resources production on local economies and households. Von der Goltz & Barnwal (2018) conducted a cross-country study with DHS survey data on health and wealth from 44 countries on 800 mining communities. They first assess the impact of mining activity on asset wealth with a difference-in-difference strategy using spatial and temporal variation in nearby mining activity. Medium and long-run asset wealth are found to increase respectively by 0.3 and 0.1 standard deviations of a country-year specific asset index. However wealth inequality seems to increase as the wealthiest households see the highest increase in asset wealth over the long run.

Loayza & Rigolini (2016) used the mining boom in Peru during the 1990s and 2000s to explore the effects of fiscal revenues from mining on local communities. Compared to nonmining areas, mining districts have larger consumption per capita, lower poverty rates and higher consumption inequality (both across and within districts). Zabsonré, Agbo & Somé (2018) also linked mining activity to increased inequality using a difference-in-difference strategy, even though results were not highly significant. They analyzed mining socioeconomic impacts in the context of the gold mining boom in Burkina Faso during the 2000s. Mining areas were found to have higher living standards (higher headcount ratios, lower poverty gaps, and higher household expenditures). Bozigar, Gray & Bilsborrow (2016) exploited a novel dataset spanning 11 years on 484 indigenous households exposed or not to oil extraction in the Ecuadorian Amazon. Fixed and random effects regressions revealed that oil extraction increases off-farm employment and asset wealth. However the observed decrease in fish harvests could hint to the environmental issues reported in other studies.

For example, Von der Goltz & Barnwal (2018) found evidence of heavy metal toxicity in mining communities. They use general knowledge over metal types and respective lead contamination to prove that in areas located near mines strongly associated with lead pollution, women were 10% more likely to be anemic, children were 5% more likely to have stunt growth and women who suffered from blood loss during pregnancy and delivery were slower to recover. Hausermann et al. (2018) documented the mining boom in Ghana following the financial crisis of 2008 which revamped gold mining activity along the Offin River's banks. Negative environmental impacts included rerouting and polluting streams and converting agricultural lands into mining pits.

b) Dutch Disease and local economic impacts

Due to its economic importance in a number of resource-rich countries, the extractive industry sector has been extensively studied, first with a macroeconomic perspective. Most importantly, natural resources production has been linked to rapid foreign exchange accumulation and currency appreciation, coined as "Dutch Disease" (Corden & Neary (1982)). A small number of studies analyzed the macro effects of Dutch Disease using computable general equilibrium models (CGE) in various case studies. The CGE framework allows taking into account complex interactions across time, inputs and sectors of the economy. The CGE model can be calibrated and estimated from a SAM (social accounting matrix). For example, Benjamin, Devarajan & Weiner (1989) found that in Cameroon, agriculture (the traditional tradable sector) contracted the most but manufacturing sectors with low substitution elasticities to imports expanded. Khan & Gottschalk (2017) also used a CGE to analyze the impact of an expansion of the mining sector between 2013 and 2016 in Mongolia. A doubling in mining production led to an appreciation of the real exchange rate by 15% and to a contraction of the tradable sector output by approximately 20%. As explained in Cherif (2013), the extent of crowding-out in the tradable sector depends positively on the interaction between revenues from natural resources' exports and the productivity gap vis-à-vis the trade partners. However even in less technologically advanced economies, there is still potential for positive spillovers occurring from backward linkages in extractive industries. Aragon & Rud (2011) came to this conclusion by studying gold mining in Peru and finding that the mines' demand for local inputs led to an increase in the local price of non-tradable goods but also to an increase in real income. On the other hand, Allcott & Keniston (2014), studying the Dutch Disease phenomena in modern-day America, found relatively small local manufacturing productivity spillovers. Additionally, Allcott & Keniston (2014) were among the few authors to tackle the migration issue following the mining boom and bust of the 1970s. They found that migration did not fully offset labor demand growth in the United States, so local wages rose. On a more local scale, Caselli & Michaels (2013) concluded that oil-rich municipalities in Brazil experienced an increase in revenue, which materialized into increased public spending. These preliminary results on migration and increase in public infrastructure are part of a relatively small body of literature.

c) Mines and migration

Few studies have specifically analyzed the impact of mining activity on migration flows and the subsequent effects on native and migrant households' welfare. First, Bonfatti & Poelhekke (2017) acknowledge the potential effects of mines on public infrastructure as most resource-rich countries export their production overseas. They hypothesize that mine-related infrastructure is more likely to be connected to the coast that neighboring countries, which would decrease trade costs with overseas countries more than with neighbors (and inversely with landlocked countries which depend on their neighbors' access to the coast). Bunte et al. (2018) use quasi-experimental evidence from Liberia to analyze the effects of extractive industries on local growth. The country requires foreign investors to invest in nearby communities' public goods (for example, they are required to build and maintain roads near mining extraction sites) in order to crowd in additional investments, create clusters of interconnected firms and foster economic agglomeration. Mining investment projects appear to positively impact local economic growth. Improved transport infrastructure and new employment opportunities act as pull factors that increase migration to mining areas and create employment in skilled or unskilled manual labor and services (Loayza & Rigolini (2016), Bryceson & Jønsson (2010), Fisher et al. (2009)). Finally, roads themselves have been proven to foster migration and regional trade by decreasing both migration and trade costs. Aggarwal (2018) and Aggarwal et al. (2018) study the effect of a change in market access in Tanzania on agricultural productivity. They find that an additional standard deviation in travel time is associated with almost 25% lower agricultural input adoption and output sales. After quantifying a spatial model of input adoption, they estimate that reducing travel costs by 50% will double input adoption.

d) Structural gravity models

Introduced by Tinbergen (1962), gravity models have been extensively used for the past fifty years to analyze bilateral interactions in trade or migration. As explained in Anderson (2016), the original gravity model, simply derived from Newton's physical law of gravity, was built on the hypothesis that economic flows are positively related to the economic masses at the origin and destination areas and inversely related to the distance between them. Thus the trade flows between o and d were predicted by the product of a gravitational constant and the relevant economic activity mass (such as output) in o and d divided by the squared distance between them. However this model couldn't fit data well, implying the exponents of the economic masses indicators and of the distance variable should be allowed to vary according to the data. Gradually, structural gravity embedded in models of resource allocation across economic sectors became widely used.

For example, Morten and Oliveira (2017) use a spatial general trade model to estimate the effect of the road network expansion in Brazil following the construction of Brasilia. They use spatial data to exploit the temporal variation in roads location and model the change in welfare with a general equilibrium trade model incorporating trade costs τ_{odt} from Eaton & Kortum (2002) and migration costs κ_{odt} from Monte et al. (2016). In their model, agents optimally choose their location each period and locations specialize in production based on their comparative advantage and the cost of importing goods from other locations. The exogenous shock in road network decreased trade and migration costs and increased welfare by 16%, 88% of which is due to decreased trade costs and 12% to lower migration costs. The model is designed in terms of Trade Market Access (TMA) and Labor Market Access (LMA) as set up in Donaldson & Hornbeck (2016).

The latter paper assesses the effects of the historical railroads expansion in the late 1800s in the United States on the agricultural sector. Following the railroads construction, a new railroad route meant new trade and migration opportunities for nearby districts but other districts located farther away from the network were also indirectly impacted by the network change and the reallocation of trade and migration flows. To take into account these various effects, the total impact on each county is captured by their trade market access, which depends on the county's lowest-cost county-to-county freight routes. The cheaper it is to trade with other counties (made possible by the improvement of the railroads network), the larger the market access. Donaldson & Hornbeck (2016) found that as railroads expand, so did some counties' market access which increased their agricultural land values.

Finally, Monte et al. (2018) estimate the effects of a reduction in commuting costs on workers' welfare, using American data from the Commodity Flow Survey, the American Community Survey and the US Census from 1960 to 2000. The authors use a quantitative general equilibrium model expressed in terms of Labor and Trade Market Access, in which trade and commuting are costly. Following a shock in productivity, they find that local employment elasticities range from 0.5 to 2.5. This variation in employment can be explained by the heterogeneity in local labor markets' openness to commuting (measured by the share of a county's residents who work in that same county).

III – The Ghanaian Mining Industry

a) Background

The second largest gold producer in Africa, Ghana exported $9.69 billion worth of gold in 2016 which represented approximately 52% of total exports. The Ministry of Lands and Natural Resources is responsible for negotiating and granting mineral rights licenses to large or small-scale mining companies. After the license has been granted, the company is required to pay an annual ground rent, annual mineral right fees, royalties fixed to 5% of revenues, as well as corporate taxes (35% in 2012). The mining company must also grant a 10% equity interest to the government.

According to the Minerals and Mining Act of 2006, any mineral found in Ghana is the property of the Ghanaian Republic. The occupier of a land where mineral is found can retain the right to graze livestock or cultivate the land, as long as it doesn't interfere with mining activity. If it does, the owner of the mining lease will determine a financial compensation to the land occupier based on a survey of the crops as compensation depends on lost properties value, loss of earnings and expected income. If the occupier prefers to be resettled, the Minister will propose a suitable and similar alternate land. As described in Goldstein and Udry (2008), Ghana's land tenure system is based on chieftaincies. Most of the land cultivated by farmers is owned by the paramount chief (also called a Stool) and is allocated according to farmers' political influence and needs. Land is controlled by a matrilineage leadership (the Abusua) as long as the Abusua members abide by the Stool's rules. Members of a particular Abusua negotiate among themselves to determine which plot to farm. This complex system of land tenure and allocation might then make even more difficult the compensation process. Is the compensation given to the Stool, the Abusua, or each individual farmer? Farmers with low bargaining power such as women or young people can have difficulty proving they were the rightful land occupiers to mining companies.

In 2013, the Ghanaian government set up the Minerals Development Fund Act (MDF) to provide additional financial resources to mining communities as well as to entice mining companies to enhance their involvement in local communities' development. The MDF allocates 20% of all mining royalties received by the Ghana Revenue Authority from holders of mining leases towards the five following goals: mitigating any negative impact of mining on local communities, funding local development and alternative livelihood projects, promoting minerals research and training mines' human capital workforce, promoting mining projects, and supporting the ministry's monitoring of mining activities. The Fund is to be managed by a committee of eleven persons, including a representative director of three different ministries (Local Government and Rural Development; Environment, Science, Technology and Innovation; Finance), the Administrator of Stool Lands, a representative of Ghana Chamber of Mines and a traditional ruler from a mining community nominated by the national House of Chiefs. Additionally, each mining community will appoint a committee in charge of managing revenue received from the Fund. This local committee is composed among others of the community's traditional rulers, a representative of each mining companies operating in the district, and two representatives of a local women and youth group. Each mining community must also establish of a Mining Community Development Scheme which will be financed by 20% of the mining royalties allocated to the national Minerals Development Fund. The rest of the national Fund is to be allocated as follows: 50% to the Office of the Administrator of Stool Lands, 13% to the Minerals Commission, 8% to the Geological Survey Department, 5% to the promotion of sustainable development projects, and 4% to the Ministry of Land and Natural Resources.

b) Employment and Migration

Artisanal and Small-Scale Mining (ASM) refers to subsistence miners who are not officially employed by a mining company and use manually-intensive methods to extract minerals. This sector is quite developed in resources rich countries and accounts for 20% of global gold production (The World Bank, 2013)[12]. Participation in ASM is usually seen as a temporary and seasonal occupation as well as an income diversification strategy for rural households, particularly for farmers during the pre-harvest season.

In Ghana, despite the fiscal importance of the large scale mining sector (17.5% of total corporate tax earnings), artisanal and small-scale mining (ASM) offers the most job opportunities in the gold mining industry. In 2014, 34% of Ghana's gold production came from the ASM which employs an estimated 1.1 million workers (compared to 16,000 for the large-scale mining sector (ICMM, 2015)). An additional 4.4 million is thought to depend on the sector (McQuilken and Hilson, 2016)[13]. In fact, ASM provides an alternative livelihood to rural households thanks to low barriers to entry and relatively regular income flows. Miners can hold various positions, from general labouring to skilled machine work or haulers. Following the rapid growth of the small-scale mining sector in the 1980s, governmental authorities made an initial effort to regulate the sector thanks to the Small-Scale Gold Mining Law (PNDC Law 218)[14] passed in 1989. The goal was to regularise and streamline small-scale gold mining and to provide official marketing channels for the gold produced by the miners. Small-scale miners who are at

[12] http://www.worldbank.org/en/topic/extractiveindustries/brief/artisanal-and-small-scale-mining
[13] McQuilken J., and G. Hilson (2016), "Artisanal and Small-Scale Gold Mining in Ghana". IIED, Country Report, August 2016.
[14] Ministry of Finance, Government of Ghana, Minerals Commission, Artisanal and Small-Scale Mining (ASM) Framework.

least eighteen years of age are required to apply for a small-scale mining licence which lasts five years and can be renewed depending on satisfactory performance.

This new structural framework, coupled with high unemployment and the decline of government's investments in enterprises, motivated many semi- and non-skilled workers to try their luck in gold mining[15]. Exploration and development in the mining industry led to an increase in infrastructures investment (road and railroad networks) and new services industries in resource-rich areas. The improvement in transportation and communication infrastructure encouraged migrants to move to the Gold Coast in search of work (Nyame et al., 2009). Migration patterns to mining areas also depend on the stages of mining (migration inflows are relatively low during the exploration phase; increase strongly during the development phase; and become net outflows during the closure stage). Nyame et al. (2009) also note that the farther migrants come from, the longer they will stay near the mining area to find work. When they can't find jobs as miners, migrants have been found to work on farms or services.

However, the informal aspect of the activity for a majority of workers (an estimated 60 to 80%) restricts access to credit, discourages long-term investments, prevents mechanization, and decreases tax revenue. Additionally, the competing use of land plots between mining and agriculture, added to land degradation and water pollution from mining activities, has created tensions between land owners and miners. A study in Northeastern Ghana by Awumbila and Tsikata[16] documented high net migration outflows to the mining areas of the South (a migration that can be explained by low land productivity and the relatively high poverty rates compared to the rest of the country) but also high environmental impact from land degradation.

[15] Nyame, F. K., Grant J. A. and N. Yakovleva (2009), "Perspectives on migration patterns in Ghana's mining industry", Resources Policy, no. 34, p. 6-11.

[16] Awumbila, M. and D. Tsikata, « Migration Dynamics and Small-Scale Gold Mining in North-Eastern Ghana : Implications for Sustainable Rural Livelihoods ».

IV – Do Mines Increase Roads Density and Decrease Migration Costs?

a) Mining Activity and Transportation Infrastructure

As documented in the literature, mine openings may increase the number and quality of roads. In fact, mining companies located in more or less populated districts need to transport minerals out of the country to reach international markets. They could rely on pre-existing transportation infrastructure (roads, railroads, bridges, ports, etc.) or obtain the authorization to build their own. In some countries, these companies are even required to pay for the infrastructure necessary for minerals transportation. In Ghana, roads construction inherent to mining activity is usually developed by the Minerals Development Fund Act (MDF) and mining companies themselves. In the first part of this section, I analyze whether mining activity significantly increases transportation infrastructure in the district. To estimate the magnitude of transport infrastructure in a district, I use total roads kilometers (roads density) in a district using Geographic Information System (GIS) data on the Ghanaian road network in 1960, 2000 (from Jedwab & Moradi (2016)) and in 2013 (from ESRI).

Additionnally, the goal of this sub-section is to assess if mining districts have significantly more roads infrastructure than other districts. Given the wide gap in roads network data (I only have three years of observations: 1960, 2000 and 2013), I create year categories (category 1 for years 1960 to 1999, category 2 for years 2000 to 2012, and category 3 for years 2013 to 2015), and compute total roads kilometers in each district for the three year categories. The estimating equation would then be:

$$log(roads\_density)_{i,t} = \beta active\_mining\_district_{i,t} + \alpha_i + \alpha_t + \varepsilon_{r,t} \qquad (1)$$

with $roads\_density_{i,t}$ the total roads kilometers in district i in year t, $active\_mining\_district_{i,t}$ a dummy variable indicating if there is an active mine at year t in district i. I also include districts and yearly fixed effects and cluster errors at the regional level. However, there is some potential endogeneity between mines and roads density: if hesitating between two districts, mining companies might decide to settle in the district with the most pre-existing transportation systems in order to decrease future investments in infrastructure. To control for this, I use the location of gold deposits in

Ghana obtained from the United States Geological Survey (USGS) and the world price of gold to compute the value of gold deposits. I use this variable as an instrument for mining activity in a district as it will be correlated with mining activity but not with local roads density. Finally, I set the value of gold deposits to 0 in non-mining districts. The final estimation equation is the following:

$$\log(roads\_density)_{i,t} = \beta \widehat{active\_mining}\_district_{i,t} + \rho_i + \rho_t + \varepsilon_{r,t} \quad (2)$$

$$active\_mining\_district_{i,t} = \beta_1\, mineral\_deposit_{i,t} + \delta_i + \delta_t + u_{i,t} \quad (3)$$

From table 1 below, the unconditional geometric mean of roads density being approximately 70km, mines increase the geometric mean of roads density by 36.7% (so mining districts have on average 25.7km of additional roads compared to other districts).

Table 1: Roads density in mining districts

VARIABLES	(1) first stage	(2) log(roads density)
dummy mining		3.674***
		(0.469)
Value of deposit	3.64e-05***	
	(2.37e-06)	
Observations	648	648
Number of district id	216	216
District FE	YES	YES
Year FE	YES	YES

Clustered standard errors at the regional level in parentheses: *** p<0.01, ** p<0.05, * p<0.1

b) Mining Activity and Migration Costs

As explained above, mining activity acts as a pull factor toward mining districts. Mine openings represent a shock in male workforce which will increase male equilibrium wage. Informal miners may also migrate to the area to access the same gold deposits as the large scale mines. Additionally, as shown in Marlet (2018) and Kotsadam and Tolonen (2016), even though female labor force participation decreases in total after a mine opening, some women find work in supporting services. These new labor opportunities attract workers to the mining areas. Furthermore, the increase in roads density documented in the previous section might help decrease the trip length from migrants' origin district to the mining district, which would make it more affordable.

In this section, I use a migration gravity equation following Morten & Oliveira (2017) to estimate the effect of mining activity on the cost of distance on migration flows between two districts. A smaller migration flows elasticity with respect to distance in mining districts would indicate that these districts have access to more nearby roads but also that their specific characteristics (average consumption, price level, comparative advantage and amenities) increase the indirect utility households derive from migrating to that mining location. I estimate the following migration gravity equation with Poisson Pseudo-Maximum Likelihood to assess if mining destination districts have lower migration costs:

$$\log(M_{od}) = \delta_o + \delta_d + \beta_1 \log(d_{od}) + \beta_2 Mining_d \log(d_{od}) + \beta_3 ActiveMining_d \log(d_{od}) + \epsilon_{od} \quad (4)$$

with M_{od} the migration flows from origin district o to destination district d, d_{od} the travel distance on the road network between origin district o to destination district d, $Mining_d$ a dummy variable indicating if a district d has a gold deposit in 2000, $ActiveMining_d$ a dummy variable indicating if a district d has an active gold mine in 2000, δ_o an origin district fixed effect, and δ_d a destination district fixed effect.

To estimate this gravity equation, I build subnational migration flows between districts using the Population and Housing Census from 2000, and retrieve travel distance on the road network between all pairs of origin-destination districts in 2000 using GIS files from from Jedwab & Moradi (2016)[17]. Also, I use a Poisson-Pseudo Maximum Likelihood (PPML) estimation which has become the standard estimation method for gravity models[18,19]. In fact, one of the common challenges in migration or trade studies is the prevalence of zero flows. The origin-destination flows matrix can thus be very sparse and a simple ordinary least squares estimation will drop flows with zero value once they are

[17] Jedwab, R. and A. Moradi, (2016), "The Permanent Effects of Transportation Revolutions in Poor Countries: Evidence from Africa", The Review of Economics and Statistics, vol. 98, no. 2, pp. 268–284.
[18] Head, K. and T. Mayer, (2013), "Gravity Equations: Workhorse, Toolkit, and Cookbook", CEPII working paper no. 2013-27.
[19] Larch M. et al., (2016), "An Advanced Guide to Trade Policy Analysis: the Structural Gravity Model", WTO publications.

log-transformed. However, zero flows contain important information as two districts might not exchange migrants due to high migration costs, preferences, or destination and origin characteristics. In comparison, the PPML technique has several advantages for count outcome variables, the first being that it keeps zero flows in the sample. It also equates total actual and predicted flows, and allows us to include destination and origin districts' labor and trade market access using fixed effects. Results are presented in Table 2 below.

Table 2: Migration flows and distance on the road network between origin and destination

VARIABLES	log(migration flows)
log(distance$_{odt}$)	-0.841***
	(0.0187)
log(distance$_{odt}$)*Mining_destination_district	-0.047
	(0.058)
log(distance$_{odt}$)*Active_mining_destination_district	0.131*
	(0.0793)
constant	5.304***
	(0.820)
Observations	10,186
R-squared	0.811
Region-year FE	YES
District-year FE	YES

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

From the previous table, as distance between origin and destination districts increases by 1%, migration flows are expected to decrease by 0.8%. However, if there is an active mine in the destination district, migration flows are expected to fall by only 0.7%. This decrease in migration costs to mining districts could indicate that their specific characteristics (such as average consumption basket and amenities) increase the indirect utility households derive from living in that mining location or that mining districts have access to better transport infrastructures for the same distance travelled as mining companies invest in roads and public infrastructure to reduce their exportation costs.

V – Theoretical Framework

a) Foundation

This paper aims at estimating the aggregate effects of mining activity on welfare and land price in Ghana after a deposit discovery. The latter is represented by an arbitrary shock in the treated district's productivity of 5%, along with a shock in migration costs of -0.13%*36.7% = -4.8% found in the previous section, and a change in the production function parameters calibrated in section VI (as mines rely relatively more heavily on land than other types of industries combined).

Following Morten & Oliveira (2017), Donaldson & Hornbeck (2016), and Monte et al. (2018), I develop a general equilibrium model with spatial linkages in trade and migration to estimate the effects of a mining shock on welfare and land prices. I estimate the change in the latter variables thanks to the change in labor market access and trade market access that follows the shock in production and transportation costs. Donaldson & Hornbeck (2016), assuming immobile labor, only defined the equilibrium prices and labor in an area in terms of Trade Market Access (TMA). This market access measures the ease of an area to trade goods with other areas depending on their relative comparative advantage and geographic distance to each other. The TMA increases with productivity (as goods become cheaper to produce) but decreases with distance to other districts (as it becomes more expensive to trade). In particular, the trade market access of a district increases as it becomes cheaper to trade with another district, especially if that district has higher trade costs with other districts. Additionally, Morten & Oliveira (2017) assumed mobile labor and costly migration (assumption that I also make below). Thus the equilibrium prices and labor in an area can also be expressed in terms of Labor Market Access (LMA) which measures an area's ease of access to workers, depending on workers' relative indirect utility in that area compared to other areas and geographic distance to each other. LMA increases with the district's indirect utility (the district becomes more attractive to workers as they have access to higher wages and better amenities) and decreases with distance (as it becomes more expensive to migrate to that district). Concerning migration and trade costs, because they are built using the ratio of a district's access to goods and labor to other districts' access to goods and labor, both

TMA and LMA capture the effects of a change in migration and trade costs not only in areas located next to new mines and roads that now have easier access to goods and labor, but also in areas located farther away that are indirectly impacted by the new infrastructure. This allows me to evaluate the aggregate effects of mine openings and roads network expansion and to estimate how they might have encouraged migration to mining districts.

The TMA and LMA of a district represent the relative ease of access to cheap goods and labor (compared to other districts) and are negatively related to the distance between each pair of districts. I approximate migration and trade costs between two districts by the distance travelled on the road network to go from the origin district to the destination district. Using Ghana's districts' administrative boundaries (there are 216 districts distributed across 10 regions in the country), I estimate the distance between each pair of districts' centroids on the roads network obtained from digitized maps for the years 1960, 2000 (source: Jedwab and Moradi (2016)[20]) and 2013 (source: ESRI data). This results in a 216 x 216 matrix of the distance by roads in kilometers between each origin-destination pair.

[20] Jedwab, R. and A. Moradi (2016), « The Permanent Effects of Transportation Revolutions in Poor Countries : Evidence from Africa », The Review of Economics and Statistics, vol. 98, no. 2, p. 268-284.

Figure a) – Large-scale gold mines

Figure b) – Road network in 1960

Figure c) – Road network in 2000

Figure d) – Road network in 2013

b) Theoretical model to evaluate trade and labor market access

b.1) Preferences and labor migration

Agents are assumed to be mobile and can choose the location where they work. They are subject to heterogeneous and stochastic location preference shocks. Each agent i from district o chooses a destination district d to maximize her Cobb Douglas utility function:

$$U_{od(i)} = \frac{b_{d(i)}}{\kappa_{od}} \left[\frac{C_d}{\alpha}\right]^{\alpha} \left[\frac{H_d^H}{1-\alpha}\right]^{1-\alpha} \quad \text{subject to} \quad w_d = P_d C_d + q_d H_d^H \tag{5}$$

where $\kappa_{od} \geq 1$ is an iceberg migration cost between origin o and destination d (I assume $\kappa_{od} = \kappa_{do}$ and $\kappa_{oo} = 1$), and H_d^H is the land surface (in acres) held by the worker in d. Additionally, $b_{d(i)}$ is an idiosyncratic amenities shock and represents worker i's heterogeneous preferences over destination districts with similar characteristics. For each worker i originating from o and living in d, idiosyncratic amenities shocks $b_{d(i)}$ are drawn from an independent Fréchet distribution: $G_{d(b)} = e^{-B_d b^{-\varepsilon}}$, where $B_d > 0$ determines the average amenities when living in location d and $\varepsilon > 1$ represents the dispersion of amenities. Additionally, the consumption goods index C_d in location d is a constant elasticity of substitution function of a continuum of tradable varieties over [1;N] sourced from each location o:

$$C_d = \left[\sum_{o=1}^{N} c_{od}^{\rho}\right]^{\frac{1}{\rho}} \text{ and } \sigma = \frac{1}{1-\rho} > 1 \tag{6}$$

Labor supply is assumed to be inelastic and of size 1, so workers receive labor income w and the total labor supply in a district will be measured by its population size. Additionally, 1-α fraction of workers' income is spent on land which is assumed to belong to immobile landowners. As documented in Ghana Housing Profile (UN Habitat, 2011)[21] and Goldstein & Udry (2008)[22], land in Ghana is under the control of villages' chieftaincy (also called a stool) and is allocated to farmers depending on their political influence and perceived need. However, land rights are more secure for cultivated plots

[21] Ghana Housing Profile, UN-Habitat, United Nations Human Settlements Programme, 2011.
[22] Goldstein, M. and C. Udry (2008), « The Profits of Power: Land Rights and Agricultural Investments in Ghana », Journal of Political Economy, vol. 116, no. 6, p. 981-1022.

than for fallow ones. So the land rental rate q_d may represent the rent given to the stool, or investment made to expand one's political influence or to improve crops' growth.

Following utility maximization, demand c_{od} for a good produced in o and consumed in d is given by the expression below where Y_d is the aggregate expenditure in d, P_d is the consumption price index in d, and p_{od} is the cost of buying one unit of c_{od} in district d:

$$c_{od} = \alpha Y_d P_d^{\sigma-1} p_{od}^{-\sigma} \quad \text{and} \quad P_d = [\textstyle\sum_{o=1}^{N} p_{od}^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{7}$$

The indirect utility of a worker living in destination d is given by:

$$V_d = B_d w_d^{\varepsilon} \kappa_{od}^{-\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon} \tag{8}$$

Each worker selects the destination where she can get the maximum utility, which is determined according to the maximum $b_{d(i)}$ that is Fréchet distributed. This implies that indirect utility is also Fréchet distributed and depends on B_d.

Consequently, migration flows M_{od} from origin o to destination d can be represented by a gravity equation and are equal to the share λ_{od} of the population L_o in origin district o that is migrating from o to d. M_{od} is then a function of the probability of moving from o to d and the labor supply of origin o:

$$M_{od} = \left(\frac{B_d w_d^{\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon} \kappa_{od}^{-\varepsilon}}{\sum_d B_d w_d^{\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon} \kappa_{od}^{-\varepsilon}} \right) L_o \tag{9}$$

$$M_{od} = \lambda_{od} L_o \text{ and } LMA_o = \textstyle\sum_d B_d w_d^{\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon} \kappa_{od}^{-\varepsilon} \tag{10}$$

Migration flows from o to d increase with the equilibrium wage and amenities in destination d, and decrease with the cost of living (given by the consumption price index and land rental rate) and migration costs (proxied with the distance between o and d). The gravity equation above also implies an elasticity $-\varepsilon$ of migration flows with respect to migration costs and of ε with respect to wage.

According to the labor market clearing condition, the endogenous population size in destination d L_d is given by the sum over all origins o of the probabilities of migrating from o to d: $L_d = \sum_{o \epsilon N} \lambda_{od} L_o$ (11)

b.2) Production and trade

Assuming perfect competition between producers, each location o produces a variety of goods according to its comparative advantage A_o and uses a Cobb-Douglas production function with labor L_o and land H_o^F:

$$Y_o = A_o L_o^{\gamma} H_o^{F^{1-\gamma}} \tag{12}$$

From profit-maximization, the equilibrium price p_{od} (which is the cost of buying in destination d a unit of the good produced in origin o) is given by:

$$p_{od} = \left(\frac{\sigma}{\sigma-1}\right) \frac{\tau_{od} w_o^{\gamma} q_o^{1-\gamma}}{A_o} \tag{13}$$

where w_o and q_o are the rental rate of labor and land respectively, and $\tau_{od} \geq 1$ is an iceberg trade cost between origin o and destination d (similarly to κ_{od}, I assume $\tau_{od} = \tau_{do}$ and $\tau_{oo} = 1$). Similarly to migration, we can derive a gravity equation for trade flows in which the flow of goods sent from origin o to destination d depends on the cost of production of the goods in o and the geographic distance between o and d, compared to the cost of production of the goods in other districts and the geographic distance between the destination d and all of the other origin districts. So trade flows X_{od} between origin o and destination d are given by the percentage π_{od} of total expenditures in d spent on goods produced in o:

$$X_{od} = \left(\frac{{A_o}^{\sigma-1} \left[w_o^{\gamma} q_o^{1-\gamma} \right]^{1-\sigma} \tau_{od}^{1-\sigma}}{\sum_o {A_o}^{\sigma-1} \left[w_o^{\gamma} q_o^{1-\gamma} \right]^{1-\sigma} \tau_{od}^{1-\sigma}} \right) Y_d \tag{14}$$

$$X_{od} = \pi_{od} Y_d \text{ and } TMA_d = \sum_o {A_o}^{\sigma-1} \left[w_o^{\gamma} q_o^{1-\gamma} \right]^{1-\sigma} \tau_{od}^{1-\sigma} \tag{15}$$

Trade flows between o and d decrease with the cost of production in origin o (so with the wage and land price in o) and with the trade costs between o and d (proxied with geographic distance). Inversely, it increases with productivity in o. A key role of TMA is that, using trade flows data, one could use this theoretical expression to retrieve the underlying consumption elasticity of substitution σ. However in practice, internal trade flows are rarely available. In their study on American counties in 1870-1890, Donaldson

& Hornbeck (2016) couldn't observe trade flows and thus were unable to directly compute the TMA. Instead, they used the population of and around an area as a proxy for its trade market access. Given the lack of data on internal trade flows between districts in Ghana, I will use the same strategy in this paper to compute an initial guess for consumption elasticity of substitution σ. Morten & Oliveira (2017) used a similar concept but were able to get some trade flows data for their study on Brazil instead of using a proxy.

Following Donaldson & Hornbeck (2016) and Monte et al. (2018), using the equilibrium pricing rule and the trade flows equation brings the following consumption price index:

$$P_d = [\sum_{o=1}^{N} p_{od}^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{16}$$

$$P_d = \left[\sum_{o=1}^{N} (\frac{\sigma}{\sigma-1})^{1-\sigma} \left(\frac{\tau_{od} w_o^{\gamma} q_o^{1-\gamma}}{A_o}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{17}$$

$$P_d = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau_{od} w_o^{\gamma} q_o^{1-\gamma}}{A_o}\right)\left(\frac{1}{\pi_{dd}}\right)^{\frac{1}{1-\sigma}} \tag{18}$$

Finally, assuming an inelastic land supply $\overline{H_o}$, the equilibrium land rental rate is given by the land market clearing equation:

$$\overline{H_o} = H_o^H + H_o^F \qquad \text{or} \qquad \overline{H_o} = \frac{(1-\alpha)}{q_o} Y_o + \frac{(1-\gamma)}{q_o} w_o L_o \tag{19}$$

b.3) General equilibrium

Given the model's parameters $\{\alpha, \gamma, \varepsilon, \sigma\}$ and exogenous variables $\{A_o, B_o, \tau_{od}, \kappa_{od}, \overline{H_o}\}$, the equilibrium vector of six endogenous variables $\{w_o, q_o, L_o, P_o, \lambda_{od}, \pi_{od}\}$ will solve the following set of six equations written below: (1) labor income in district o equals labor expenditure in o (which is a fraction ϒ of total production in o, or the sum of goods flows sent from o to all possible destinations d), (2) land market clearing, (3) migration flows probabilities, (4) trade flows probabilities, (5) price index, and (6) labor market clearing.

$$w_o L_o = \gamma \sum_{d \epsilon N} \pi_{od} Y_d \tag{20}$$

$$q_o = \frac{w_o L_o}{H_o}\left[\frac{1-\gamma}{\gamma} + 1 - \alpha\right] \tag{21}$$

$$\lambda_{od} = \left(\frac{B_d w_d^{\varepsilon}\left[P_d^{\alpha} q_d^{1-\alpha}\right]^{-\varepsilon} \kappa_{od}^{-\varepsilon}}{\sum_d B_d w_d^{\varepsilon}\left[P_d^{\alpha} q_d^{1-\alpha}\right]^{-\varepsilon} \kappa_{od}^{-\varepsilon}}\right) \tag{22}$$

$$\pi_{od} = \left(\frac{A_o{}^{\sigma-1}\left[w_o^{\gamma} q_o^{1-\gamma}\right]^{1-\sigma} \tau_{od}^{1-\sigma}}{\sum_o A_o{}^{\sigma-1}\left[w_o^{\gamma} q_o^{1-\gamma}\right]^{1-\sigma} \tau_{od}^{1-\sigma}}\right) \tag{23}$$

$$P_d = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\tau_{od} w_o^{\gamma} q_o^{1-\gamma}}{A_o}\right)\left(\frac{1}{\pi_{dd}}\right)^{\frac{1}{1-\sigma}} \tag{24}$$

$$L_d = \sum_{o \epsilon N} \lambda_{od} L_o \tag{25}$$

Again, the goal of this paper is to compute the change in welfare and land rental rates following a mine opening. The latter is represented using a shock in the district's productivity of 5%, along with a simultaneous change in the production function's parameter ϒ (the share of labor) from 0.92 to 0.32 (computed in section VI-b below) and in the trade and migration costs of -4.8%. Similarly to Monte et al. (2018), I will introduce these shocks to each district separately. I will then use initial guesses for changes in w_d and λ_d at time t: $\widehat{w}_d^{(t)}$=1 and $\hat{\lambda}_d^{(t)}$=1 in the following iterative algorithm (in which $\hat{x} = \frac{x'}{x}$) to update conjectures to $\widehat{w}_d^{(t+1)}$ and $\hat{\lambda}_d^{(t+1)}$ until convergence:

$$\hat{L}_d^{(t)} = \frac{\bar{L}}{L_d} \sum_{o \epsilon N} \lambda_{od} \widehat{\lambda_{od}}^{(t)} \tag{26}$$

$$\hat{q}_d^{(t)} = \widehat{w}_d^{(t)} \hat{L}_d^{(t)} \tag{27}$$

$$\hat{\pi}_{od}{}^{(t)} = \left(\frac{\hat{A}_o{}^{\sigma-1}\left[\widehat{w}_o^{\gamma(t)} \hat{q}_o^{1-\gamma(t)}\right]^{1-\sigma} \hat{\tau}_{od}^{1-\sigma}}{\sum_{o \epsilon N} \pi_{od} \hat{A}_o{}^{\sigma-1}\left[\widehat{w}_o^{\gamma(t)} \hat{q}_o^{1-\gamma(t)}\right]^{1-\sigma} \hat{\tau}_{od}^{1-\sigma}}\right) \tag{28}$$

$$\hat{P}_d{}^{(t)} = \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\hat{\tau}_{dd} \widehat{w}_d^{\gamma(t)} \hat{q}_d^{1-\gamma(t)}}{\hat{A}_d}\right)\left(\frac{1}{\hat{\pi}_{dd}{}^{(t)}}\right)^{\frac{1}{1-\sigma}} \tag{29}$$

$$\hat{\lambda}_{od}{}^{(t+1)} = \left(\frac{\hat{B}_d \hat{w}_d^{\varepsilon(t)} \left[\hat{P}_d^{\alpha(t)} \hat{q}_d^{1-\alpha(t)} \right]^{-\varepsilon} \hat{\kappa}_{od}^{-\varepsilon}}{\sum_d \lambda_{od} \hat{B}_d \hat{w}_d^{\varepsilon(t)} \left[\hat{P}_d^{\alpha(t)} \hat{q}_d^{1-\alpha(t)} \right]^{-\varepsilon} \hat{\kappa}_{od}^{-\varepsilon}} \right) \tag{30}$$

$$\hat{w}_o{}^{(t+1)} = \frac{\gamma}{\hat{L}_o{}^{(t)}} \sum_{d \epsilon N} \hat{\pi}_{od}{}^{(t)} \hat{Y}_d{}^{(t)} \pi_{od} Y_d \tag{31}$$

VI – Data and Calibration Strategy

In order to solve for the general equilibrium and compute the change in welfare and land prices following a shock in mining activity, I have to estimate the model's parameters {α, γ, ε, σ} from the data.

a) Share of land in workers' utility (1-α)

The workers' Cobb-Douglas utility function depends on consumption index C_d with weight α and land surface H_d^H with weight 1-α. From the first order conditions, 1-α also represents the share of land in households' expenditure. Using the Ghana Living Standard Survey waves from 1988 to 2013, I am able to retrieve households' annual income, daily and annual average expenditure on a variety of goods (durable and non-durable), daily and annual average food expenditure, as well as land rental rate per acre. The share of land in households' total expenditure ranges from 2% in 1988 to 11.3% in 2013. These estimates are in line with the literature as the UN-Habitat found that housing rents represented between 1.5% and 11.5% of households' monthly expenditure in large cities in 2005 and the Global Consumption Database of the World Bank indicates that housing rental costs represented 4.97% of the average consumption expenditures in 2010. Given that the migration flows from district to district are estimated using the 2000 Population and Housing Census (the only year available), I use 1-α = 3% which corresponds to the estimate from the closest wave of Living Standard Survey (1998-1999).

b) Share of land in firms' production function (1-ϒ)

Firms use a Cobb-Douglas production function to produce goods from labor (with weight ϒ) and land (with weight 1-ϒ). To compute ϒ for mining and non-mining firms, I use the only two waves of Microenterprise Surveys available from 2007 and 2013. I am able to retrieve the annual value of output and of expenditure on labor and land rentals. One advantage of these surveys is that the firm's industry is listed. This allows me to estimate a constrained linear regression of the production function where the log of annual output value is regressed on the log of annual labor expenditure, log of annual land rentals value, as well as year and industry fixed effects. From table 3 below and as predicted, firms listed in the mining industry seem to use a larger share of land than other types of firms combined (68.3% compared to 8.3%).

Table 3: Weight of labor and land in firms' production function

VARIABLES	(1) non-mining firms	(2) mining firms
log_labor	0.917***	0.317
	(0.0524)	(0.206)
log_land	0.0828	0.683***
	(0.0524)	(0.206)
Constant	8.625***	5.165**
	(0.442)	(1.999)
Observations	388	18
year FE	YES	YES
industry FE	YES	YES

Robust standard errors in parentheses : *** p<0.01, ** p<0.05, * p<0.1

c) Consumption elasticity of substitution: σ

From the general equilibrium model, I derive the following expression for the land rental rate q_d:

$$\log(q_d) = \frac{\log((1-\gamma)\bar{H}_d^{-1}A_d)}{1+\sigma(1-\gamma)} - \frac{\gamma\sigma}{1+\sigma(1-\gamma)}\log(w_d) + \frac{1}{1+\sigma(1-\gamma)}\log(TMA_d) \qquad (32)$$

$$\text{with } TMA_d = \sum_o {A_o}^{\sigma-1}\left[w_o^{\gamma} q_o^{1-\gamma}\right]^{1-\sigma} \tau_{od}^{1-\sigma}.$$

So the land rental rate in district d q_d is a nonlinear function of the total factor productivity A_d and the elasticity of substitution (also trade flows elasticity to trade costs) σ, both of which are unknown. Hence there are only 216 equations for 432 unknowns. To solve for σ, I follow the strategy of Donaldson & Hornbeck (2016) and approximate the trade market access using the population in other districts weighted by the distance in kilometers to district d:

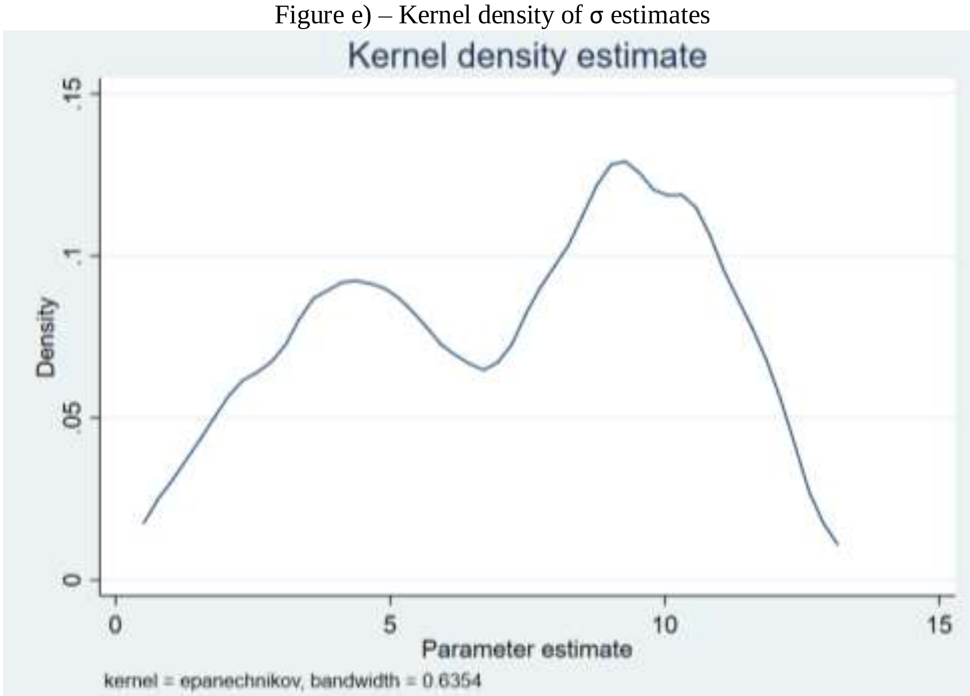
$$\widetilde{TMA}_d = \sum_{o \neq d} \tau_{od}^{1-\sigma} Pop_o \tag{33}$$

The equation for $\log(q_d)$ can then be written as:

$$\log(q_d) = f(\sigma)_d + \varsigma_{od} = -\frac{\gamma\sigma}{1+\sigma(1-\gamma)}\log(w_d) + \frac{1}{1+\sigma(1-\gamma)}\log\left(\widetilde{TMA}_d\right) + \varsigma_{od} \tag{34}$$

where ς_{od} is orthogonal to $f(\sigma)_d$ conditional on district and region fixed effects. I solve for σ using a grid search on an evenly spaced grid with 2,000 points and get an average value of 7.21 with a 95% confidence interval between 4.68 and 9.73.

Figure e) – Kernel density of σ estimates



This estimate is consistent with the literature: Donaldson & Hornbeck (2016) found 8.22 in the 1870-1890 United States, Caliendo & Parro (2015)[23] got an estimate of 8.11 for agriculture in 1993 for the NAFTA countries, and Head & Mayer (2014)'s literature survey found a mean value of 6.74[24]. Morten & Oliveira (2017) and Monte et al. (2018) assumed an elasticity of substitution σ of 4, which I will also use in robustness tests.

[23] Caliendo, L. and F. Parro (2015), "Estimates of the Trade and Welfare Effects of NAFTA", Review of Economic Studies, vol. 82, 1-44.
[24] Head, K. and T. Mayer (2014), "Gravity Equations: Workhorse, Toolkit, Cookbook", Handbook of International Economics, vol. 4, Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds. (New York: Elsevier, 2014)

d) Migration flows elasticity to destination district's wage: ε

From section V, workers are assumed to select a destination district d in order to maximize their utility. The migration flows between origin district o and destination district d were defined as follow:

$$M_{od} = \left(\frac{B_d w_d^{\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon} \kappa_{od}^{-\varepsilon}}{\sum_d B_d w_d^{\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon} \kappa_{od}^{-\varepsilon}} \right) L_o$$

Even though I observe migration flows M_{od}, wage w_d, land rental rate q_d, population L_o and migration costs κ_{od}, districts' amenities B_d are unobservable. Thus in order to compute ε, I follow the strategy by Morten & Oliveira (2017) and Monte et al. (2018) which consists in first retrieving destination districts' unobserved indirect utility using districts' fixed effects from a migration gravity equation, then evaluating the impact of a change in wage on the indirect utility. First, the gravity equation for migration is estimated using the following equation:

$$\log(M_{od}) = \delta_o + \delta_d + \beta_1 \log(d_{od}) + \beta_2 X_{od} + \epsilon_{od} \quad (35)$$

where M_{od} is the flow of people migrating from origin district o to destination district d, d_{od} is the distance in kilometers one has to travel on the road network in 2000 to go from o to d, δ_o is an origin fixed effect, δ_d is a destination fixed effect and X_{od} is a set of variables to control for unobserved heterogeneity of migration (a dummy equal to 1 if the districts are in the same region, a dummy equal to 1 if the main ethnic group in origin district is the same as in the destination district, and a dummy equal to 1 if the same religious group represents the majority of the population in both districts).

Because missing migration flows represent the fact that no one is migrating between o and d, it is important to take them into account in the estimation. The gravity equation for migration is then estimated using a Poisson-Pseudo Maximum Likelihood and a negative Binomial method as a robustness test in order to take into account pairs of districts with 0 observed migration flows. Results are presented in the table 4 below. All estimations give a strong negative and significant coefficient for the effect of distance on migration flows. The PPML and negative Binomial are preferred methods of estimation, however, since

PPML give expected signs for controls (on same religion and same region), I choose the estimate of -0.572 as the elasticity of migration flows with respect to distance.

Figure f) - Migration flows between o and d and distance traveled on the road network

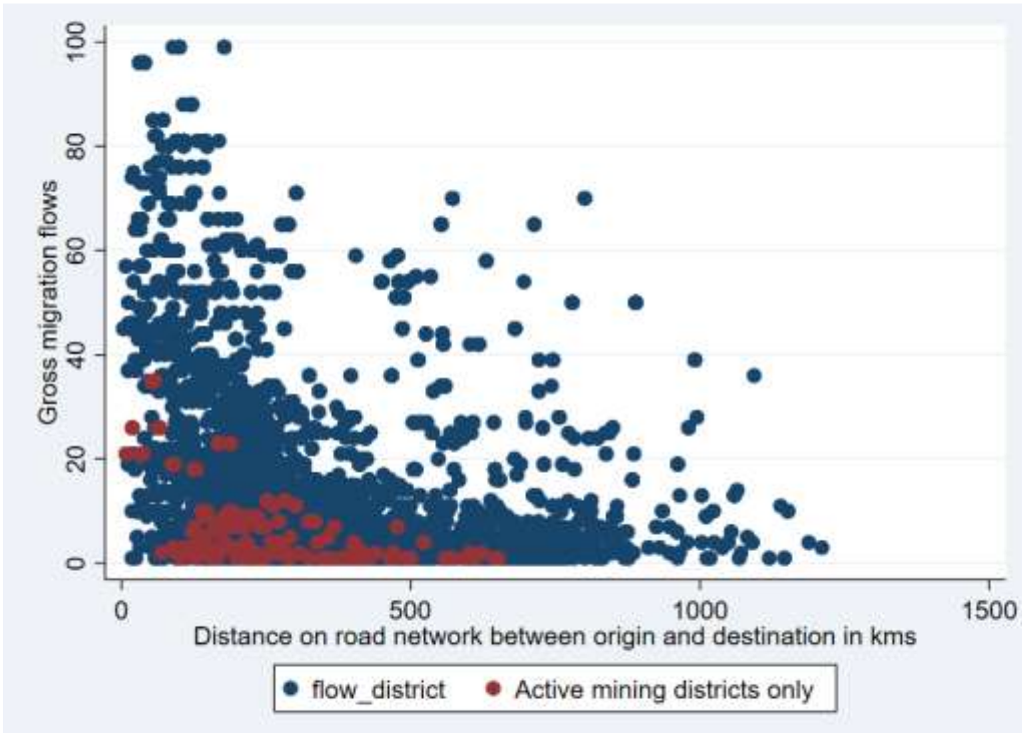


Table 4: Gravity equation for migration

VARIABLES	(1) OLS	(2) PPML	(3) PPML-FE	(4) negative binomial
Log of distance in km between districts	-0.897***	-0.572***	-0.572***	-1.130***
	(0.00772)	(0.0215)	(0.0215)	(0.0454)
Same ethnicity	0.234***	0.251***	0.251***	0.235**
	(0.0194)	(0.0493)	(0.0493)	(0.0959)
Same religion	-0.186***	0.119***	0.119***	-0.0409
	(0.0113)	(0.0362)	(0.0362)	(0.0534)
Same region	-0.159***	0.372***	0.372***	0.186
	(0.0169)	(0.0334)	(0.0334)	(0.139)
Constant	5.592***	0.880	2.776***	-0.978***
	(0.0470)	(0.547)	(0.130)	(0.130)
Observations	45,373	45,374	45,373	45,374
R-squared	0.459	0.366		
origin_district FE	YES	YES	YES	YES
destination_district FE	YES	YES	YES	YES

Clustered standard errors at the origin-destination district pair level in parentheses: *** p<0.01, ** p<0.05, * p<0.1

d.1) Computation of ε

From the Poisson-Pseudo Maximum Likelihood estimation results obtained in column (2) of table 4, I retrieve the destination district fixed effects. As explained in Morten & Oliveira (2017), these estimated fixed effects $\hat{\delta}_d$ represent the destination-specific component of indirect utility which was given by: $V_d = B_d w_d^{\varepsilon} \kappa_{od}^{-\varepsilon} [P_d^{\alpha} q_d^{1-\alpha}]^{-\varepsilon}$.

So, $\hat{\delta}_d = B_d + \varepsilon \log(w_d) - \varepsilon\alpha \log(P_d) - \varepsilon(1-\alpha)\log(q_d)$. Additionally, the unobserved common amenity value B_d is approximated with a region fixed effect δ_r: $B_d = \delta_r + \xi_d$. $\hat{\delta}_d$ can be written as: $\hat{\delta}_d = \delta_r + \varepsilon \log(w_d) - \varepsilon\alpha \log(P_d) - \varepsilon(1-\alpha)\log(q_d) + \xi_d$ (37).

Furthermore, an equilibrium condition of the model is that rents in district d q_d can be expressed as a function of wages in d, trade market access and some parameters as already mentioned in section VI-c):

$$\log(q_d) = \frac{\log((1-\gamma)\bar{H}_d^{-1} A_d)}{1+\sigma(1-\gamma)} - \frac{\gamma\sigma}{1+\sigma(1-\gamma)}\log(w_d) + \frac{1}{1+\sigma(1-\gamma)}\log(TMA_d)$$

A reduced-form estimate of $\log(q_d)$ can be written as: $\log(q_d) = \rho_r + \beta \log(w_d) + \omega_d$. However, wages, prices and land rental rates might be endogenous. In fact, the higher the destination-specific component, the more migrants will be attracted to this district, resulting in an increase in population. Consequently, wages, consumption and land prices might increase. Morten & Oliveira used Bartik shocks to instrument for wages and prices. Due to data restriction, I use instead the variation in other districts' rainfall (obtained from the Global Precipitation monthly grids of University of Delaware's Climate Database[25]) weighted by their respective population and their distance to district d as an instrument for wages and prices as the rainfall in other districts will only impact district d's amenities through changes in local wages and prices. Following Monte et al. (2018) and assuming the two are unrelated, I also use the total factor productivity of the destination district estimated in the section below as an additional instrument. The equations for wages and rents are estimated simultaneously using a constrained three-staged least squares method. Results are presented in table 5 below and the estimate of

[25] http://research.jisao.washington.edu/data/ud/

ε=3.236 is in line with previous results in the literature (Morten & Oliveira (2017) found a migration elasticity to wage of 2.24 while Monte et al. (2018) found an elasticity of 3.30). From table 5 below, after a mine opens, as wages in destination district increase by 1%, migration flows to that district are expected to increase by 3.2%.

Table 5: Estimation of ε

VARIABLES	(1) Destination district fe	(2) Log rents
log_wage	3.236*	1.450*
	(1.677)	(0.840)
log_price	-1.945	
	(1.358)	
log_rents	-1.276	
	(1.645)	
Observations	80	80
R-squared	-0.224	0.983
region FE	YES	YES

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

VII – Counterfactuals

Now that I have estimated the main parameters (described below in table 6) of the theoretical model, I calibrate the model to solve for the spatial general equilibrium and compute the change in welfare and land prices following a shock in mining activity. I will represent this shock in mining activity in three different ways: first I will only increase the total factor productivity in each district by 5% and compare results between treated districts and other districts according to distance from where the shock happened (shock 1). Then, in addition to increasing the TFP by 5%, I will also change the production function's parameters to represent the fact that mines rely more on land than labor (shock 2). Finally, in addition to increasing the TFP by 5% and changing the production function's parameters, I will decrease by 4.8% the migration and trade costs to the district in which the mining shock is taking place to represent the fact that mining companies tend to invest heavily in transport infrastructures (shock 3).

Table 6: Parameters

Parameter	Signification	Value
α	Share of consumption in households' expenditure	0.97
γ	Share of labor in production function	0.92 (non-mining firms) 0.32 (mining firms)
ε	Migration flows elasticity to destination district's wage	3.236
σ	Consumption elasticity of substitution	7.21

a) Welfare and rents elasticities in targeted districts

Kernel densities of welfare and rents elasticities in just the treated districts (districts which received the shocks) are presented below in figure g. To simplify interpretation, I take the log of the change in welfare (and rents) $\hat{x}$ (which is equal to $\frac{x'}{x}$). These results can then be interpreted as the percentage change in welfare and rents following a shock in mining activity.

Figure g) – Kernel densities of welfare and land rental rates elasticities in treated districts

g1) - Welfare elasticities g2) – Land rental prices elasticities

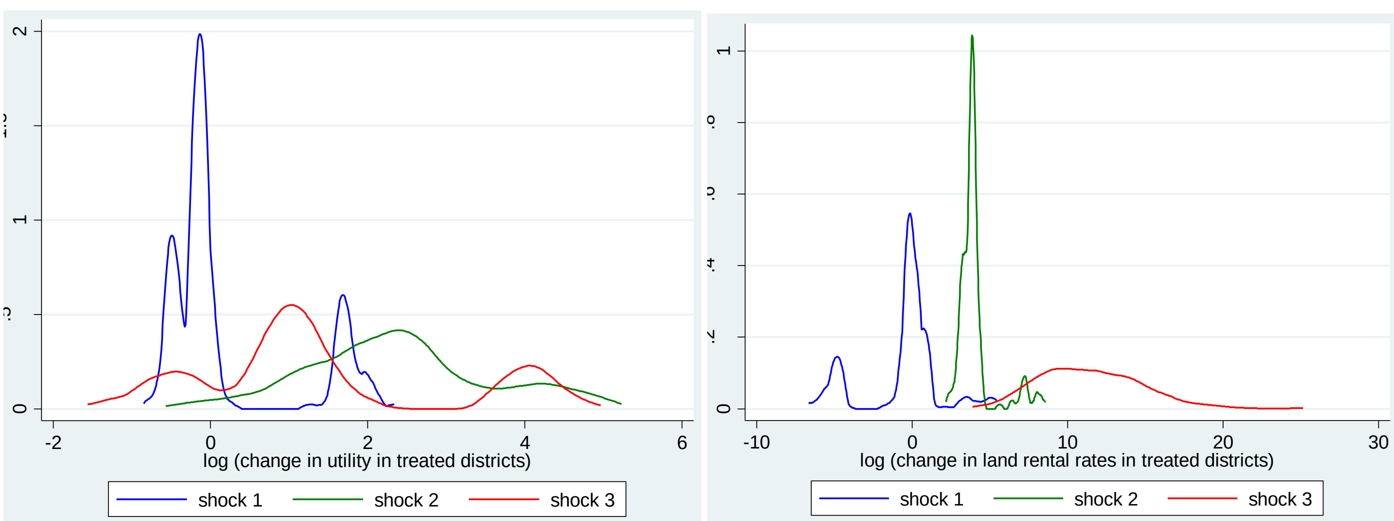
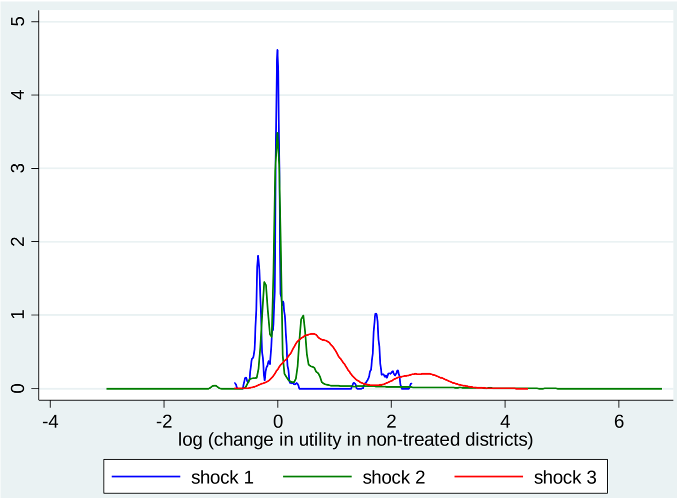
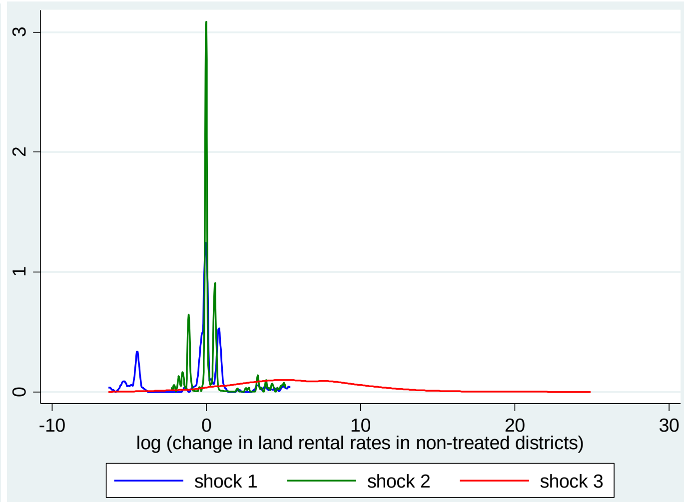


Figure h) – Kernel densities of welfare and land rental rates elasticities in non-treated districts

h1) - Welfare elasticities



h2) – Land rental prices elasticities



Again in this exercise, I realize 216 counterfactual exercises in which I increase the total factor productivity by 5% in each district separately (shock 1), increase TFP and land weight in the production function from 0.08 to 0.68 (shock 2), and increase TFP and land weight and decrease bilateral migration and trade costs to/from treated districts by 4.8% (shock 3). I then computed the equilibrium change in land rental price and welfare for these treated districts. After increasing TFP by 5%, welfare across treated districts increases by approximately 0.19% on average, with a 95% confidence interval of 0.08% and 0.3%. Paradoxically, non-treated districts seem to benefit more as welfare increases by 0.31% on average but there is less heterogeneity across non-treated districts since the 95% confidence interval is only between 0.30% and 0.31%. These results can be explained by the change in land rental rates: since the treated districts' firms become more productive, they increase their factors of production use, thus putting upward pressure on equilibrium wages and land rents. As firms increase labor demand, wages go up, increasing workers' welfare. It also creates more competition in the land market, increasing land rental rates. However, due to spatial trade linkages, the treated district is now relatively more competitive than other districts, and is more likely to trade with the rest of the country as it can sell goods at a cheaper relative price. This decrease in the price index attracts migrants initially but as the model converges and prices keep increase, labor supply decreases in the treated district which decreases rents by 0.6% on average.

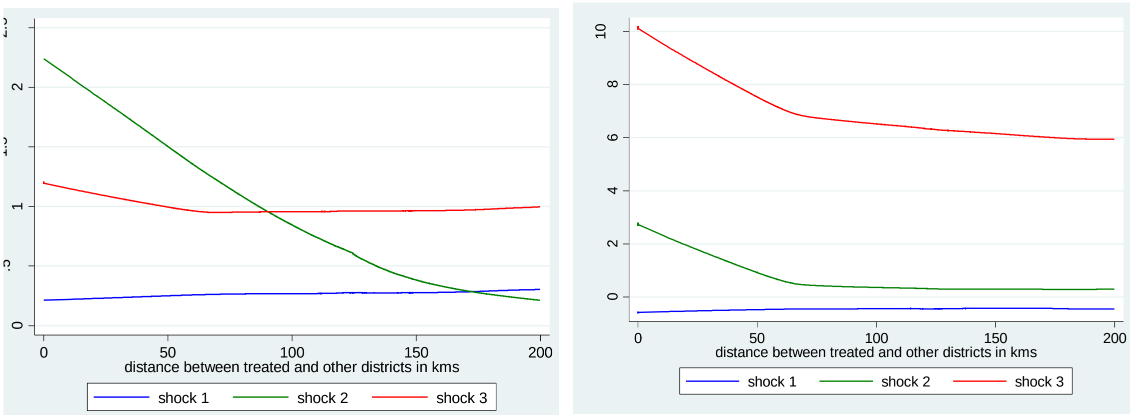
Additionally, the increase in welfare in the treated districts is much larger for shocks 2 and 3 than for shock 1: indirect utility increases on average by 2.4% in shock 2 (with a 95% confidence interval between 2.2% and 2.5%) and by 1.3% for shock 3 (with a 95% confidence interval between 1.2% and 1.6%). This happens despite the larger increase in rental rates elasticities between shock 1 and shocks 2 and 3. In fact, in the three shocks, TFP increases by 5% but in shocks 2 and 3, firms rely more on land, thus increasing rental prices. Land rents in shock 2 increase on average by 4% in treated districts (only 0.25% in non-treated) and by 11.5% in shock 3 (5.9% in non-treated districts). First, the larger increase in rents in shock 3 explains the lower variation in utility in shock 3 compared to shock 2. Second, the 5% decline in trade and migration costs introduced in shock 3 appears to support the geographical propagation of the shock since non-treated districts have a larger increase in welfare and rents in shock 3 versus shock 2: 1.04% vs 0.17% for utility and 5.9% vs 0.25% for rents. Even though land weight in the production function increases only in the treated district for both shocks, thus increasing land rental rates and decreasing wages at the beginning, the decline in migration and trade costs make it easier for households to migrate out of the district and settle in nearby areas. As labor supply decreases in the treated district (and increases in nearby districts), equilibrium wage go up. This relationship between welfare and land rates is shown in the graphs below from section b).

b) Welfare and rents elasticities in other districts

Lowess smoothing graphs comparing welfare and rents elasticities in all districts (on the y-axis) and the distance to the district affected by the shock (on the x-axis) are presented below in figures i1 and i2.

Figure i) – Lowess smoothing of elasticities in relation to distance to the shock

i1) - Lowess welfare elasticities i2) – Lowess rents elasticities



Elasticities in districts other than the one targeted by the shock seem to follow a pattern similar to what was described in the previous section: welfare and rents elasticities are lowest for shock 1 and the effect of distance from the shock remains the same. However, the effect of distance on the percentage change in welfare is stronger in shocks 2 and 3 as indirect utility increases in districts near the shock. As firms in the treated district rely more on land, land rents increase a lot in that district. Additionally, it is easier for workers to migrate to nearby districts in shock 3, thus increasing competition for land in these districts, and land rental rates themselves. In conclusion, while the effects on welfare and land rates decline rapidly with distance in shock 2, they remain quite high in shock 3, indicating a spatial propagation of the shock through districts' linkages in trade and migration.

IX – Conclusion

In this paper, I contributed to the extractive industries literature by providing evidence that mining is not just an enclave industry and doesn't only impact areas next to the mines. I demonstrated that a mining boom disrupts local economic markets through two main channels, the first of which is a change in the production function. In fact, mines will heavily rely on land compared to traditional firms or farms and this implies a decrease in the weight of labor and an increase in the weight of land in a Cobb-Douglas production function. This was shown in section VI-b where I used a constrained linear estimation and micro-enterprise surveys from the World Bank and computed that land's weight is only 0.08 in non-mining firms, but increases to 0.68 for mining firms. One caveat to keep in mind is that these are conservative estimates since the micro-enterprise surveys only present data for formal private firms with no minimum on the number of employees, while it is heavily documented that (1) informal mining is widely present in Ghana, and (2) large-scale mines are likely to have an even greater share of land.

The second channel through which mining affects local areas is the construction of roads and other transport infrastructures as mining companies often participate in the financing and construction of transport infrastructures necessary to the export of minerals. Thanks to roads maps data from Esri and Jedwab and Moradi (2016), I was able to compute the roads densities for each district in Ghana in 1960, 2000 and 2013 and estimated that roads densities increased by 36.7% in mining districts using an instrumental variable strategy in which I instrumented mining activity in a district with the value of gold deposits in that district. Additionally, I built gross migration flows between districts using Ghana Living Standard Surveys from 2000 and estimated a migration gravity equation to find that mining activity decrease migration costs by 4.8% to and from mining districts compared to non-mining districts.

Finally, I used a general equilibrium model with spatial linkages in trade and migration and ran three different counterfactual experiments to model a mine opening in a district. After the first shock (a 5% increase in productivity), welfare (as measured by indirect utility) increases mildly while the change in land rental rates is not significant. Shocks 2 and 3 build on shock 1 and represent an increase in land's weight in the production function and a 4.8% decrease in migration costs respectively. The percentage increase in rents is much larger in shock 2 and shock 3 than shock 1 since the land demand shock from firms increases land's equilibrium price. Welfare also increases after both shocks due to outward migration flows from the district, which mitigate the decrease in wages. Additionally, the decrease in migration costs from and to the treated district in shock 3 allows for the spatial propagation of the shock. The increase in rents is lower than in shock 2 but more evenly spread out across treated and non-treated districts. Our results indicate a strong effect on indirect utility and rents up to 200kms from the treated district and shed a new light on the mechanisms through which a mining boom can spread to nearby regions. An interesting expansion to the model would be to allow for intermediate inputs as well as elastic labor supply to the private and farming sector to model the change in sectoral employment composition as documented in Kotsadam and Tolonen (2016) and in Fafchamps et al. (2017).

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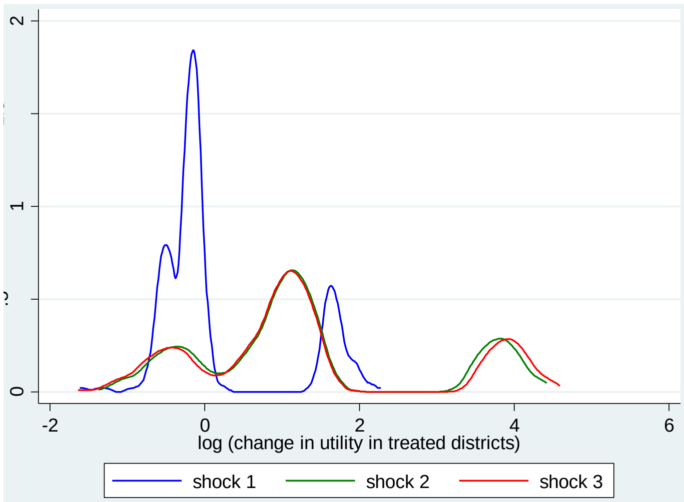
APPENDIX

Appendix A: Welfare and rents elasticities in treated and other districts when σ=4

Figure j) – Kernel densities of welfare and land rental rates elasticities in treated districts

j1) – Welfare elasticities



j2) – Land rental rates elasticities

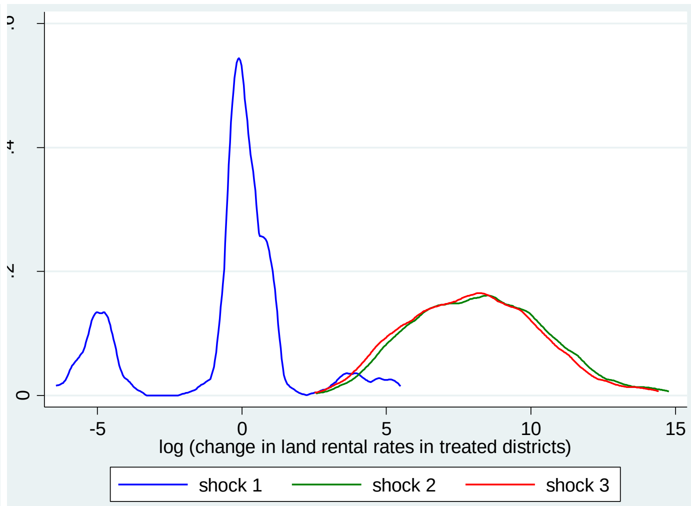
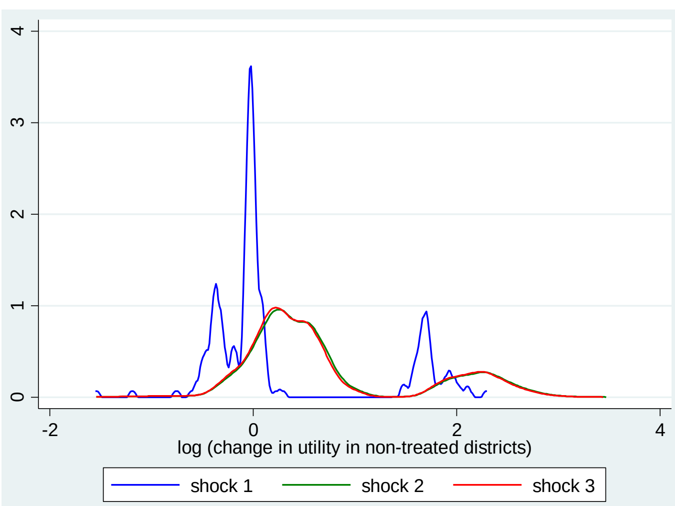
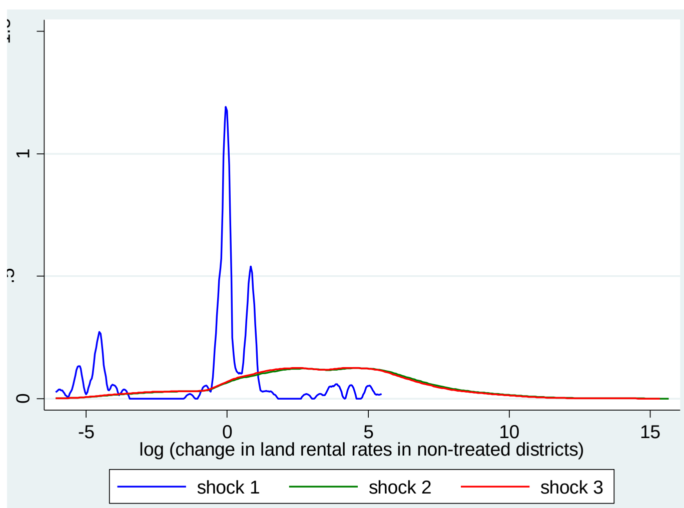


Figure k) – Kernel densities of welfare and land rental rates elasticities in non-treated districts

k1) – Welfare elasticities



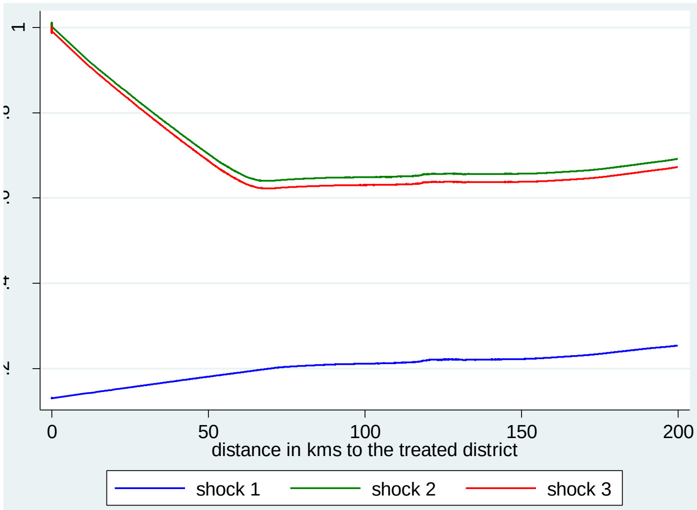
k2) – Land rental rates elasticities



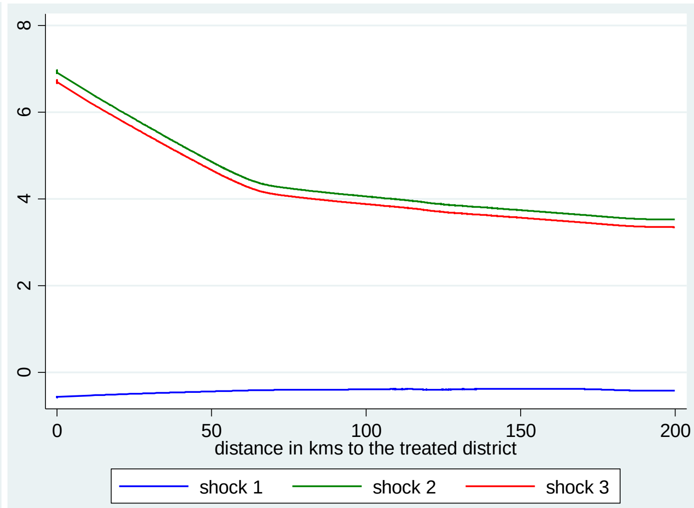
Appendix B: Elasticities in relation to distance to the shock when σ=4

Figure l) – Lowess smoothing of elasticities in relation to distance to the shock

l1) - Lowess welfare elasticities



l2) – Lowess rents elasticities



Appendix C: Welfare and rents elasticities in treated and other districts when migration and trade costs decrease by 10%, 15%, and 20%.

Figure m) – Kernel densities of welfare and land rental rates elasticities in treated districts

m1) – Welfare elasticities m2) – Land rental rates elasticities

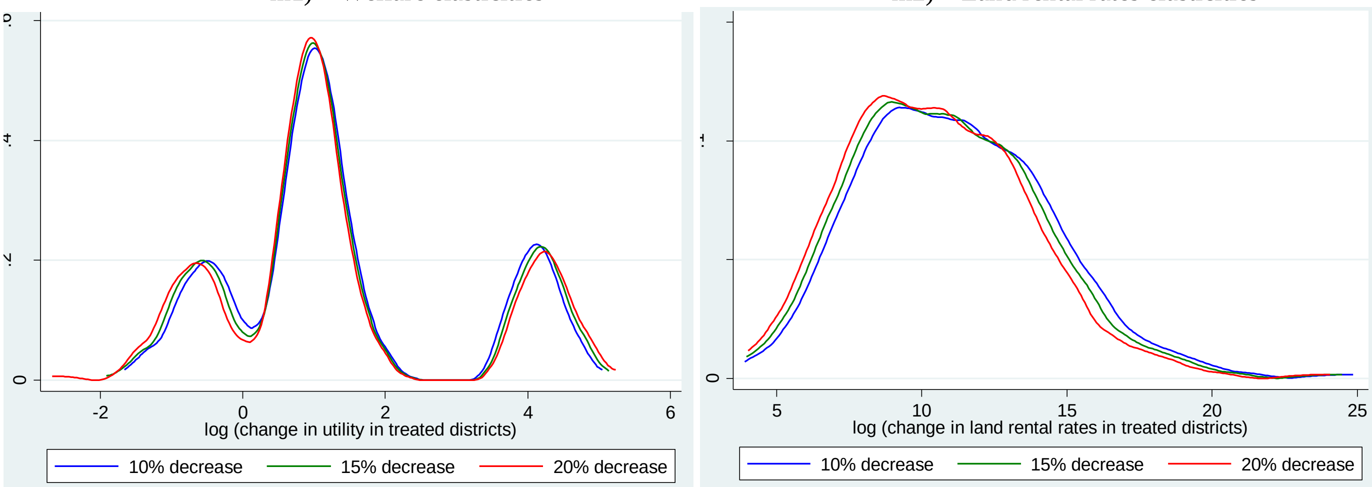


Figure n) – Kernel densities of welfare and land rental rates elasticities in treated districts

n1) – Welfare elasticities n2) – Land rental rates elasticities

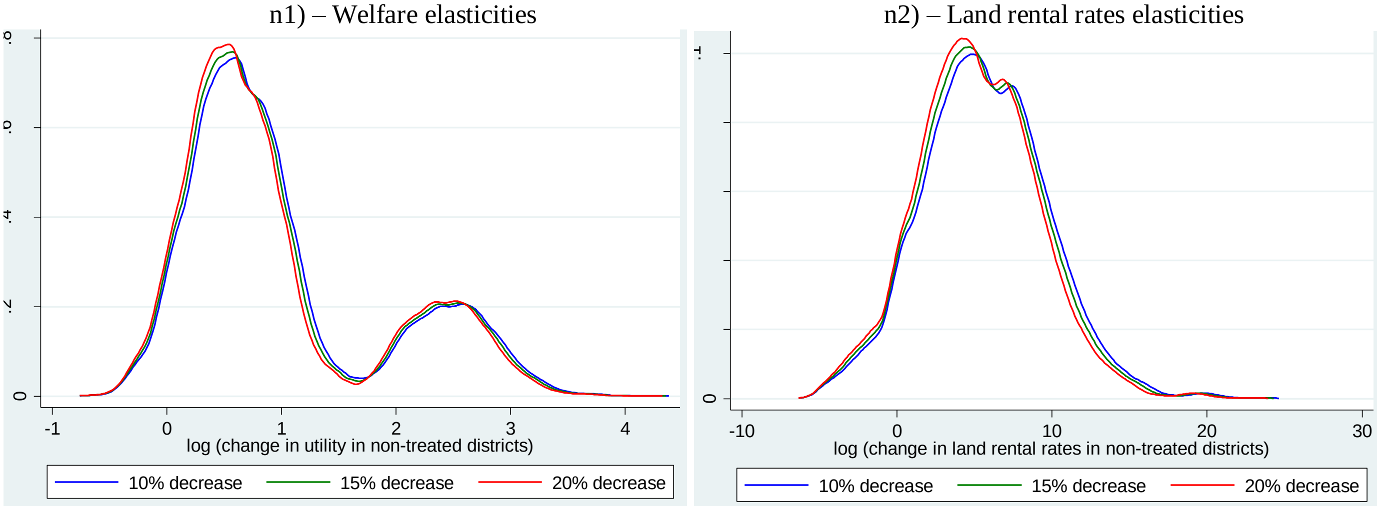


Figure o) – Lowess smoothing of elasticities in relation to distance to the shock

o1) - Lowess welfare elasticities o2) – Lowess rents elasticities