Resource Rents, Urbanization and Structural Transformation

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Abstract

We study the role of resource rents in explaining the distinct urbanization and structural transformation patterns, observed in many developing countries in the last few decades. We present a simple model where the effect of resource rents on urbanization and structural transformation depends on income redistribution between rural and urban areas. Combining several spatially granular data sets by geography, including global property-level mining data, global high-resolution population data layer, and the population census microdata, we empirically test the question at the city level on a global scale and estimate the causal effect of mineral price shocks of nearby mines on city outcomes. We find that on a global average, mining booms result in an increase in the urban population, and the reallocation of labor from agriculture to low-skilled services. The effects are mainly driven by African cities, consistent with the phenomenon of "Urbanization without Industrialization" in these countries. We explore several potential mechanisms. The evidence suggests that low opportunity cost due to low agricultural productivity in African countries incentivizes rural farmers to migrate in response to income shock instantiated by mining booms.

Key Words: resource rents, mineral price, urbanization, structural transformation

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1 Introduction

Historically, urbanization in the European and Neo-European countries has accompanied industrialization (Michaels et al., 2012; Jedwab and Vollrath, 2015; Gollin et al., 2016), and there is a strong positive correlation between urbanization and income per capita.[1] In the past few decades, however, urbanization in many developing countries has deviated from this pattern. In particular, many developing countries—especially those in sub-Saharan Africa—have high rates of urbanization at low levels of per capita income, and have limited industrialization at the same time (Glaeser, 2014; Rodrik, 2016; Henderson and Kriticos, 2018; Diao et al., 2019, 2021; McMillan and Zeufack, 2022). The reasons behind this divergence between urbanization, industrialization, and economic growth are not well understood.

In this paper, we study whether high resource rents in sub-Saharan Africa can explain its distinct urbanization and structural transformation patterns. A large literature emphasizes changes in income as a key driver of structural transformation, with the idea being that increased income generates higher demand for non-agricultural goods and results in labor reallocation out of agriculture (Murphy et al., 1989; Kongsamut et al., 2001; Gollin et al., 2002). In an influential paper, Gollin et al. (2016) links the fact, that African countries have abundant natural resources exported, to this demand channel to explain the unique urbanization and industrialization patterns observed in sub-Saharan Africa. Corresponding the high natural resource exports to an income effect—a large portion of which is spent in the urban sector—they argue that the rich natural resources in sub-Saharan Africa can cause urbanization at a low level of GDP per capita, while at the same time, having no effect on or even impeding industrialization. This explanation, however, is not without challenge. For example, Henderson and Kriticos (2018) reexamines the consumer city argument, and concludes that neither traditional structural transformation forces nor natural resource rents can explain how sub-Saharan Africa is urbanizing.

We shed light on this debate by examining how the city population and local industrial structure respond to mineral price shocks of nearby mines. Different from previous studies, we exploit the city-level variation and exogenous changes in international mineral prices to achieve identification. We correspond the increases in mineral prices to positive income shocks to test the above consumption city hypothesis. To conduct the empirical analysis, We combine several spatially granular data sets: a collection of all urban settlements across the

[1]For example, De Long and Shleifer (1993) and Acemoglu et al. (2002) use the urbanization rate as a proxy for income per capita.

world with a population above a certain threshold, a global high-resolution population data layer, a global property-level mining data containing the coordinates of each mining property and the primary commodities produced, and the population census microdata from IPUMS. The scale and spatial granularity of these data sets enable us to evaluate the relationship between mineral price changes, urban population growth, and changes in industrial structure in a comparable way across time and countries.

We combine different data sources by geography. We use cities as the basic units of analysis. The primary outcomes of interest are changes in population density and industrial composition within 30 km (or 60 km) of every city's centroid. The key explanatory variable is defined as the average price change of the minerals produced in the mines located within 60 (or 120 km) of each city's centroid, which is a proxy for resource rents. Our study period is from circa 1975 to circa 2015, and both the outcome variables and explanatory variables are defined over a period of about 10 years, depending on the data availability. We identify the causal effect of resource rent on urbanization and structural transformation under a long-difference empirical framework. With the inclusion of country fixed effects as well as country-group by period fixed effects, we exploit the across-city within-country temporary variations in changes in population and employment shares due to changes in the world price of the main minerals extracted nearby the city.

To guide the empirical work, we build a simple model of labor allocations in a three-sector two-region (rural and urban) small open economy where structural transformation could occur in both regions while urbanization occurs via rural-urban migration. This is different from the traditional view that equalizes structural transformation with urbanization. Revenue from natural resources raises incomes, which are unevenly distributed between two regions and can be used to buy tradable goods from domestic and world markets. In our model, resource rent increases do not necessarily lead to a high urbanization rate. The urbanization rate would increase in response to rising resource rent only if the urban area obtains most of the resource revenue. In sum, the model predicts that the effect of resource rent on urbanization and structural transformation in open economies depends on income redistribution between rural and urban areas.

In the first part of our analysis, we estimate how the city population changes in response to the changes in the mineral prices of the mines surrounding each city. Using the global full sample, we find a positive effect: mining booms nearby the city lead to significant urban population growth. A 10% increase in the average global mineral price of the mines located within 60km of the city centroids leads to a 0.42% increase in population density within 30km of the city centroids. The effect diminishes as we consider mining sites located farther away from the cities, i.e., from 60km to 120km, which suggests that urban population growth is less responsive to faraway mining booms. The effect of mineral price changes on city population growth is also larger in the central areas of the cities (i.e. within 30 km of the centroids) than in the peripheral areas of the cities (i.e. between 30 and 60 km away from the cities), lending support to the consumption city hypothesis which states that increasing demand is disproportionately distributed in city interiors (Glaeser et al., 2001). The results are robust to a series of sensitivity checks, including the selection of the city sample, the range of buffer zones, the inclusion of country-by-period fixed effects, and the correction of spatial correlation in standard errors.

We then exploit the heterogeneity of the effect by region.[2] We find that the effect is largest and most significant among African cities than among others. A 10% increase in relevant global mineral price results in a 1.33% increase in city population density in sub-Saharan Africa and a 2.15% increase in North Africa, respectively, both of which are much higher than the global average effect (0.42%). Mining booms account for roughly 33% and 45% of the urban population growth between 1975 and 2015 in sub-Saharan Africa and North Africa, respectively. In contrast, we find a small or no impact of mineral price shocks on the city population for the other country groups.

In the second part of the paper, we investigate how the industrial composition of a city changes in response to the changes in the mineral prices of the nearby mines. The results in this exercise, together with the results in the first part of the paper, are of central importance for understanding why the urbanization and structural transformation processes in many of today's developing countries deviate from past experiences. On a global scale, we find that mineral price spikes lead to structural transformation out of agriculture: a 10% increase in mineral prices decreases the employment share in agriculture by 0.36 percentage points. The labor force is primarily reallocated to the service sector, particularly to the low-skilled service sector. A 10% increase in relevant mineral prices leads to a 0.3-percentage-points increase in low-skilled services and a 0.02-percentage-points increase in high-skilled services.

We then show that mineral price shocks affect structural transformation differentially across regions in the world. Again, African cities exhibit special patterns: the labor reallocation out of the agricultural sector is particularly fast in the presence of positive mineral price shocks in Africa than in the rest of the world. A 10% increase in mineral prices re-

[2]We define 7 country groups in the world: sub-Saharan Africa, North Africa, Latin America, South Asia, East Asia, Europe and Central Asia, and North America, according to the classification of World Bank in its website: https://datahelpdesk.worldbank.org.

sults in a 0.84 percentage points decrease in the employment share in agriculture and 0.70 percentage points increase in the employment share in low-skilled services, which are much larger than the global average (0.36 and 0.30 percentage points) [3]. This result is consistent with their high responsive rate of the urban population to mineral price shocks found in the first part of the analysis. These facts, taken together, indicate that African cities indeed experience urbanization and structural transformation that are very different from the rest of the world, and mineral resource rents could play an important role in explaining the differences.

We explore the potential mechanisms behind the fact that African cities respond differently to mineral price shocks. To do so, we interact mineral prices with the African region dummies, as well as interact mineral prices with country characteristics, and see whether the inclusion of country characteristics absorbs the effect of the African region dummy. We consider four main country characteristics: resource reliance—measured by the ratio of natural resource export (including ores and metals) to GDP, agricultural productivity—measured by the cereal yield, infrastructure—measured by access to electricity, and human capital—measured by average years of schooling. We find a significant role of agricultural productivity in explaining the distinct responsiveness of African cities. Mineral price booms lead to higher urban population growth and faster structural transformation out of agriculture when local agricultural productivity is lower. The relatively lower agricultural productivity in African countries can explain about 1/3 (and almost completely) of African cities' exceptionally higher elasticity of urban population (and employment share of low-skilled services) to mineral price shocks. A plausible explanation is farmers face lower opportunity costs of moving out of the rural areas if their local agricultural productivity is lower (Henderson and Turner, 2020). On the other hand, we do not find any other country characteristics to be able to absorb the effect of the African region dummies.

To summarize, by combining several global data sets with the high-resolution feature, as well as the changes in world mineral price as an exogenous source of resource rent changes, our paper provides the first city-level, a worldwide test of the consumption city hypothesis in explaining the distinct urbanization and structural transformation patterns of sub-Saharan Africa. Our results both lend support to and show the limitations of this hypothesis. On the one hand, our results show that the mining booms in our study period can explain

[3] We conduct a bunch of robustness checks in the appendix, and show that our results are not driven by different city samples, different buffer zones, country-specific time trends, the spatial correlation of cities, and a few countries where geo-referenced population census data is only available for very large subnational administrative units.

a significant fraction of the overall increases in urban population and in the employment share in the non-agricultural sector in Africa. The African cities also exhibit especially high sensitivity of population changes and structural transformation to mineral price changes, indicating the consumption city hypothesis could be at work. On the other hand, our results also show that there is a substantial fraction of urbanization and structural transformation in Africa that cannot be explained by the booms in resource prices. In addition, why African cities respond differently to mineral price shocks is still not well understood. Among all major mechanisms proposed in the literature, the low opportunity cost mechanism—which results from the low agricultural productivity (Henderson and Turner, 2020)—has the largest potential to explain Africa's uniqueness.

Besides casting light on the debate on the causes of urbanization without industrialization in Africa, our paper is also related to several other strands of literature. First, more broadly, our research connects to the macro-development literature on structural transformation, including Baumol (1967); Ngai and Pissarides (2007); Herrendorf et al. (2014); Huneeus and Rogerson (2020), and urbanization, see Glaeser (2014); Henderson et al. (2017); Jedwab et al. (2017). Our empirical approach is similar to those who use various microdata to investigate macro-development questions in a growing literature, see Bustos et al. (2016); Hjort and Poulsen (2019); Bustos et al. (2020); Asher and Novosad (2020); Fried and Lagakos (2021); Gollin et al. (2021); Eckert and Peters (2022); Fajgelbaum and Redding (2022); Fiszbein (2022), and a good review paper by Lagakos and Shu (2021). The previous empirical papers focus on testing the productivity growth channel of structural transformation. In contrast, in this paper, we test an equally important yet much less empirically studied channel of structural transformation—the demand-driven channel.

Second, we add to the literature on the role of resources booms in economic development, see Corden and Neary (1982); Sachs and Warner (2001); Van der Ploeg (2011); Glaeser et al. (2015); Harding and Venables (2016); Allcott and Keniston (2018); Cavalcanti et al. (2019); Mamo et al. (2019). While most of the work examines whether there is a resource curse following a resource boom by studying a specific natural resource or a single country, we extend the analysis to a global scale and to many mineral resources and show that natural resource booms could have highly heterogeneous effects on different parts of the world.

Third, our paper is related to research on cross-country productivity differences in agriculture in economic growth literature, including Restuccia et al. (2008); Lagakos and Waugh (2013); Gollin et al. (2014); Adamopoulos and Restuccia (2022); Suri and Udry (2022). While most of this research focuses on understanding why productivity differences across countries are so much larger in agriculture, our work highlights the role of agricultural productivity in shaping the heterogeneous paths of urbanization and structural transformation in response to mineral price shocks.

Fourth, a growing empirical literature has examined the relationship between mining activity and socio-economic outcomes, ranging from real income (Aragón and Rud, 2013), infant mortality (Benshaul-Tolonen, 2019), crime (Axbard et al., 2021), workplace injuries (Charles et al., 2022), conflicts (Dube and Vargas, 2013; Berman et al., 2017), corruption (Asher and Novosad, 2019), and deforestation (Goldblatt et al., 2022). In contrast to these studies, our focus is on the reallocation of economic activity across sectors and the movement of population across regions.

The remainder of the paper is structured as follows. Section 2 develops a simple model to illustrate the role of resource rents on urbanization and structural transformation. Section 3 describes our data sources and provides summary statistics. Section 4 introduces our empirical strategy. Section 5 presents the results on the impact of mining activity on urbanization and structural transformation. Section 6 explores the potential mechanisms. Section 7 concludes.

2 Model

In this section, we present a simple model to illustrate the effects of resource rent on urbanization and structural transformation in small open economies. We consider each country as a small open economy. In each small open economy, there are three sectors, agriculture, manufacturing, and service, and two areas, rural and urban. There is only one production factor, labor. The agricultural and manufacturing goods are freely mobile across and within economies, but service goods can only be produced and consumed in the local area. Production factor is immobile across economies, but can freely move between the rural area and the urban area within the economy.

2.1 Setup

The small open economy has 1 unit of workers, and consists of two areas: urban and rural. There are three sectors, agriculture, manufacturing, and service. Manufacturing good is only produced in the urban area, while agricultural good is only produced in the rural area. Both rural and urban areas provide service goods, which can only be locally consumed.

Preference and Consumption

Individuals have a log-linear utility function over the three goods: food produced in the rural area (c_a), manufacturing goods produced in the urban area (c_m), and services produced where they live (rural or urban) (c_s).

$$U = \beta_a \ln c_a + \beta_m \ln c_m + \beta_s \ln c_s \tag{1}$$

where β_a, β_m, β_s are all between zero and one, and $\beta_a + \beta_m + \beta_s = 1$. Individuals in the rural area own income I^r, while individuals in the urban area own income I^u. Following Gollin et al. (2016), we assume that natural resources serve only as a source of income, and do not enter the utility function directly for consumption.

Production

Production of goods requires only labor in three sectors. Production in each sector is

$$Q_j^k = A_j^k (L_j^k)^{1-\alpha} \tag{2}$$

where $j \in (a, m, s)$ denotes the specific sector of production, and $k \in (r, u)$ denotes the specific area of production. We omit superscript k for agriculture and manufacture, as they are produced in only one area. A_j^k is the productivity level, capturing any effects of capital and/or land in production. α is between zero and one, and identical across all sectors. The functional form also suggests that there are diminishing marginal products of labor in each production activity. This ensures that there will be an incentive to have workers in each sector.

Resource Rent

The economy possesses a natural resource, which has no domestic demand but can be exported. The revenue from exporting natural resources R can be used to pay for agricultural and manufacturing goods from the domestic market and world market. Assuming that ηR is equally distributed to individuals in the urban area, and $(1-\eta)R$ is equally distributed to individuals in the rural area. $0 <= \eta <= 1$.

2.2 Equilibrium

The agricultural and manufacturing goods have international prices, p_a^* and p_m^*, that are taken as given by consumers and producers. The price of service goods, both in rural and urban, are determined endogenously, and denoted by p_s^r and p_s^u.

Utility Maximization

Taking these prices as given, the budget constraint for the individual is

$$p_a^* c_a^k + p_m^* c_m^k + p_s c_s^k = I^k$$

where $k \in (r, u)$. Given that services are by definition only produced locally, total expenditure on them must equal the total value of production.

$$p_s^k c_s^k = \beta_s I^k = p_s^k Q_s^k \tag{3}$$

Production Maximization and Labor Mobility

Labor mobility across regions and between sectors ensures that wage is equalized across all sectors.

$$(1-\alpha) p_a^* A_a L_a^{-\alpha} = (1-\alpha) p_s^r A_s^r (L_s^r)^{-\alpha} \tag{4}$$

$$(1-\alpha) p_m^* A_m L_m^{-\alpha} = (1-\alpha) p_s^r A_s^r (L_s^r)^{-\alpha} \tag{5}$$

$$(1-\alpha) p_s^u A_s^u (L_s^u)^{-\alpha} = (1-\alpha) p_s^r A_s^r (L_s^r)^{-\alpha} \tag{6}$$

The labor market clears.

$$L_s^u + L_s^r + L_m + L_a = 1 \tag{7}$$

Since we presume that the total measure of workers in the economy is equal to one, so each L_j^k term can be interpreted as the share of labor working in that sector.

Balanced Trade

The two tradable goods, i.e., agricultural and manufacturing goods, can be produced domestically, imported from the rest of the world, or exported. Assuming balanced trade in two areas yields the following two conditions.

$$(1-\eta) R + p_a^* Q_a + p_s^r Q_s^r = I^r \tag{8}$$

$$\eta R + p_m^* Q_m + p_s^u Q_s^u = I^u \tag{9}$$

Labor Allocation

We have 8 unknown variables: L_s^r, L_s^u, L_m, L_a, p_s^r, p_s^u, I^r, I^u. According to utility maximization (equation (3)*2), labor market clearing conditions (equation (4) (5)(6)(7)), trade balance conditions (equation (8) and (9)), we can have solutions to each unknown variable.

Let $\bar{A} = \left[(p_m^* A_m)^{1/\alpha} + (p_a^* A_a)^{1/\alpha}\right]^\alpha$,

$$\beta_s \eta R(1 - L_s^r - L_s^u)^\alpha + \beta_s (p_m^* A_m)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}} (1 - L_s^r - L_s^u) = (1 - \beta_s)\bar{A} L_s^u \tag{10}$$

$$\beta_s (1-\eta) R(1 - L_s^r - L_s^u)^\alpha + \beta_s (p_a^* A_a)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}} (1 - L_s^r - L_s^u) = (1 - \beta_s)\bar{A} L_s^r \tag{11}$$

$$L_m = (\frac{p_m^* A_m}{\bar{A}})^{\frac{1}{\alpha}} (1 - L_s^r - L_s^u) \tag{12}$$

$$L_a = (\frac{p_a^* A_a}{\bar{A}})^{\frac{1}{\alpha}} (1 - L_s^r - L_s^u) \tag{13}$$

2.3 Comparative Statics

In the following paragraphs, we assess the response of labor allocations to resource booms. First, we study how the employment share in each sector responds to the rise of resource rent. We then examine how resource rent affects urbanization. Last, we show that agricultural productivity also has a mediation role in the relationship between resource rent and urbanization rate.

Proposition 1 (Resources and Structural Transformation)

(1) $\partial L_s / \partial R > 0$

(2) $\partial L_m / \partial R < 0$

(3) $\partial L_a / \partial R < 0$

Furthermore, the sign of $\partial L_s^r / \partial R$ *and* $\partial L_s^u / \partial R$ *depends on* η *– the share of resource revenue received by the urban area.*

When $0 < \eta < \beta_s \lambda_m$, $\partial L_s^u / \partial R < 0$ *and* $\partial L_s^r / \partial R > 0$.

When $\beta_s \lambda_m < \eta < 1 - \beta_s + \beta_s \lambda_m$, $\partial L_s^u / \partial R > 0$ *and* $\partial L_s^r / \partial R > 0$.

When $\eta > 1 - \beta_s + \beta_s \lambda_m$, $\partial L_s^u / \partial R > 0$ *and* $\partial L_s^r / \partial R < 0$.

Proof:

By adding equation (10) and (11), we can get an equation of R and L_s. The partial relationship of L_s and R can then be established by taking derivatives in this equation using the implicit function theorem. The other partial relationships can be backed out using the labor allocation conditions in the equilibrium. The details can be found in the appendix.

Increased resource revenues bring more income to both the rural area and the urban area, and then generate higher demand for all goods. As demand for agricultural and manufacturing goods can be met via imports from the world market using the increased revenue from R, so labor can be reallocated to the local service sector. The employment share in the service sector increases with R, and the employment share of agriculture and manufacturing decreases with R. The distribution of service workers in rural and urban areas depends on the value of η – the share of resource revenue received by the urban area. If η is very small, the urban area just gains much less income than the rural area, then labor will move to the rural area and enter the service sector there. Vice versa. If resource revenue is distributed quite evenly (not absolutely even), that η is not too small or too large, then the service sector in both areas will grow.

Given the labor allocations, the urbanization rate U is equal to the proportion of workers in the manufacturing sector and service sector in the urban area.

Let $\lambda_a = (\frac{p_a^* A_a}{\bar{A}})^{\frac{1}{\alpha}}$ and $\lambda_m = (\frac{p_m^* A_m}{\bar{A}})^{\frac{1}{\alpha}}$, $\lambda_a + \lambda_m = 1$, $L_s^r + L_s^u = L_s$.

$$U = L_m + L_s^u = (1 - L_s^r - L_s^u)(\frac{p_m^* A_m}{\bar{A}})^{\frac{1}{\alpha}} + L_s^u = \lambda_m - \lambda_m L_s + L_s^u$$

Proposition 2 (Resources and Urbanization)

when $\eta > \lambda_m$,

$$\partial U / \partial R > 0$$

Proof

Add partial relationships of L_s and L_s^u to R can generate the partial relationship between u and R. The details can be found in the appendix.

An increase in resource revenue leads to more labor shifted to the urban area, and therefore a higher urbanization rate when the urban area gets a large part of the avenue from exporting natural resources. This is fairly intuitive, considering that the urban area has more houses, buildings, facilities, and infrastructure because the government usually spends much more income there.

Proposition 3 (The Role of Agricultural Productivity)

when $R > \bar{A}(\frac{1-\beta_s}{2})^{1-\alpha}\frac{1}{\beta_s}$,

$$\frac{\partial U / \partial R}{\partial A_a} < 0$$

Proof

Take the partial relationship to A_a from $\partial U / \partial R$. The details can be found in the appendix.

When the resource rent owned by the economy is not too small (in the appendix, we show the condition is $R > \bar{A}(\frac{1-\beta_s}{2})^{1-\alpha}\frac{1}{\beta_s}.$), the higher the agricultural productivity is, the urbanization rate is less sensitive to the increase of resource rent. The intuition behind this is that agricultural productivity is a kind of opportunity cost. High agricultural productivity suggests a high opportunity cost for leaving the agricultural sector and fewer incentives for moving to the urban area.

3 Data and Summary Statistics

In this section, we describe our data sources and variables and provide summary statistics.

3.1 Data Description

We are interested in whether mineral price booms result in urbanization and structural transformation, and examine this question at the city level instead of at the country level (see Gollin et al. (2016); Henderson and Kriticos (2018) for example). To construct the variables from various data sources, we proceed in the following steps. First, we select the universe of global cities with a population above 300K (200K), obtaining their lat/longs. These cities represent all the human settlements above a certain population size. Second, based on the centroids of this list of cities, we draw circles to encompass the mines surrounding each city. We then examine the impact of price changes of the minerals produced in nearby mines on two major outcomes of the cities: the city population and the local industrial composition. We describe the data merge process as well as each data source in detail below.

Urban Agglomerates and Population Data First, we locate the centroids of a collection of urban settlements covering the whole world using data provided by World Urbanization Prospects 2018 Revision (WUP 2018) and Africapolis. WUP 2018 presents estimates and projections of the urban population mainly based on official statistics. It identifies 1,860 urban agglomerates with at least 300,000 inhabitants in 2018, accounting for about 55% of the world's population residing in urban areas in 2018.[4] Africapolis defines urban units in Africa by two criteria: a continuously built-up area detected via satellite and aerial imagery, and more than 10,000 inhabitants since 1960 calculated by official demographic data. We

[4]The criteria of WUP to distinguish between urban and rural areas involve administrative designations, demographic characteristics, economic characteristics, and other assessments like the existence of paved streets, water-supply systems, sewerage systems, or electric lighting.

select the cities in Africapolis that reached a population of at least 200,000 at some point since 1960, which yields a sample of 181 African cities.[5] By combining cities in WUP (excluding Africa) and in Africapolis (Africa only), we obtain the coordinates of the centroids for a list of 2,041 cities in the world.[6]

After determining the centroids of the cities, the second step is to define consistent geographical boundaries across cities and time. This is challenging because the geographic sizes of cities are different and vary over time. To ensure comparability, we draw a circle of fixed radius around each city's centroid—which we call buffer zones hereafter—to define the "local" population (and "local" industrial structure later) for each city. In the baseline, we consider 30-km buffer zones, but also consider 40-60 km buffer zones for robustness checks.[7]

To calculate population changes within equally-sized buffer zones across the world, we use the Global Human Settlement population layer (GHSL) released by European Commission in 2019 (Florczyk et al., 2019). GHSL provides estimated gridded population in the world at the 250-m resolution for the years 1975, 1990, 2000, and 2015. These high-resolution population data are estimated based on administrative unit-level population data from the census, as well as the 30-m resolution Landsat data circa 2015 processed by EU (Corbane et al., 2018, 2019).[8] We spatially merge the GHSL 250-m gridded population data with the buffer zones of cities, and then obtain the average population density within the buffer zones for each city in each sample year (1975, 1990, 2000, and 2015).

Mining Data We then link the information on these cities to the information on mining sites nearby each city. Again, to define "nearby", we consider mining sites that were located within a distance of each city. The distance thresholds we use include 30/60/90/120 km away from the city centers. It is worth mentioning that the distance thresholds for mining sites are

[5] We adopt a different threshold for defining African cities because African cities are, on average, much smaller than the rest of the world. Using a smaller threshold would keep a larger sample of African cities.

[6] We also experiment with different city samples: cities only from WUP 2018, or non-African cities from WUP 2018 combined with African cities from Africapolis which reached a population of at least 100,000 at some point since 1960. We test the robustness of our results using these alternative city samples in the appendix.

[7] In this way, we are studying city population changes at the intensive margin (population growth of existing cities) rather than studying the extensive margin (the formation of new cities).

[8] The GHSL data map the population data from the census units into these 250-m grid squares according to the spatial distribution and density of the footprint of built cover within each area. The built cover information is made available by the Landsat data. More information about the GHS data can be found in Florczyk et al. (2019). Another population raster data is Gridded Population of the World version 4 (GPWv4). GPWv4 sets up the world in grid cells of approximately one kilometer and assumes that the population is evenly distributed across a polygon-shaped enumeration area. The GHSL uses the census unit population data the same as GPWv4, but allocates the population to grid cells in a different way.

different from the distance thresholds for defining the local population and local industrial structure. We make this distinction clear in the later analysis and conduct robustness checks on both thresholds.

The original data set on mining sites contain information on the location and characteristics of 33,262 mining sites around the world, collected by SNL Financial from company annual reports, technical reports, news articles, etc. For each mine, we know the current and historic operating status, the primary commodities produced, mine characteristics, reserves, and work history. However, annual production data and the year when production started are not available for the majority of the properties. We thus mainly exploit the information on mining sites' coordinates and the primary mineral produced. We calculate the distance between each mine and each city center all over the world and keep the mines within a certain radius of the city center for each city. Panel A in Figure A1 of the appendix depicts how we match mining sites with cities.

We retrieve information on global mineral prices from the World Bank Commodity Price Data (The Pink Sheet), supplemented by US Geological Survey (USGS). We obtain yearly price data for 10 minerals from the World Bank and another 14 minerals from USGS spanning over the sample period. Table A1 in the appendix summarizes the price data source and the number of mining sites for each mineral in our sample. 38.5% of the mines produce gold as the primary commodity. The other primary commodities include coal, copper, iron ore, nickel, silver, zinc, etc.

We construct the average price change of the *relevant* minerals experienced by each city during each period, which is used as the main independent variable throughout the paper. We first calculate the price changes (log difference) of the main commodity during each period for every mine in the dataset[9]. For each city, there may be multiple mines surrounding it. We take the simple average of the log price changes of all mines surrounding the city. This measure captures the intensity of the mineral price shocks experienced by each city.

Industrial Structure Data Besides linking mineral price changes to local population changes, we also link mineral price changes to local industrial structure. To measure industrial structure, we draw on population census microdata from IPUMS to calculate employment shares by sector within the buffer zone of each city. Since the administrative boundaries defined in IPUMS are inconsistent with our defined city buffer zones (30km is used as the baseline), we spatially join these two data sources by taking the weighted average of the vari-

[9]The periods are the same as the sample periods when outcome variables are observed.

able contained within each city buffer zone. Panel B of Figure A1 in the appendix illustrates the spatial join.[10]

We select all available samples provided by IPUMS according to three criteria: (1) the geo-referenced information of subnational administrative units is available in the country; (2) the sector information in which a person worked is not missing; (3) there are at least two rounds of census between 1975 and 2015 for the country, which allow us to calculate the changes in employment shares. We finally obtain 260 rounds of population census from 75 countries spanning from 1970 to 2017.[11] Table A3 in the appendix lists all the samples of population census or individual survey data used in this paper. In calculating the employment shares, we restrict to workers aged between 16 and 55. We group the industry codes into 5 categories: agriculture, manufacturing, high-skilled services, other services, and not recorded industries.[12]

Other Data We use other country-level indices—including cereal yields, access to electricity, the ratio of natural resource export to GDP, and education attainment—from the World Development Indicators. Countries are categorized into 7 groups mentioned in footnote 3.

3.2 Summary Statistics

We present summary statistics and plot the spatial patterns of the key explanatory variables and outcome variables using the above data. Figure 1 maps the location of the cities in the global sample and their population growth rates between 1975 and 2015. The majority

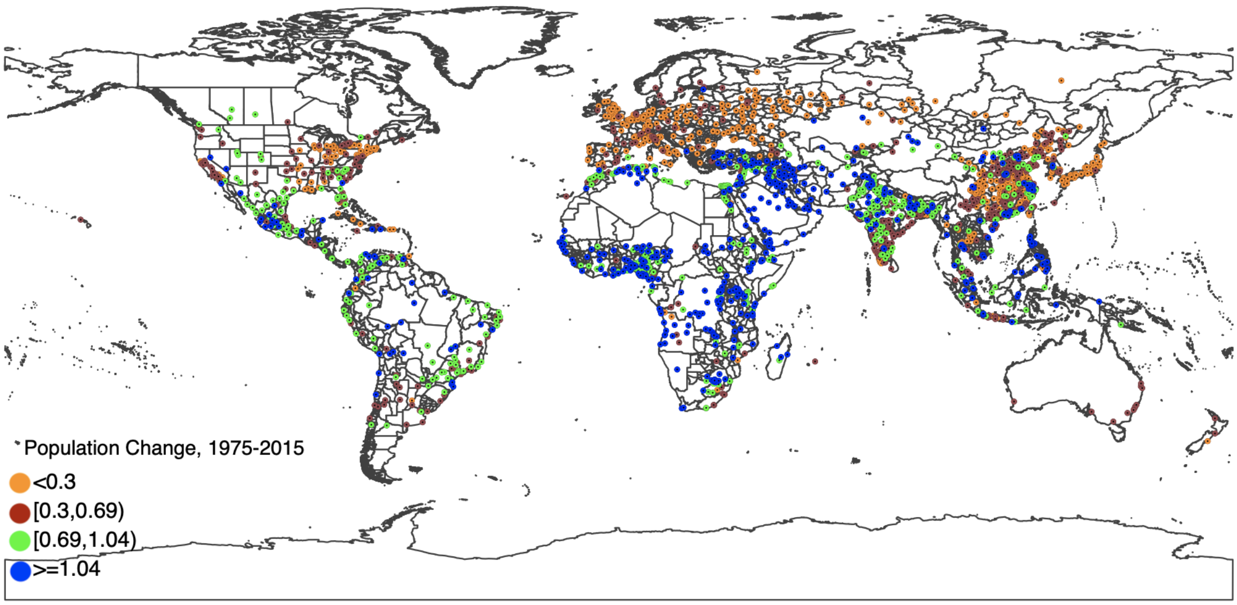
[10]Specifically, we first intersect the city buffer zones with the global shapefile and calculate the area of the overlapping parts between each administrative unit and the city buffer zone using QGIS. Then, for each overlapping part, we estimate its number of employees by the number of employees in the corresponding, greater administrative unit in IPUMS, multiplied by the area share of this overlapping part in the total area of the corresponding administrative unit. We then sum the number of employees of each overlapping part contained within each buffer zone to obtain the buffer-zone-level estimate of the number of employees. Based on these sector-specific employee estimates, we can derive the employment shares at the city buffer zone level.

[11]For India, IPUMS does not have ready population census data but has representative individual employment survey data. We complement the sample with 4 rounds of Indian survey data that satisfy our sample selection criteria.

[12]Specifically, agriculture includes agriculture, fishing, and forestry. High-skilled services include financial services and insurance, business services, and real estate. Other services include electricity, gas, water and waste management, construction, wholesale and retail trade, hotels and restaurants, transportation, storage, and communications, public administration and defense, education, health and social work, other services, private household services, and services not specified. Not recorded industries refer to those who answer other industry, n.e.c, response suppressed, unknown.

of the cities have experienced positive population growth in this period.[13] There is also large heterogeneity in the log change in population between 1975 and 2015 across the space, ranging from -3.223 (Nay Pyi Taw of Myanmar) to 8.283 (Luanda of Angola). On average, the population grows fastest in Africa, followed by South Asia and Latin America. Cities in Europe and North America saw smaller increases in population during the sample period.

Figure 1: The Spatial Distribution of Cities and Their Population Changes: 1975-2015



Notes: Figure 1 plots the distribution of cities in the global range (N = 2041), and their population change during 1975 to 2015. Population change is calculated by the difference in log population density within the radius of 30km of city center.

In addition to documenting the population changes in our global sample of cities, we also document how the industrial structure of these cities (and their nearby areas) changed in our study period. Table 1 summarizes both the levels of and the 1970s-2010s changes in the employment shares by sector and region. During the whole sample period, the cities in our sample on average have experienced a reallocation of labor from the agricultural sector to the non-agricultural sectors. The employment share of agriculture declined by 9.6 percentage points on average from the 1970s to the 2010s. The sectors to which the agricultural workers switch differ across regions. For cities in Latin America, Europe, Central Asia, and North America, the labor force left both agriculture and manufacturing and entered

[13] Here, we define cities as the centroids together with their 30-km buffer zones across the world.

into services. Cities in sub-Saharan Africa and North Africa saw a reallocation of labor from agriculture toward low-skilled services but saw little changes in the share of employment in manufacturing and high-skill services. In East Asia and South Asia, the labor force switched out of agriculture and entered into manufacturing and other services.

Panel B of Table 1 displays the levels of the cities' employment shares in the 2000s.[14] Cities in Asia and Africa had the highest employment shares in agriculture than the other regions. African cities had the lowest share of employment in manufacturing, but they had a relatively high share of employment in low-skilled services. Combined with the fact shown in Figure 1, these patterns echos the fact of "urbanization without industrialization" in Africa documented in Gollin et al. (2016).

Table 1: The Change and Level of Employment Share By Sector and Region, 1970s-2010s

	All cities	East Asia	South Asia	Latin America	sub-Saharan Africa	Middle East and North Africa	Europe and Central Asia	North America
Panel A: Change in employment share from 1970s to 2010s (city buffer zone <= 30 km)								
Agriculture	-0.096	-0.113	-0.166	-0.086	-0.078	-0.095	-0.048	-0.017
Manufacturing	-0.012	0.014	0.007	-0.039	-0.003	0.010	-0.083	-0.043
High-skilled services	0.025	0.019	0.016	0.030	-0.005	0.015	0.038	0.063
Other services	0.090	0.096	0.150	0.074	0.094	0.087	0.106	0.004
Not recorded industries	-0.003	-0.009	-0.005	0.027	-0.005	-0.015	-0.005	-0.008
Number of cities	1,403	534	189	208	94	81	138	159
Panel B: Level of employment share in 2000s (city buffer zone <= 30 km)								
Agriculture	0.307	0.505	0.361	0.092	0.194	0.288	0.148	0.012
Manufacturing	0.145	0.148	0.153	0.138	0.114	0.100	0.153	0.151
High-skilled services	0.057	0.026	0.026	0.062	0.045	0.026	0.104	0.168
Other services	0.455	0.285	0.453	0.620	0.515	0.579	0.583	0.664
Not recorded industries	0.028	0.025	0.000	0.082	0.101	0.006	0.009	0.000
Number of cities	1,311	534	187	202	60	53	116	159

Notes: Panel A calculates the change in employment shares of the city within a radius of 30km of the city center. Panel B presents the average level of employment share in the 2000s.

As described in the previous subsection, we link the global sample of cities to the global sample of mining sites by spatial proximity. Table 2 provides the descriptive statistics of the mining sites. Several features are worth noting. First, within a certain buffer zone of the cities, not all the cities have mines in their surrounding areas. For example, only 30% of the cities have a mine within 30km of their centers. The fraction of the cities having at least

[14] We focus on the 2000s because population censuses in many developing countries are not available until more recent years, making the level of employment shares at the beginning of the sample period less comparable across countries.

one mine surrounding them gradually increases as the buffer zones expand—to 77.7% as the radius of the buffer zones increases to 120 km. The average number of mines ranges from 1.17 (in the 30-km buffer zones) to 11.95 (in the 120-km buffer zones). Second, the mining sites tend to be spatially clustered. Conditional on observing at least one mine located within 30-120 kilometers of the city center, the average number of mines ranges from 3.88 to 15.34. The mines in proximity tend to produce the same kind of mineral commodity. For example, the average number of primary commodities produced by these mines is only 1.48 within the 30-km buffer zones and it is only 2.87 within the 120-km buffer zones. This pattern suggests that, in the presence of many mineral price shocks, one urban agglomerate is usually affected by only one or several kinds of mineral prices. Given the high-volatility nature of mineral prices, this fact suggests that there is great uncertainty in the resource rents generated by nearby mining sites, which is useful for the identification of the effects we are interested in.

Table 2: Descriptive Statistics of Mines: City-level

	Mines' largest distance to city center			
	30km	60km	90km	120km
For all cities (N = 2041)				
Whether there are any mines	0.301	0.523	0.672	0.777
Average number of mines	1.169	3.576	7.200	11.95
For cities with mines surroundingly				
Number of cities	615	1,067	1,371	1,586
Average number of mines	3.880	6.840	10.718	15.379
Average number of primary commodities	1.481	1.856	2.379	2.873

Notes: Table 2 is calculated by authors based on the data of city center and information of mining sites.

We finally show the trends of mineral prices by mineral type in Figure A3 in the appendix. For many mineral commodities, we observe two peaks in world prices—one in the early 1980s and the other in the early 2000s. This is consistent with the two commodity super-cycles documented in the previous literature. The upward trends in the mineral commodity prices in the 1980s peak are typically attributed to the post-World War-II reconstruction of Western Europe and Japan and to the cartelization of the crude oil market (Cuddington and Jerrett, 2008; Erten and Ocampo, 2013). The escalation in commodity prices in the 2000s is often attributed to rising global demand, driven by rapid growth and the search for natural resources from emerging markets (Humphreys, 2010; Carter et al., 2011; Canuto et al., 2014; Reinhart et al., 2016). In our analysis, the variation in local resource rents comes from changes in world prices across different minerals and across time.

4 Empirical Strategy

To estimate the impact of mineral price changes on urbanization and structural change, we use the following long-difference equation as the baseline econometric specification:

$$\Delta Y_{i,t} = \beta_0 + \beta_1 \Delta \log Price^R_{i,t} + \alpha Y^{Initial}_{i,t} + \gamma \log NumMines^R_i + \lambda_c + \eta_{gt} + \epsilon_{i,t} \qquad (14)$$

where $\Delta Y_{i,t}$ is the outcome variable of interest, i.e., log changes in population[15] or changes in the employment share by sector in city i during period t. In the main analysis, we calculate the outcome variables within the 30km buffer zone of city i, and use the 60 km buffer zone as a robustness check. For each city, the population density is available for four years (circa 1975, 1990, 2000, 2015). We then obtain changes in population (density) in three periods for each city: 1975-1990, 1990-2000, and 2000-2015. On the other hand, the period in which employment share data are available depends on the census years, which vary across countries. So we measure changes in employment share in various periods for cities from different countries.

The key independent variable, $\Delta \log Price^R_{i,t}$, is the average price change of the mines located within R km of city i during the same period t as the dependent variable $\Delta Y_{i,t}$. As introduced before, we first calculate the log change in price for the primary commodity produced by each mine during each period and then average those price changes over all mines surrounding the city. We consider the price changes of the mines around the cities from small radius to larger ones: 30 km, 60 km, 90 km, and 120 km. β_1 is the coefficient of interest, which captures how sensitive the outcome variable is to the changes in the mineral prices of the mines located within the city buffer zone.

As shown in Table 2, a non-negligible proportion of the cities observe no mining sites in their surrounding areas, which is especially high if we consider only the mines within 30 km of the city centers (70%). Therefore, in the main analysis, we restrict the regression sample to cities observing at least one mine in the corresponding buffer zones. By making this restriction, we are comparing "resource cities" that experienced fast mineral price changes with "resource cities" that experienced slow mineral price changes, and are also comparing the same city across different time periods. An alternative approach in the literature is to assume that the price change is equal to zero for cities that have no mines in nearby areas (Berman et al., 2017). In the robustness checks, we show that our results are similar using

[15] or equivalently, population density since we fix the geographic boundaries of cities

this alternative (full) sample of cities.

The identifying assumption for estimating equation (14) is that the world price of minerals is exogenous to city outcomes. Given that most mines produce a small fraction of the worldwide output,[16] each mine can be viewed as a price taker, we think this is a reasonable assumption. Nevertheless, we still add country group (7 groups) $\times$ period fixed effects η_{gt} to control for country-group-specific time trends in the outcome variables. We also include the country fixed effects, λ_c, which absorb the effect of any time-invariant country characteristics that could be correlated with changes in population and industrial structure.

We further control for the initial value of the outcome variable, $Y_{i,t}^{Initial}$, which refers to initial log population density in the population regressions, or initial employment shares in the agricultural, manufacturing, and mining sectors in the employment share regressions. In addition, we control for the log number of mining sites, $\log NumMines_i^R$, located in the corresponding buffer zone, which captures the idea that resource abundance in the local area might have an effect on the outcome variables. We cluster the standard errors at the city level to allow for city-specific serial correlations. As a robustness check, we also estimate the standard errors using the spatial HAC correction methods by Conley (1999) and Colella et al. (2019). We show our results are robust to these two approaches.

5 Results

In this section, we present our empirical results. First, we estimate the effect of mineral price changes on the urban population. After establishing a positive relationship between mineral price changes and urban population growth, we turn to investigate how mining booms surrounding the city affect the structural transformation in the city and its nearby areas, measured by employment shares by sector. In both parts of the analysis, we both estimate a global average effect and the heterogeneous effects by region.

5.1 Urbanization

Table 3 reports the effect of mineral price change on urban population growth on a global scale. In columns (1) to (3), we consider the price change of mines located within 60/90/120 km of the city center, while the outcome is population growth within the 30-km buffer zone of the city. Across the specifications, we find that mineral price shocks are significantly

[16] There are 33,262 mining sites and 24 mineral types in our sample.

positively associated with urban population growth. A 10% increase in the relevant global mineral prices leads to a 0.23-0.42% increase in urban population density. The effect is the largest and most significant for the price shocks of the mines within 60 km of the cities. When we enlarge the buffer zones to encompass more mines, i.e., to 90-km and 120-km buffer zones, the effect of mineral price change becomes smaller and less significant. This pattern suggests that urban population growth is less affected by mining activities that are far away from the cities.

In columns (4)-(6), we define the outcome as urban population growth within the 60km buffer zone of the city. We find a smaller and less significant effect of mineral price changes on urban population growth compared to the effect on urban population growth within the 30-km buffer zone (columns (1)-(3)). The larger effect in the central cities compared to peripheral areas is suggestive of the consumption city hypothesis, which states that resource rents will be spent disproportionately in cities, thus creating more jobs and attracting more workers there. We also see that the urban population increases by more when the initial population density is lower, suggesting a mean reversion pattern in urban population growth. We verify that controlling for initial population density does not affect the estimates of the coefficient on mineral price changes.

During the sample period, the average annual price change rate is about 2.6%. According to our estimates, this translates into a 0.11% (=2.6*0.042) annual increase in urban population density. On the other hand, the average growth rate of the urban population within the 30-km buffer zones is approximately 24% among cities with mines surrounded during 1975-2015. Therefore, our estimates suggest that positive mineral price shock contributes to roughly 18% (=0.11*40/24) of the observed urban population growth for the sample cities during the period of 1975-2015.

We perform a series of sensitivity checks and present the results in Table A5 in the appendix. In Panel A, B, C, and D, we show that our results are not driven by the sample selection of cities or the range of the city buffer zones. Panel E further includes country-by-period fixed effects. Panel F takes spatial correlation into account, and estimates standard errors by the approach proposed Conley (1999). Our findings are robust to these as well.

So far, we find that mining booms lead to significant increases in urban population density on a global scale. However, how the effect varies across regions is not well-known. As depicted in Figure 1 in Section 3.2, cities across the world have experienced very different urbanization patterns. But do urban populations in different regions exhibit different sensitivities to mineral price shocks? The global coverage of our assembled data set offers a rare opportunity

Table 3: Price Shock and Population Change: Global Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
Outcome	Delta Log Population Density in the City					
	City buffer zone = 30 km			City buffer zone = 60 km		
Mines' largest distance to city center	60km	90km	120km	60km	90km	120km
Price Change	0.042***	0.023*	0.029*	0.032**	0.015	0.022
	(0.015)	(0.012)	(0.017)	(0.014)	(0.011)	(0.016)
Log Initial Population Density (city buffer zone = 30km)	-0.044***	-0.046***	-0.050***			
	(0.009)	(0.008)	(0.008)			
Log Initial Population Density (city buffer zone = 60km)				-0.033***	-0.034***	-0.041***
				(0.008)	(0.007)	(0.007)
Fixed Effect	Country group * period, country					
N	3,201	4,113	4,758	3,201	4,113	4,758
adj. R2	0.549	0.537	0.550	0.548	0.537	0.549

Notes: Table 3 reports regression coefficients of equation 14. The dependent variables are delta log population density within the radius of 30km (Columns 1-3) or 60 km (Columns 4-6) of the city. The buffer zone of cities for the independent variable (price change) and the control variable (log number of mines) correspond to the mines' largest distance to the city center. The buffer zone of the log initial population density is consistent with the dependent variable. Countries are categorized into 7 groups according to the Classification of World Bank: sub-Saharan Africa, Middle East, and North Africa, Latin America and the Caribbean, South Asia, East Asia, Europe, and Central Asia, and North America. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

to examine this heterogeneity.

We estimate the following equation to investigate the region-specific impact of mineral price shock on urban population growth

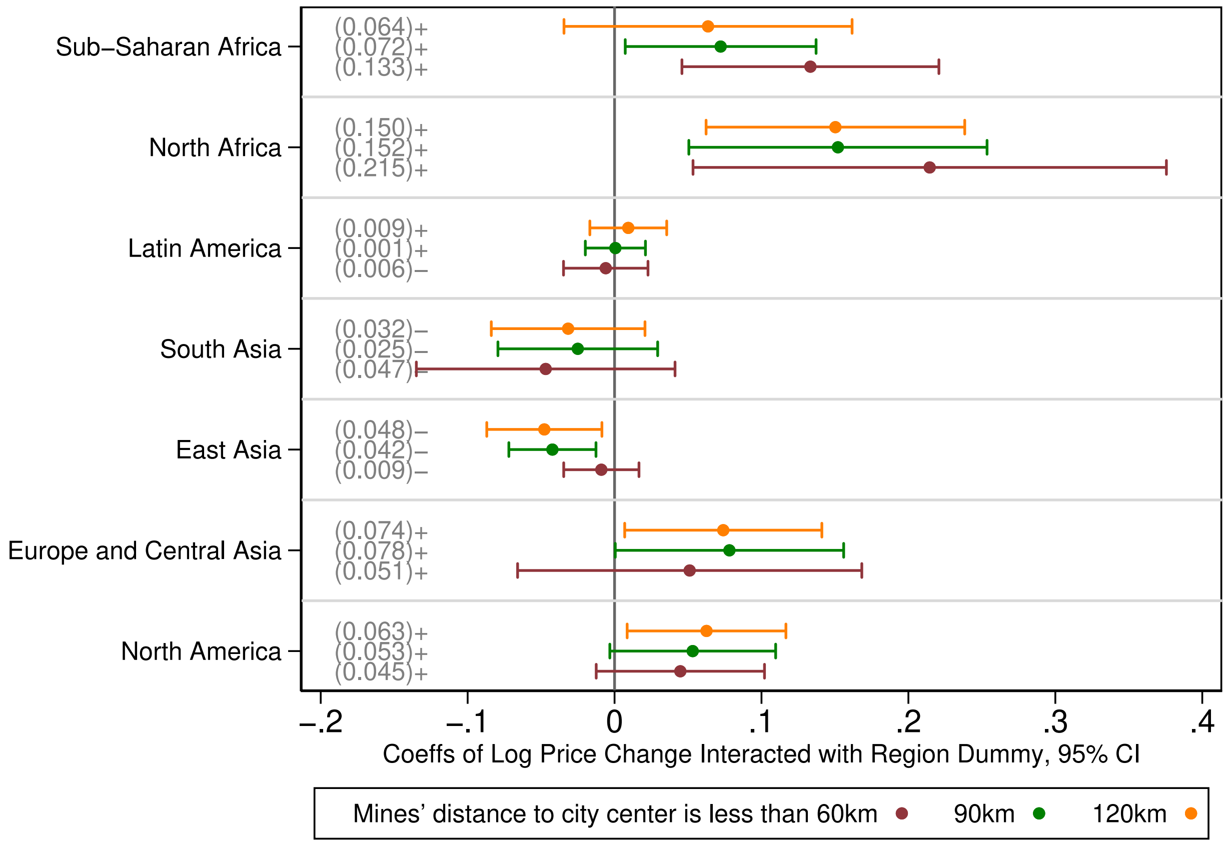
$$\begin{aligned} \Delta Y_{i,t} = \beta_0 + \sum_g \beta_{1g} \Delta \log Price^R_{it} \times \mathbb{1}(Country_{i,c} \in Group_g) + \alpha Y^{Initial}_{i,t} \\ + \gamma \log NumMines^R_i + \lambda_c + \eta_{gt} + \epsilon_{i,t} \end{aligned} \tag{15}$$

Similar to equation 14, $\Delta Y_{i,t}$ and $\Delta \log Price^R_{it}$ are changes in the outcome variables and mineral prices experienced by the city, respectively. $\mathbb{1}(Country_{i,c} \in Group_g)$ are dummy variables that equal to one if the city i of country c belongs to country group g, and 0 otherwise. We obtain 7 regional dummy variables in the end, corresponding to the classification of the country group. The coefficient of interest is β_{1g}, which captures the average effect of mineral price shock on population growth for urban cities in country group g.

Figure 2 plots the estimated coefficients of interactions between mineral price shock and country group dummies. The red, green, and blue lines correspond to different distances to locate nearby mining sites around the city. Again, each regression sample only consists of cities having at least one mine in corresponding nearby areas.

Several patterns stand out. First, the effect of mineral price shocks on urban population

Figure 2: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 30 km



Notes: Figure 2 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variable is the log change in population density within a radius of 30km of the city. All the regressions control for the initial log population density of the city, log number of mines within the radius of 60km (Red), 90km (Green), or 120km (Orange) of the city, country group × period fixed effects, and country fixed effects. Standard errors are clustered at the city level.

growth is the largest and most significant for African cities than others. An increase in global mineral price by 10% results in around a 0.64-1.33% increase in the urban population over circa 10 years in sub-Saharan Africa, and a 1.5-2.15% increase in North Africa. Given that population density within the sub-sample of cities increases on average by 50% and 42% in North Africa and sub-Saharan Africa from 1975 to 2015 respectively, it suggests that mineral booms account for roughly 45% and 33% of the increase in people living in the sample cities in these two regions [17]. The magnitude decreases when we enlarge the mine buffer zones to

[17] According to the estimated coefficients of red lines in Figure 2 (when mine buffer zone is 60 km), 45% is equal to $2.6 \times 40 \times 0.215/50$; and 33% is equal to $2.6 \times 40 \times 0.133/42$.

include mines farther away from the cities, which suggests the effect of mineral price shocks diminishes over distance.

Second, the average positive effect of mineral price changes on urban population growth in Table 3 is mostly driven by African cities. We find no impact of mineral price changes on urban population growth in Latin America and South Asia, a negative effect in East Asia, and a marginally positive effect in Europe and North America. We find similar results when adopting a larger city buffer zone (60 km) to calculate the urban population, as shown in Figure A4. The results are also robust to the inclusion of cities without mines in nearby areas or alternative city samples, incorporating country-by-period fixed effects, and considering the spatial correlation of cities, as shown in A5, A6, A7, A8, and A9.

To summarize, the results in this subsection suggest that, by interpreting positive mineral price changes as increases in resource rents, the increases in local resource rents could induce urbanization, and such a positive association is mainly found in Africa, lending support to the consumption city hypothesis.

5.2 Structural Transformation within Cities

The classical economic models often assume that the process of urbanization is accompanied by industrialization, where farmers migrate to cities and look for manufacturing jobs there. Yet, recent evidence suggests that urbanization and industrialization are not synonymous (Jedwab and Vollrath, 2015; Gollin et al., 2016). In this subsection, we explore how industrial composition within the cities and their greater areas changes in response to nearby mineral price shocks. Similar to the last subsection, We begin by estimating the global average effect, and then estimate the heterogeneous effects across regions.

Table 4: Price Shock and Change in Employment Shares Within Cities: Global Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Outcome = Delta Change in Employment Share of									
	Agriculture		Manufacture		High-Skilled Services		Other Services		Not Recorded	
Mines' largest distance to city center	60km	120km	60km	120km	60km	120km	60km	120km	60km	120km
Panel A City buffer zone = 30 km										
Price Change	-0.014***	-0.016***	0.001	0.003	0.002**	0.002**	0.029***	0.032***	-0.018***	-0.020***
	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
Fixed Effect	Country group * period, country									
N	1,940	2,910	1,940	2,910	1,940	2,910	1,940	2,910	1,940	2,910
adj. R2	0.233	0.237	0.198	0.193	0.340	0.342	0.315	0.304	0.280	0.240
Panel B City buffer zone = 60 km										
Price Change	-0.011**	-0.017***	0.001	0.002	0.003**	0.003***	0.027***	0.031***	-0.020***	-0.018***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
Fixed Effect	Country group * period, country									
N	2,024	3,048	2,024	3,048	2,024	3,048	2,024	3,048	2,024	3,048
adj. R2	0.259	0.241	0.193	0.186	0.306	0.310	0.277	0.270	0.237	0.207

Notes: Table 4 reports coefficients of equation 14. The dependent variables are delta changes in employment shares by industry within the city's radius of 30km (Panel A) or 60km (Panel B). The buffer zone of cities for the independent variable (price change) and the control variable (log number of mines) correspond to the mines' largest distance to the city center. All the regressions control for the initial employment share of agriculture, manufacturing, and mining within a radius of 30km/60km of the city. Countries are categorized into 7 groups according to the Classification of World Bank: sub-Saharan Africa, Middle East, and North Africa, Latin America and the Caribbean, South Asia, East Asia, Europe, and Central Asia, and North America. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

Table 4 presents the estimated global average effect of mineral price shocks on industrial composition within different buffer zones of the cities. Panel A focuses on the changes in the employment shares within the 30 km buffer zones of the cities, and Panel B focuses on the changes within the 60 km buffer zones of the cities. The odd-numbered columns examine the effect of the price changes of the mines falling in the 60 km buffer zones, while the even-numbered columns examine the effect of the price changes of the mines in the 120 km buffer zones. We have the following findings.

First, agricultural employment share decreases significantly in response to rising mineral prices. Take the results in column (2) of Panel A as an example. A 10% increase in mineral prices leads to a reduction in the employment share in agriculture by around 0.16 percentage points. By column (10) of panel A, a 10% increase in mineral prices also results in a 0.2-percentage-point decrease in the employment share in not recorded industries—a large fraction of which represent people working in both farms and other non-farm sectors (Henderson et al., 2021).

Second, columns (7) and (8) in both panels suggest that the labor force is reallocated mainly to the other (low-skill) service sectors. A 10% increase in mineral prices leads to an increase in the employment share in other services by around 0.32 percentage points (column (8)). Mining booms also significantly increase the employment share of high-skilled services, but with much smaller magnitudes (columns (5) and (6)). Moreover, mineral price shocks have no impact on the manufacturing employment share (columns (3) and (4)).

Third, by comparing the odd-numbered columns with the even-numbered columns (e.g., (1) with (2), (3) with (4), and so on), we expand the buffer zones from a radius of 60 km to 120 km to encompass more mines to examine the price effects of these proximate mines. We find the effects are of similar magnitudes under the two radii of buffer zones, which implies that resource rents from faraway mines have a similar effect as the effect of the resource rents from nearby mines. This pattern contrasts with the results using the urban population as the outcome (Table 3), in which we see the urban population is less affected by mines located farther away from the cities.

We also compare the coefficients in Panel A and Panel B in the same columns, where we define the outcome as the sectoral employment share within the 60 km/120 km buffer zones of the cities, respectively. A larger buffer zone covers more suburban areas and even rural areas if the city size is small enough. We observe similar effects of mineral price shocks under these two outcome definitions—that is—structural transformation driven by commodity booms occurs at a similar pace in both the core and periphery areas of the cities.

Again, this pattern contrasts with the results using the urban population as the outcome (Table 3), where we find the population in the city core areas is more responsive to the price shocks. Taking both sets of comparison results together, we conclude that resource-driven urbanization and resource-driven changes in industrial composition do not necessarily go hand-in-hand. A more plausible scenario is that a substantial fraction of structural transformation occurs within the rural areas and within the urban areas, in addition to the traditional view of equalizing structural transformation with rural-to-urban migration.

We conduct additional robustness checks in Table A6 and Table A7 of the appendix. We show that our findings are robust to different sample selection rules, different definitions of the city buffer zone, the inclusion of country-specific time trends, the correction of spatial correlation in the standard errors, and the exclusion of cities from countries with available geo-referenced information only for large administrative units in IPUMS dataset.

Next, we investigate whether mineral price shocks affect structural transformation differently across regions in the world. We estimate equation (15) using changes in employment share by sector as the outcome variable. The North African region is excluded from the regressions due to its small sample size. We plot the coefficient estimates by region and by sector in Figure 3, where we examine city buffer zones of 60 km and mine buffer zones of 120 km [18]. We observe three important patterns.

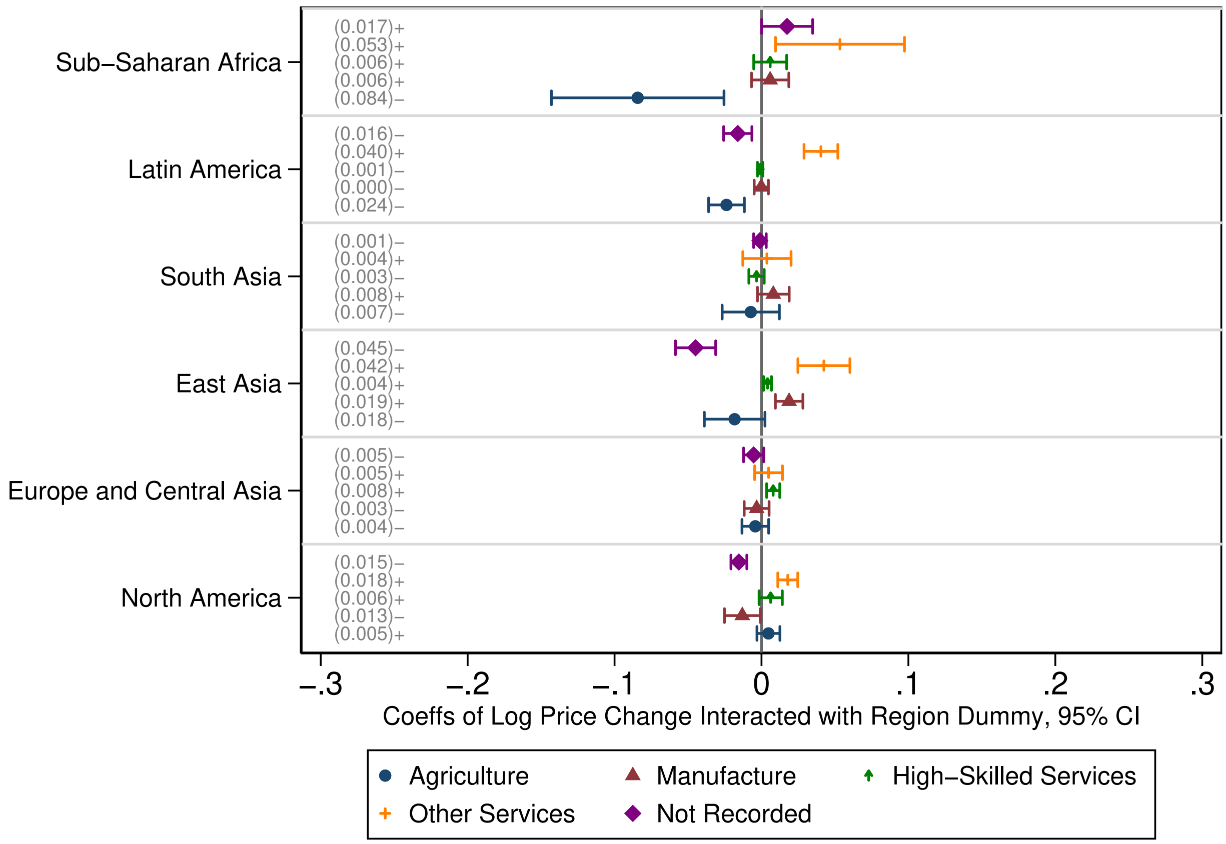
First, in response to the same degree of mineral price shocks, the sub-Saharan African cities exhibit the largest degree of reallocation of employment across sectors: the labor force transitions out of the agricultural sector and into the other sectors, primarily into the other (low-skill) service sector. The coefficient on prices for sub-Saharan Africa is several times larger than this coefficient for the other regions in the world—a pattern we will try to explain in the next section.

Second, across different regions, in response to rising mineral prices, the most common direction of reallocation of labor is an increase in the share of employment in the other (low-skill) service sector. This is consistent with the consumption city hypothesis, which suggests that resource rents will be spent disproportionately on urban non-tradable goods and services, which create the demand for labor in related sectors.

Third, for most parts of the world, there is little evidence for "the resource curse" in the sense of crowding out manufacturing activity: the coefficient on mineral prices interacted with manufacturing is statistically indistinguishable from zero for many regions. There are

[18] In the appendix, we show the estimation results using different buffer zones in Figure A10 and A11, and other robustness checks in Figure A13, A14, A15, A16, A17, A18, and A19.

Figure 3: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km



Notes: Figure 3 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The price change is the average log change of the price of mines located within a radius of 120km of the city. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the radius of 60km of the city, log number of mines within the radius of 120km of the city, country group $\times$ period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

two exceptions though: in East Asia, the manufacturing sector expands in the presence of positive mineral price shocks, suggesting that the cities in this region seem to have been able to reap the benefits of resource rents and promote industrial development. On the other hand, quite surprisingly, cities in North America have experienced a decline in employment share in manufacturing in response to mining booms. This result is in contrast with Allcott and Keniston (2018), who find no evidence for the resource curse, where the resource is defined by the oil and gas reserves. But this result is consistent with Glaeser et al. (2015), who find that proximity to historical mines is associated with reduced entrepreneurship for cities in the 1970s and onward in industries unrelated to mining. The different types of resources considered could be an explanation.

5.3 Further Sensitivity Checks

In this subsection, we conduct further sensitivity checks to address a few potential concerns regarding to the baseline results.

We examine whether global mineral price shock directly affects local mining activity. We estimate equation 14 using the change in the absolute level of employment in the mining sector as the outcome variable. The results are stored in table A4. We find that spikes in mineral price increase employment in the local mining sector.

6 Mechanisms: What Makes Africa Different?

The results in Figure 2 and Figure 3 show that Africa/sub-Saharan Africa exhibits significantly different patterns of urbanization and structural transformation patterns in response to mineral price shocks compared to the rest of the world. The exceptionality of African cities raises a natural question: what factors make Africa so different? In this section, we first review the literature and summarize several hypotheses that might explain this phenomenon. We then merge our global mining, population, and industrial composition data set with country characteristics to test different hypotheses. Again, the global scale of our data set and the cross-country comparability feature distinguishes our paper from previous studies.

6.1 Hypotheses on Why Africa is Different

There is a growing interest in Africa due to its distinctive patterns of urbanization and industrialization. On the one hand, Gollin et al. (2016) argues the critical role played by natural resource exports, which are disproportionately spent on urban private services (induce urbanization), and also crowd out manufacturing by affecting exchange rates and wage costs (no industrialization). They provide country-level evidence to support their argument. On the other hand, Henderson and Kriticos (2018) and Henderson and Turner (2020) challenge this explanation because they find that increases in natural resource rents are not associated with increased urbanization in sub-Saharan Africa, when exploiting temporal variations on industrialization, urbanization, and resource exploitation together. Instead of emphasizing resource exports, they propose that low rural productivity in Africa is more likely to be the reason behind the phenomenon of "urbanization without industrialization." The fact that African countries have a low level of agricultural productivity by global standards is well documented (Adamopoulos and Restuccia, 2022; Suri and Udry, 2022). It is potentially highly relevant to the urbanization without industrialization phenomenon because low agricultural productivity implies a lower opportunity cost of moving out of agriculture and the rural areas. Therefore, farmers could be more responsive to positive labor demand shocks in the non-agricultural sector or in urban areas, such as the labor demand shocks created by mineral resource rents. We shed light on this debate by estimating how the city-level elasticity of population and industrial composition to mineral price changes varies with country-level resource reliance and agricultural productivity measures.

A few recent studies find that rural electrification could induce structural change and affect the migration patterns in developing countries (Fried and Lagakos, 2021) or in the early stage of economic development in developed countries (Vidart, 2022). From the perspective of labor supply, Porzio et al. (2022) pays special attention to the role of human capital growth in both mediating and driving the decline of agricultural employment share and structural transformation. To account for the potential effects of infrastructure and human capital levels on urbanization and structural change, we also estimate how country-level rural electrification rate and average years of schooling affect cities' responsiveness to mineral price shocks.

We retrieve four country-specific measures—each of which corresponds to one of the above four hypotheses—from the World Development Indicators. All four measures refer to the year 1970 [19]. We also use the number of mines in local city buffer zones to measure resource intensity at the city level. We then provide summary statistics of these five variables by country group in Table 5. We highlight four patterns.

First, sub-Saharan African cities have a relatively high level of resource intensity than South Asia, East Asia, and Europe, as proxied by the number of mines nearby the city. In contrast, the resource intensity of cities in North Africa and the Middle East is very low. But the ratio of natural resource exports to GDP in sub-Saharan Africa, North Africa, and the Middle East is the highest compared to the rest of the world. This is because our paper focuses exclusively on mineral resources but not on gas and oil, which are particularly

[19] These variables are available in 1970 for most of the countries (over 90%). For those who do not, we obtain these measures from the earliest year during the sample (before 2000). The results are robust if we only use these variables available in the year 1970.

abundant in North Africa and the Middle East.

Second, agricultural productivity is the lowest in Africa among all regions. In 1970, cereal yields per hectare in sub-Saharan Africa were only half those in Latin America and South Asia and less than one-third of those in Europe and North America.

Third, the level of access to electrification was the lowest in sub-Saharan Africa compared to other regions in 1970: only 20% of the population had access to electricity in sub-Saharan Africa, while this rate was at 37.57% in South Asia and was above 90% in the rest of the regions.

Fourth, sub-Saharan African countries had few years of schooling among the population aged 25 or above compared to the other regions in the 1970s. The average years of schooling were only 2.57 in sub-Saharan Africa, but it was ranked above South Asia, which had average years of schooling of only 1.67.

Overall, the above results show that there are dramatic differences in terms of resource intensity, natural resource export rate, agricultural productivity, access to electricity, and the level of human capital between Africa and the other regions. In the next subsection, we will assess whether these differences help explain the distinctive responsiveness of urbanization and structural transformation to resource rents in Africa compared to the rest of the world.

Table 5: Comparison Among Mechanism Variables

Region	Resource Intensity, # Mines Within 120 KM	Natural Resource Export, % of GDP	Cereal Yield, Kg Per Hectare	Access to Electricity, % of Population	Years of Schooling, Population 25+
sub-Saharan Africa	11.62	3.58	892.87	20.48	2.57
Middle East and North Africa	1.37	3.76	1278.72	90.46	4.18
Latin America and The Caribbean	14.47	2.32	1552.62	79.95	4.39
South Asia	2.12	0.09	1512.17	37.57	1.67
East Asia and Pacific	7.92	2.47	2212.27	74.47	5.51
Europe and Central Asia	9.69	2.67	2586.93	99.76	7.96
North America	12.87	2.05	2632.85	100.00	10.53

Notes: Natural resource export includes ores and metals export. Resource intensity is proxied by the number of mines within a radius of 120km around the city. Cereal yield, access to electricity, natural resource export, GDP, and education attainment are from World Development Indicators. We obtain these measures from the earliest year (before 2000) in which the variable is available during the sample period, i.e., in 1970 in most of the countries.

6.2 Testing the Different Hypotheses

To test different hypotheses, we estimate the regression specification below:

$$\begin{aligned}\Delta Y_{i,t} = {} & \beta_0 + \beta_1 \Delta \log price_{it}^R + \beta_2 \Delta \log price_{it}^R \times \mathbb{1}(country_{i,c} \in sub\text{-}Saharan\ Africa) \\ & + \beta_3 \Delta \log price_{it}^R \times \mathbb{1}(country_{i,c} \in North\ Africa) + \beta_4 \Delta \log price_{it}^R \times \omega_{i,c} \\ & + \alpha Y_{i,t}^{Initial} + \gamma \log NumMines_i^R + \lambda_c + \eta_{gt} + \epsilon_{i,t}\end{aligned} \tag{16}$$

where $\mathbb{1}(Country_{i,c} \in sub\text{-}Saharan\ Africa)$ and $\mathbb{1}(country_{i,c} \in North\ Africa)$ are dummy variables that equal to one if city i of country c belongs to the country group of sub-Saharan Africa or North Africa, respectively, and 0 otherwise. $\omega_{i,c}$ indicates the above-mentioned mechanism variables at the country or city level, which is measured in the closest initial year during the sample period. The coefficient β_1 captures the average effect of mineral price shocks for a typical, non-African city. The coefficient β_2 and β_3 are the differences in the price effect between (sub-Saharan and North) African cities and a typical non-African city (i.e., the price effect for a typical sub-Saharan African city is $\beta_1 + \beta_2$, and that for a typical North African city is $\beta_1 + \beta_3$). β_4 indicates whether each mechanism variable itself has an effect on the price elasticity.

Table 6 reports the estimation results using log changes in population within the 30 km city buffer zones as the outcome variable. Panel A and B use the 60 km and the 90 km buffer zones to locate the mines nearby the cities, respectively.[20] The mechanism variables are excluded from the regression in column (1) and are included one by one separately from column (2) to column (5). We highlight the following findings.

First, column (1) in both panels suggests that North Africa and sub-Saharan Africa behave very differently from the rest of the world: their urban population is significantly more responsive to changes in mineral prices, confirming the pattern observed in Figure 2. Take the results in Panel A as an example. The coefficient on *price change* is 0.001, which suggests that the population of the cities outside Africa is almost completely unresponsive to mineral price shocks. However, the coefficients on prices interacted with the North Africa dummy and the sub-Saharan Africa dummy are 0.213 and 0.132, respectively, both of which are statistically significant. This result suggests that the global average positive effects obtained in Table 3 are almost entirely driven by Africa.

Second, we examine the coefficients on prices interacted with the five mechanism vari-

[20] Here, we do not report the results using the 120 km buffer zones for mines because the baseline results in Table 3 and Figure 2 suggest that urban population growth is less affected by faraway mines.

Table 6: Price Shock and Population Change Within Cities: Mechanisms, City Buffer Zone = 30 KM

Mechanism	(1) Baseline	(2) Resource Intensity	(3) Natural Resource Export	(4) Agricultural Productivity	(5) Access to Electricity	(6) Human Capital
Panel A Mines' distance to city c <= 60KM						
Price Change * North Africa	0.213**	0.214**	0.269***	0.198**	0.211**	0.065
	(0.083)	(0.084)	(0.093)	(0.081)	(0.083)	(0.041)
Price Change * sub-Saharan Africa	0.132***	0.132***	0.125***	0.090**	0.108**	0.116*
	(0.046)	(0.046)	(0.045)	(0.046)	(0.047)	(0.062)
Price Change	0.001	0.001	0.004	0.022*	0.008	-0.001
	(0.010)	(0.010)	(0.010)	(0.012)	(0.012)	(0.010)
Price Change * Mechanism		0.000	0.016**	-0.033***	-0.012	0.005
		(0.004)	(0.007)	(0.007)	(0.011)	(0.006)
N	3,201	3,201	3,132	3,174	3,168	2,835
Panel B Mines' distance to city c <= 90KM						
Price Change * North Africa	0.161***	0.167***	0.177***	0.155***	0.161***	0.055*
	(0.053)	(0.053)	(0.055)	(0.052)	(0.053)	(0.030)
Price Change * sub-Saharan Africa	0.081**	0.079**	0.074**	0.052	0.059	0.061
	(0.035)	(0.035)	(0.035)	(0.036)	(0.039)	(0.039)
Price Change	-0.009	-0.008	-0.006	0.003	-0.003	-0.010
	(0.010)	(0.010)	(0.010)	(0.011)	(0.011)	(0.009)
Price Change * Mechanism		0.007**	0.012**	-0.023***	-0.011	0.002
		(0.003)	(0.006)	(0.006)	(0.009)	(0.005)
N	4,113	4,113	4,035	4,077	4,074	3,630

Notes: Table 6 reports estimated coefficients of equation 16. The dependent variables are delta log population density within a radius of 30km of the city. All mechanisms are measured in the baseline year and normalized to have a mean of 0 and a standard deviation of 1. All the regressions control for the initial log population density in the city, and the log number of mines. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

ables from column (2) to column (6). We find that only the coefficients on *price change* × *natural resource exports* and *price change* × *agricultural productvity* are robustly significant across Panels A and B. The coefficient on *price change* × *natural resource exports* is positive, suggesting that the cities in countries that rely more heavily on resource exports are more responsive to mineral price shocks. This result also echoes the consumption city hypothesis, which suggests the higher reliance on resource exports, the more resource rents would translate into an income effect, which, in turn, would induce demand-driven urbanization. The coefficient on *price change* × *agricultural productvity* is negative, suggesting that the cities in countries that have lower agricultural productivity are more responsive to mineral price shocks. As explained in Subsection 6.1, this pattern can be explained by the lower opportunity costs faced by farmers living in low-agricultural-productivity countries. On the other hand, the interactions between prices and the other three mechanism variables—resource intensity, access to electricity, and human capital—are all insignificant, indicating that these mechanisms have little potential to explain the different population elasticities to mineral price changes across regions.

Third, we focus on the coefficients on $price\ change \times North\ Africa$ and $price\ change \times sub - Saharan\ Africa$ and compare these coefficients across columns with the benchmark column (1). A reduction in magnitude and statistical significance indicates that the addition of the corresponding mechanism variable attenuates the effect of the region-specific price elasticity, thus showing the importance of the corresponding mechanism in explaining Africa's uniqueness. For North Africa, we find that among the five mechanism variables, only the inclusion of the human capital measure reduces the baseline price elasticity of North Africa—from 0.213 to 0.065. For sub-Saharan Africa, we find that the inclusion of agricultural productivity reduces the price elasticity by the largest degree—the coefficient drops from 0.132 to 0.090 in Panel A, and from 0.081 to 0.052 in Panel B, amounting to a 30% decrease in magnitude. This result suggests that among the four hypotheses, the opportunity cost hypothesis has the largest potential in explaining the unique urbanization patterns of sub-Saharan Africa.

Next, we turn to examine which mechanism best explains Africa's uniqueness in terms of structural change. We report the results in Table 7. For conciseness, we use the city buffer zone of 30 km and mine buffer zone of 120 km in the main text and present the robustness checks in the appendix. Again, due to the small sample size, we omit the North African observations as well as the regional dummy from the regressions. We summarize the main findings as follows.

First, as column (1) of Panel A shows, sub-Saharan Africa behaves very differently from the rest of the world in terms of the responsiveness of agricultural employment share to mineral price shocks, which confirms the pattern in Figure 3. Column (1) of Pane D also shows that the employment share in other service sectors in African cities are more responsive to mineral shocks compared to the rest of the world, although such a difference is not statistically significant.

Second, we turn to the interaction terms between mineral price changes and the mechanism measures. In column (4) across the four panels, we find that lower agricultural productivity escalates the effect of mining booms on structural transformation: following an increase in mineral prices, the agricultural employment share decreases by more, and em-

Table 7: Price Shock and Change in Employment Shares Within Cities: Mechanisms, City Buffer Zone = 30km, Mine Buffer Zone = 120km

Mechanism	(1) Baseline	(2) Resource Intensity	(3) Natural Resource Export	(4) Agricultural Productivity	(5) Access to Electricity	(6) Human Capital
Panel A Delta Change in Emp. Share of Agriculture						
Price Change * sub-Saharan Africa	-0.095***	-0.090**	-0.080**	-0.082**	-0.130***	-0.123***
	(0.036)	(0.036)	(0.040)	(0.036)	(0.037)	(0.029)
Price Change	-0.014***	-0.014***	-0.015***	-0.018***	-0.005	-0.014***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.004)
Price Change * Mechanism		-0.006***	-0.008	0.010**	-0.018***	0.003
		(0.002)	(0.007)	(0.005)	(0.006)	(0.003)
N	2,828	2,828	2,821	2,828	2,826	2,773
Panel B Delta Change in Emp. Share of Manufacture						
Price Change * sub-Saharan Africa	0.001	-0.002	-0.003	-0.007	0.005	0.001
	(0.006)	(0.006)	(0.007)	(0.007)	(0.009)	(0.006)
Price Change	0.003	0.003	0.003	0.006**	0.002	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Price Change * Mechanism		0.004***	0.002*	-0.006*	0.002	-0.004
		(0.001)	(0.001)	(0.004)	(0.003)	(0.003)
N	2,828	2,828	2,821	2,828	2,826	2,773
Panel C Delta Change in Emp. Share of High-Skilled Services						
Price Change * sub-Saharan Africa	0.005	0.005	-0.007	0.000	-0.000	0.009
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)
Price Change	0.001*	0.001*	0.003***	0.003***	0.003**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Price Change * Mechanism		0.001	0.007***	-0.004**	-0.003	0.002*
		(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
N	2,828	2,828	2,821	2,828	2,826	2,773
Panel D Delta Change in Emp. Share of Other Services						
Price Change * sub-Saharan Africa	0.026	0.015	0.030	-0.008	0.038	0.061**
	(0.029)	(0.030)	(0.031)	(0.030)	(0.031)	(0.025)
Price Change	0.031***	0.032***	0.031***	0.043***	0.028***	0.030***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.004)
Price Change * Mechanism		0.014***	-0.002	-0.026***	0.006	0.012***
		(0.002)	(0.006)	(0.006)	(0.007)	(0.004)
N	2,828	2,828	2,821	2,828	2,826	2,773

Notes: Table 7 reports estimated coefficients of equation 16. The dependent variables are delta changes in employment shares by industry within a radius of 30km of the city. The price change is the average log price change of mines located within a radius of 120km of the city. All mechanism variables are at the country level, except resource intensity which is at the city level and additionally controlled in Column (2). All mechanisms are measured in the baseline year and normalized to have a mean of 0 and a standard deviation of 1. All the regressions control for the initial employment share of agriculture, manufacturing, and mining within a radius of 30km of the city, and log the number of mines within a radius of 120km of the city. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

ployment shares in manufacturing and services increase by more. Higher resource intensity, better access to electrification, and a higher level of human capital also promotes the mining-related structural transformation, as shown in columns (2), (5), and (6).

Third, we examine whether these mechanisms attenuate the gap between sub-Saharan Africa and the other regions. We mainly focus on Panel A (agriculture) and Panel D (low-skilled services), since mining booms induce a labor reallocation from agriculture to low-skilled services in sub-Saharan African cities. Panel A shows that none of the five mechanism variables reduces the gap between SSA and the other regions in terms of structural transformation out of agriculture. Controlling access to electricity and the level of human capital, the gap becomes even greater, making the question of why SSA is different even more puzzling. On the other hand, Panel D shows that among these five mechanism variables, agricultural productivity has the largest effect in reducing the gap—controlling for this variable completely explains why African cities are more likely to switch to the low-skill service sector after experiencing positive mineral price shocks.

In summary, in this section, we have tested four major hypotheses of why Africa has experienced different urbanization and structural transformation patterns. The results so far lend the most favorable support to the low agricultural productivity/low opportunity cost hypothesis. However, a large portion of Africa's uniqueness is still unexplained, which calls for future studies.

7 Conclusion

Both urbanization and structural transformation are central topics in the studies of development and economic growth. While historically urbanization is accompanied by industrialization in developed countries, it does not recur in today's developing countries–especially those in sub-Saharan Africa, which experienced rapid urbanization but with little industrialization. In this paper, we study the role of resource rents in driving this diverging pattern of urbanization and structural transformation. We examine this question at the city level on a global scale, by combining several spatially granular data sets, including property-level mining data, population data layer, and population censuses microdata. We estimate the causal effect of mineral price shocks of nearby mines on the city population and the local industrial composition.

We have three key findings. First, we find a significant and positive effect of mineral price spikes on urbanization. Using a global sample, mining booms contribute to around 18% of the observed urban population growth for global cities during the period of 1975-2015. The effect is mainly found in African cities, where positive mineral shocks account for roughly 33% of the urban population growth in sub-Saharan Africa and 45% in North Africa.

Second, we show that mining booms nearby the city promote structural transformation out of agriculture in the city. Again, the effect is pronounced in African cities. In response to positive mineral price shocks, African cities experienced a particularly faster speed of labor reallocation out of agriculture and to low-skilled services than in the rest of the world. Taking the first finding together, we find that African cities indeed present a distinct pattern of resource-led urbanization and resource-led structural transformation.

Third, we study specifically how features by region may explain why African cities respond differently to mineral price spikes regarding urban population growth and industrial structure. Among the four characteristics we consider: resource reliance, agricultural productivity, access to electricity, and human capital, we find a significant role of agricultural productivity in explaining the distinct responsiveness of African cities to mineral price shocks. We show that the difference between sub-Saharan Africa and other regions in the world substantially diminishes after accounting for the role of agricultural productivity.

While our data sample is extensive and globally comparable, it is worth noting that we study the immediate effect of mining activity on local urbanization and structural transformation. Understanding the long-run impacts of resource-led urbanization and structural transformation will be important for thinking about the growth of cities and the process of development. Another interesting question is to understand the different implications for the economic growth of resource-led urbanization versus industry-led urbanization. We view these as a fruitful avenue for future research.

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Appendix on Resource Rents, Urbanization and Structural Transformation

Contents

A Model

A.1 Equilibrium

According to equation (4), (5)

$$L_a + L_m = \left[(p_m^* A_m)^{1/\alpha} + (p_a^* A_a)^{1/\alpha}\right] (p_s^r A_s^r)^{\frac{1}{\alpha}} L_s^r = \bar{A}^{\frac{1}{\alpha}} (p_s^r A_s^r)^{\frac{1}{\alpha}} L_s^r = 1 - L_s^r - L_s^u$$

we have

$$(p_s^r A_s^r)^{\frac{1}{\alpha}} = \frac{\bar{A}^{\frac{1}{\alpha}} L_s^r}{1 - L_s^r - L_s^u}$$

$$(p_s^u A_s^u)^{\frac{1}{\alpha}} = \frac{\bar{A}^{\frac{1}{\alpha}} L_s^u}{1 - L_s^r - L_s^u}$$

$$(p_s^r)^{\frac{1}{\alpha}} = (\frac{\bar{A}}{A_s^r})^{\frac{1}{\alpha}} \frac{L_s^r}{1 - L_s^r - L_s^u}$$

$$(p_s^u)^{\frac{1}{\alpha}} = (\frac{\bar{A}}{A_s^u})^{\frac{1}{\alpha}} \frac{L_s^u}{1 - L_s^r - L_s^u}$$

For the trade balance condition in the rural area,

$$(1-\eta)R + p_a^* Q_a = I^r - p_s^r Q_s^r = \frac{p_s^r Q_s^r}{\beta_s} - p_s^r Q_s^r$$

$$\beta_s (1-\eta) R + \beta_s (p_a^* A_a)^{\frac{1}{\alpha}} (p_s^r A_s^r)^{\frac{\alpha-1}{\alpha}} (L_s^r)^{1-\alpha} = (1-\beta_s) p_s^r A_s^r (L_s^r)^{1-\alpha}$$

$$\beta_s (1-\eta) R + \beta_s (p_a^* A_a)^{\frac{1}{\alpha}} \frac{\bar{A}^{\frac{\alpha-1}{\alpha}}}{(1 - L_s^r - L_s^u)^{\alpha-1}} = (1-\beta_s) \frac{\bar{A}}{(1 - L_s^r - L_s^u)^{\alpha}} L_s^r$$

$$\beta_s (1-\eta) R (1 - L_s^r - L_s^u)^{\alpha} + \beta_s (p_a^* A_a)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}} (1 - L_s^r - L_s^u) = (1-\beta_s) \bar{A} L_s^r \tag{A1}$$

Similar for the trade balance condition in the urban area,

$$\eta R + p_m^* Q_m = I^u - p_s^u Q_s^u = \frac{p_s^u Q_s^u}{\beta_s} - p_s^u Q_s$$

$$\beta_s \eta R + \beta_s (p_m^* A_m)^{\frac{1}{\alpha}} (p_s^r A_s^r)^{\frac{\alpha-1}{\alpha}} (L_s^r)^{1-\alpha} = (1-\beta_s) p_s^u A_s^u (L_s^u)^{1-\alpha}$$

$$\beta_s \eta R + \beta_s (p_m^* A_m)^{\frac{1}{\alpha}} \frac{\bar{A}^{\frac{\alpha-1}{\alpha}}}{(1 - L_s^r - L_s^u)^{\alpha-1}} = (1 - \beta_s) \frac{\bar{A}}{(1 - L_s^r - L_s^u)^{\alpha}} (L_s^u)$$

$$\beta_s \eta R (1 - L_s^r - L_s^u)^{\alpha} + \beta_s (p_m^* A_m)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}} (1 - L_s^r - L_s^u) = (1 - \beta_s) \bar{A} L_s^u \tag{A2}$$

A.2 Comparative Statics

Labor share of service in rural and urban area w.r.t resource rent R

Adding equation (A1) and (A2),

$$\beta_s R (1 - L_s^r - L_s^u)^{\alpha} + \beta_s \bar{A} (1 - L_s^r - L_s^u) = (1 - \beta_s) \bar{A} (L_s^u + L_s^r)$$

$$\beta_s R (1 - L_s)^{\alpha} + \beta_s \bar{A} = \bar{A} L_s \tag{A3}$$

$$\partial L_s / \partial R = \frac{\beta_s (1 - L_s)^{\alpha}}{\alpha \beta_s R (1 - L_s)^{\alpha-1} + \bar{A}} > 0 \tag{A4}$$

Labor share of service in rural area w.r.t resource rent R

Let $\lambda_a = (\frac{p_a^* A_a}{\bar{A}})^{\frac{1}{\alpha}}$ and $\lambda_m = (\frac{p_m^* A_m}{\bar{A}})^{\frac{1}{\alpha}}$, $\lambda_a + \lambda_m = 1$

$$\begin{aligned}
\partial L_s^r / \partial R &= \frac{1}{(1 - \beta_s)\bar{A}} (\beta_s (1 - \eta)(1 - L_s)^{\alpha} - (\beta_s (1 - \eta) R \alpha (1 - L_s)^{\alpha-1} + \beta_s (p_a^* A_a)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}})(\partial L_s / \partial R)) \\
&= \frac{\beta_s (1 - L_s)^{\alpha}}{(1 - \beta_s)\bar{A}} ((1 - \eta) - (\beta_s (1 - \eta) R \alpha (1 - L_s)^{\alpha-1} + \beta_s (p_a^* A_a)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}}) \frac{1}{\alpha \beta_s R (1 - L_s)^{\alpha-1} + \bar{A}}) \\
&= \frac{\beta_s (1 - L_s)^{\alpha}}{(1 - \beta_s)(\alpha \beta_s R (1 - L_s)^{\alpha-1} + \bar{A})} (1 - \eta - \beta_s \lambda_a) \\
&= \frac{1 - \eta - \beta_s \lambda_a}{1 - \beta_s} (\partial L_s / \partial R)
\end{aligned}$$

Labor share of service in urban area w.r.t resource rent R

$$\begin{aligned}
\partial L_s^u / \partial R &= \frac{1}{(1 - \beta_s)\bar{A}} (\beta_s \eta (1 - L_s^r - L_s^u)^{\alpha} - (\beta_s \eta R \alpha (1 - L_s^r - L_s^u)^{\alpha-1} + \beta_s (p_m^* A_m)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}})(\partial L_s / \partial R)) \\
&= \frac{\beta_s (1 - L_s)^{\alpha}}{(1 - \beta_s)\bar{A}} (\eta - (\beta_s \eta R \alpha (1 - L_s)^{\alpha-1} + \beta_s (p_m^* A_m)^{\frac{1}{\alpha}} \bar{A}^{\frac{\alpha-1}{\alpha}}) \frac{1}{\alpha \beta_s R (1 - L_s)^{\alpha-1} + \bar{A}}) \\
&= \frac{\beta_s (1 - L_s)^{\alpha}}{(1 - \beta_s)(\alpha \beta_s R (1 - L_s)^{\alpha-1} + \bar{A})} (\eta - \beta_s \lambda_m) \\
&= \frac{\eta - \beta_s \lambda_m}{1 - \beta_s} (\partial L_s / \partial R)
\end{aligned}$$

When $0 < \eta < \beta_s \lambda_m$, $\partial L_s^u / \partial R < 0$ and $\partial L_s^r / \partial R > 0$.

When $\beta_s\lambda_m < \eta < 1 - \beta_s + \beta_s\lambda_m$, $\partial L_s^u/\partial R > 0$ and $\partial L_s^r/\partial R > 0$.

When $\eta > 1 - \beta_s + \beta_s\lambda_m$, $\partial L_s^u/\partial R > 0$ and $\partial L_s^r/\partial R < 0$.

Labor share of agriculture w.r.t resource rent R

$$\partial L_a/\partial R = -\lambda_a(\partial L_s/\partial R) < 0$$

Labor share of manufacturing w.r.t resource rent R

$$\partial L_m/\partial R = -\lambda_m(\partial L_s/\partial R) < 0$$

Urbanization rate w.r.t resource rent R

$$\begin{aligned}
\partial U/\partial R &= -\lambda_m(\partial L_s/\partial R) + \partial L_s^u/\partial R \\
&= -\lambda_m(\partial L_s/\partial R) + \frac{\eta - \beta_s\lambda_m}{1-\beta_s}(\partial L_s/\partial R) \\
&= \frac{\eta - \lambda_m}{1-\beta_s}(\partial L_s/\partial R)
\end{aligned}$$

$\partial U/\partial R > 0$ if $\eta > \lambda_m$. That is to say, when most of the avenue from the natural resource is distributed to the urban area, the urbanization rate U is increasing with total resource rent R.

A.3 The Role of Agricultural Productivity

First, start from equation (A3), it is easy to show that

$$\frac{\partial L_s}{\partial A_a} < 0$$

and

$$\beta_s < L_s < 1$$

For the urbanization rate,

$$\begin{aligned}
\partial U/\partial R &= \frac{\eta-\lambda_m}{1-\beta_s}(\partial L_s/\partial R) \\
&= \frac{\eta-\lambda_m}{1-\beta_s}\frac{\beta_s(1-L_s)^\alpha}{\alpha\beta_s R(1-L_s)^{\alpha-1}+\bar{A}} \\
&= \frac{\eta-\lambda_m}{1-\beta_s}\frac{1}{\frac{\alpha R}{1-L_s}+\frac{\bar{A}}{\beta_s(1-L_s)^\alpha}} \\
&= \frac{\eta-\lambda_m}{1-\beta_s}\frac{1}{\frac{\alpha R}{1-L_s}+\frac{R}{L_s-\beta_s}} \\
&= \frac{(\eta-\lambda_m)(1-L_s)(L_s-\beta_s)}{(1-\beta_s)(\alpha R(L_s-\beta_s)+R(1-L_s))} \\
&= \frac{(\lambda_m-\eta)(L_s-1)(L_s-\beta_s)}{(1-\beta_s)((\alpha-1)RL_s+R(1-\alpha\beta_s))}
\end{aligned}$$

(1) With the increase of A_a, L_s is decreasing, so $(\alpha-1)RL_s$ is increasing, and $\frac{1}{(1-\beta_s)((\alpha-1)RL_s+R(1-\alpha\beta_s))} > 0$ is decreasing.

(2) With the increase of A_a, λ_m is decreasing, so $\lambda_m-\eta$ is decreasing.

So to show that

$$\frac{\partial U/\partial R}{\partial A_a} < 0$$

we just to show

$$\frac{\partial((L_s-1)(L_s-\beta_s))}{\partial A_a} < 0 \tag{A5}$$

Since $(L_s-1)(L_s-\beta_s)$ is decreasing with L_s when $L_s < \frac{\beta_s+1}{2}$, and increasing with L_s when $L_s > \frac{\beta_s+1}{2}$, and $\frac{\partial L_s}{\partial A_a} < 0$.

The condition (A5) will be satisfied if $L_s > \frac{\beta_s+1}{2}$. This is equal to

$$\beta_s R(1-\frac{\beta_s+1}{2})^\alpha + \beta_s\bar{A} > \bar{A}\frac{\beta_s+1}{2}$$

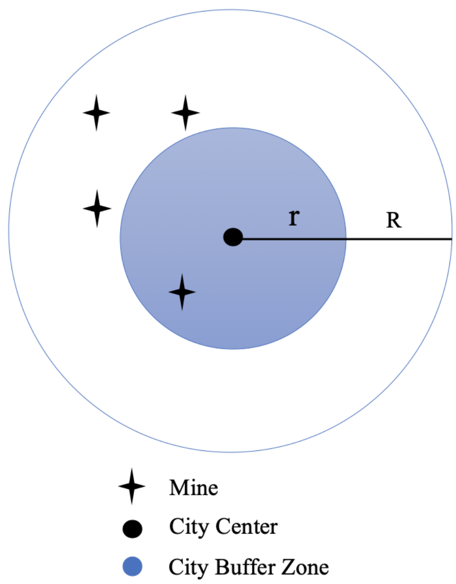
$$R > \bar{A}(\frac{1-\beta_s}{2})^{1-\alpha}\frac{1}{\beta_s}$$

That is to say, when resource rent R is quite high, the higher productivity is, and the urbanization rate is less sensitive to the increase of resource rent.

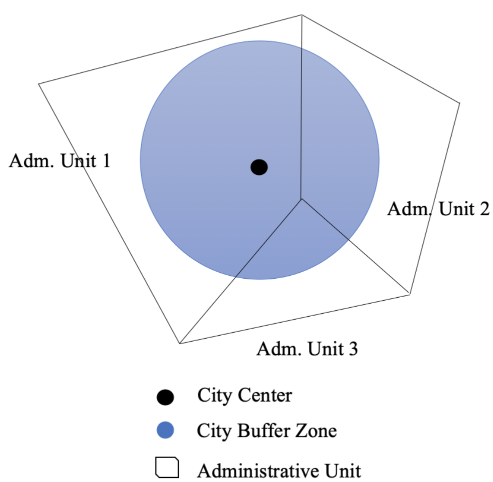
B Data

B.1 Data Match Process

Figure A1: An Illustration of Data Matching Process



(a) Match Mines with Cities



(b) Match IPUMS with Cities

Notes: Figure A1 shows the data matching process. Panel A shows how to map mining sites with cities. Panel B shows how to calculate employment by industry within city buffer zones.

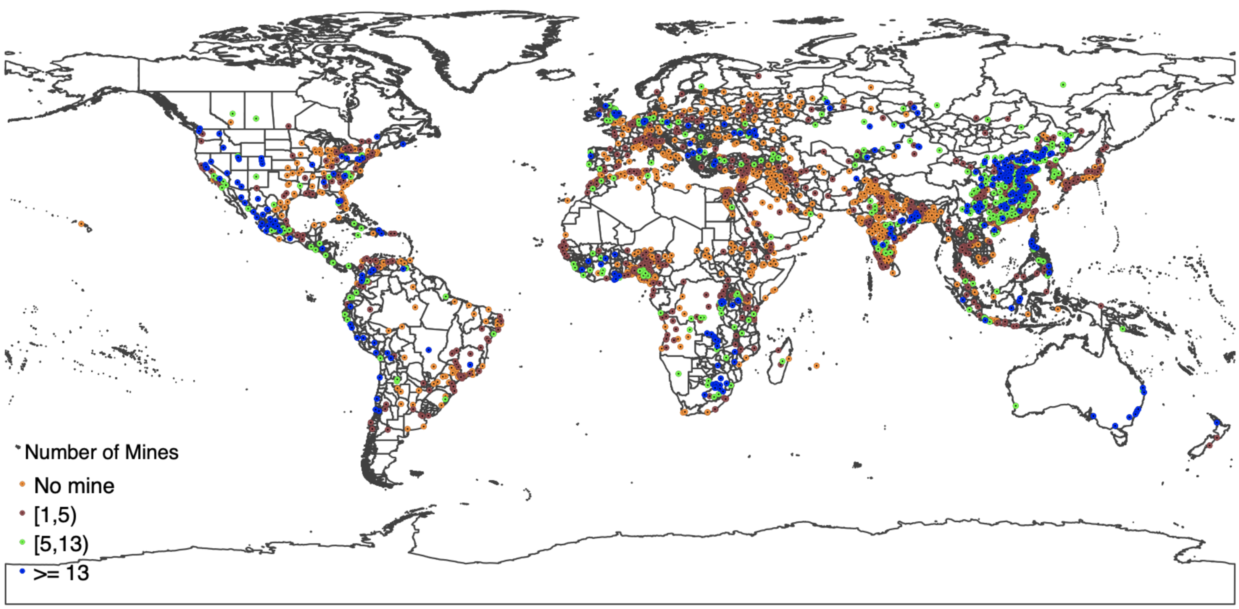
B.2 Mining Sites Data

Table A1: Data Source of Price Series and Number of Mining Sites By Mineral

	Commodity	Price Series Range		Number of Mines	Source
		First Year	Last Year		
1	Antimony	1970	2015	50	USGS
2	Chromium	1970	2015	7	USGS
3	Coal	1970	2015	5,163	World Bank
4	Cobalt	1970	2015	36	USGS
5	Copper	1970	2015	4,249	World Bank
6	Diamonds	1970	2015	1,437	USGS
7	Gold	1970	2015	12,835	World Bank
8	Ilmenite	1970	2015	141	USGS
9	IronOre	1970	2015	1,853	World Bank
10	Lead	1970	2015	250	World Bank
11	Lithium	1970	2015	192	USGS
12	Manganese	1970	2015	197	USGS
13	Molybdenum	1970	2015	301	USGS
14	Nickel	1970	2015	1,172	World Bank
15	Phosphate	1970	2015	267	USGS
16	Platinum	1970	2015	326	World Bank
17	Potash	1970	2015	190	USGS
18	Silver	1970	2015	1,066	World Bank
19	Tantalum	1970	2015	71	USGS
20	Tin	1970	2015	216	World Bank
21	Titanium	1970	2015	26	USGS
22	Tungsten	1970	2015	130	USGS
23	Vanadium	1970	2015	47	USGS
24	Zinc	1970	2015	965	World Bank

Notes: Calculated by authors.

Figure A2: The Spatial Distribution of Cities and Mines



Notes: Figure A2 plots the distribution of cities in the global range (N = 2041), and the number of mines within the radius of 90km of the city center.

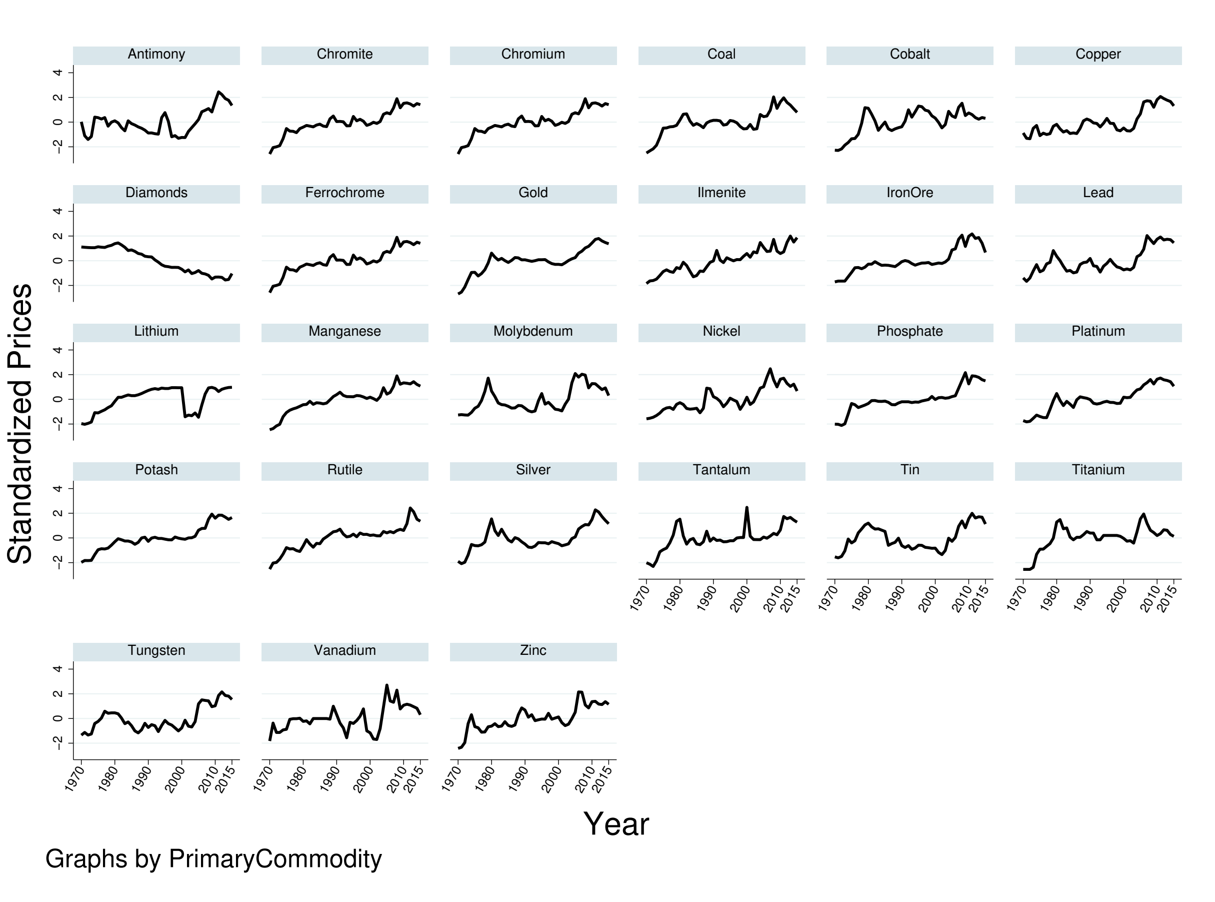
Table A2: Number of Mining Sites Nearby the City By Region

	Mines' largest distance to city center							
	30km		60km		90km		120km	
	#Cities	#Mines	#Cities	#Mines	#Cities	#Mines	#Cities	#Mines
sub-Saharan Africa	291	4.732	489	9.215	636	13.962	723	19.942
Middle East and North Africa	63	1.286	126	1.762	225	2.16	333	2.793
Latin America and Caribbean	234	3.385	363	7.017	450	11.56	528	16.301
South Asia	93	4.742	165	7.782	261	9.644	363	11.132
East Asia	828	3.768	1,422	6.325	1,701	10.612	1,803	16.624
Europe and Central Asia	255	4.4	426	6.887	546	10.038	651	13.028
North America	81	2.778	210	6.7	294	11.796	357	18.832
All	1,845	3.88	3,201	6.840	4,113	10.718	4,758	15.379

Notes: Calculated by authors. #Cities is the number of cities that have at least one mining site in the corresponding nearby areas. #Mines is the average number of mining sites for cities that have at least one mining site in the corresponding nearby areas.

B.3 Mineral Price Data

Figure A3: Standardized Price Series for 24 Minerals: 1970-2015



Notes: All prices are in logarithm, and standardized to have a mean of 0 and a standard deviation of 1.

B.4 IPUMS Data

Table A3: Samples from IPUMS

Country	Year	Country	Year
Argentina	1970, 1980, 1991,2001	Kyrgyz Republic	1999, 2009
Armenia	2001, 2011	Liberia	1974, 2008
Austria	1971, 1981, 1991, 2001, 2011	Malawi	1998, 2008
Bangladesh	1977, 1999, 2004, 2009	Malaysia	1970, 1980, 1991, 2000
Belarus	2002, 2009	Mali	1987, 1998, 2009
Belgium	1975, 1982, 1990, 1999, 2006, 2011	Mauritius	1990, 2000, 2011
Benin	1979, 1992, 2002, 2013	Mexico	1970, 1990, 1995, 2000, 2005, 2010, 2015
Bolivia	1976, 1992, 2001, 2012	Mozambique	1997, 2007
Botswana	2001, 2007	Nepal	2001, 2011
Brazil	1970, 1980, 1991, 2000, 2010	Nicaragua	1971, 1995, 2005
Cambodia	1998, 2004, 2008, 2013	Palestine	1997, 2007, 2017
Canada	1971, 1981, 1991, 2001, 2011	Panama	1970, 1980, 1990, 2000, 2010
Chile	1982, 1992, 2002, 2017	Papua New Guinea	1980, 2000
China	1982, 1990, 2000	Paraguay	1972, 1982, 1992, 2002
Colombia	1973, 1993, 2005	Peru	1993, 2007
Costa Rica	1973, 1984, 2000, 2011	Philippines	1990, 1995, 2000, 2010
Cuba	2002, 2012	Portugal	1981, 1991, 2001, 2011
Dominican Republic	1970, 1981, 2010	Puerto Rico	1980, 1990, 2000, 2005, 2010
Ecuador	1982, 1990, 2001, 2010	Romania	1977, 1992, 2002, 2011
Egypt	1986, 1996, 2006	Russia	2002, 2010
El Salvador	1992, 2007	Rwanda	2002, 2012
Ethiopia	1994, 2007	Senegal	1988, 2013
Fiji	1976, 1986, 1996, 2007, 2014	Slovak Republic	1991, 2001, 2011
France	1975, 1982, 1990, 1999, 2006, 2011	South Africa	2001, 2007
Germany	1970, 1971, 1981, 1987	Spain	1981, 1991, 2001, 2011
Ghana	1984, 2000, 2010	Suriname	2004, 2012
Greece	1971, 1981, 1991, 2001, 2011	Switzerland	1970, 1980, 1990, 2000
Guatemala	1973, 1981, 1994, 2002	Tanzania	2002, 2012
Guinea	1983, 2014	Thailand	1970, 1980, 1990, 2000
Haiti	1982, 2003	Togo	1970, 2010
Honduras	1974, 1988, 2001	Trinidad and Tobago	1980, 1990, 2000
India	1987, 1999, 2004, 2009	Turkey	1985, 1990, 2000
Indonesia	1971, 1976, 1980, 1985, 1990, 1995, 2000, 2005, 2010	United Kingdom	1991, 2001
Iran	2006, 2011	Uruguay	1963, 1985, 1996, 2006
Ireland	1971, 1981, 1986, 1991, 1996, 2002, 2006, 2011, 2016	United States	1970, 1980, 1990, 2000, 2005, 2010, 2015
Italy	2001, 2011	Venezuela	1981, 1990, 2001
Jamaica	1982, 1991, 2001	Vietnam	1989, 1999, 2009
Kenya	1979, 1989, 1999, 2009	Zambia	1990, 2000, 2010

Notes: India samples come from India 0.09% socio-economic survey data, provided by IPUMS.

C Result

C.1 Mining Boom and Mining Sector Expansion

Table A4: Price Shock and Mining Sector Within Cities: Global Analysis

	(1)	(2)
	Outcome = Delta Log Employment in Mining Sector	
Mines' largest distance to city center	60km	120km
Panel A City buffer zone = 30 km		
Price Change	0.322***	0.316***
	(0.078)	(0.061)
Fixed Effect	Country group * period, country	
N	1,873	2,729
adj. R2	0.344	0.342
Panel B City buffer zone = 60 km		
Price Change	0.301***	0.345***
	(0.083)	(0.068)
Fixed Effect	Country group * period, country	
N	1,953	2,901
adj. R2	0.432	0.412

Notes:Table A4 reports coefficients of equation 14. The dependent variables are delta log changes in employment of the mining sector within the radius of 30km of the city (Panel A) or 60 km (Panel B). All the regressions control for the log number of mines (buffer zone same as it for price shock) and initial log employment in the mining sector (buffer zone same as it for dependent variable). All regressions control for country group × period fixed effects and country fixed effects. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

C.2 Robustness Checks

C.2.1 Mining Boom and Urbanization: Global

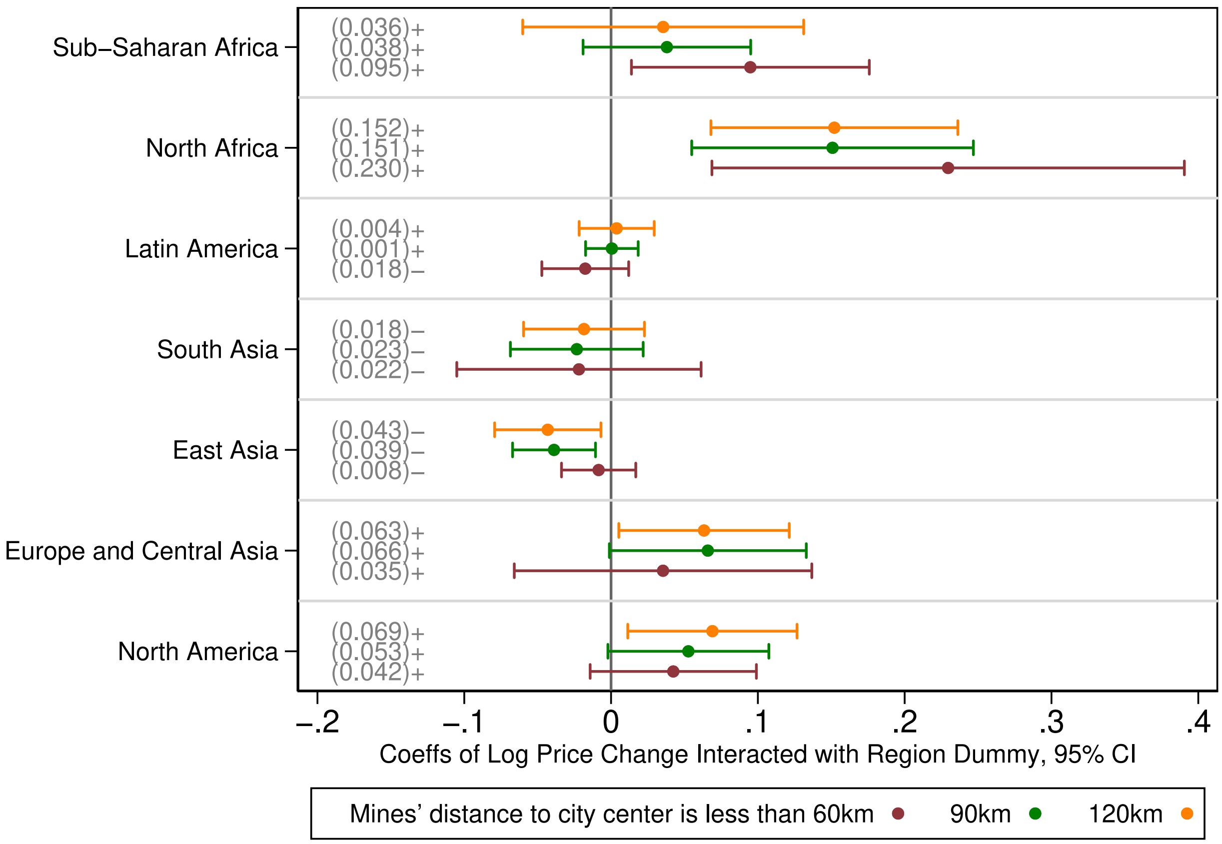
Table A5: Price Shock and Population Change: Global Analysis, Robustness Checks

	(1)	(2)	(3)	(4)
	Delta Log Population Density			
Mines' largest distance to city center	30km	60km	90km	120km
Panel A Cities With and Without Mines				
Price Change	0.013*	0.020***	0.014**	0.017*
	(0.007)	(0.007)	(0.007)	(0.009)
N	6,123	6,123	6,123	6,123
Panel B City Buffer Zone = 50 KM				
Price Change	0.038**	0.036**	0.016	0.024
	(0.018)	(0.014)	(0.011)	(0.017)
N	1,845	3,201	4,113	4,758
Panel C Only Cities from WUP 2018				
Price Change	0.036*	0.031*	0.017	0.028*
	(0.020)	(0.016)	(0.012)	(0.015)
N	1,725	2,973	3,807	4,374
Panel D Cities from WUP 2018 and African Cities With Population Threshold Above 100K				
Price Change	0.039**	0.038***	0.026**	0.032**
	(0.017)	(0.014)	(0.012)	(0.015)
N	2,154	3,765	4,842	5,643
Panel E Country * Period FE				
Price Change	0.039**	0.037**	0.015	0.018
	(0.019)	(0.017)	(0.013)	(0.020)
N	1,728	3,072	3,969	4,626
Panel F Spatial Correlation				
Price Change	0.041**	0.042**	0.023	0.029
	(0.020)	(0.019)	(0.016)	(0.018)
N	1,845	3,201	4,113	4,758

Notes: Table A5 reports regression coefficients of equation 14. The dependent variables are delta log population density within the radius of 30km of the city, except in Panel B which is 50 km. All the regressions control for the log number of mines (buffer zone same as it for price shock) and initial population density (buffer zone same as it for dependent variable). All regressions control for country group × period fixed effects and country fixed effects, except in Panel E which controls for country × period fixed effects. Standard errors in parentheses are clustered at the city level, except in Panel F which is Conley (1999) standard errors in parentheses allowing for spatial correlation within a 500 km radius and for infinite serial correlation. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

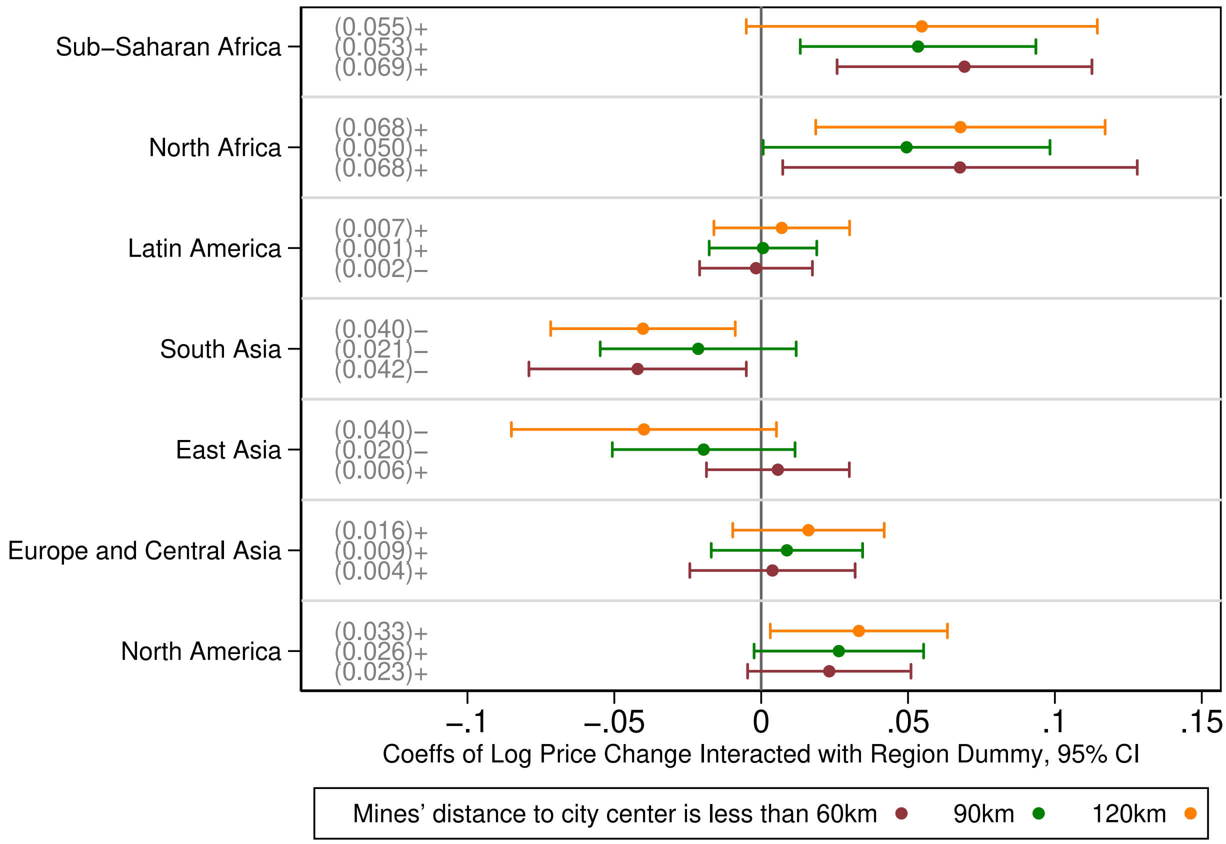
C.2.2 Mining Boom and Urbanization: Regional

Figure A4: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 60KM



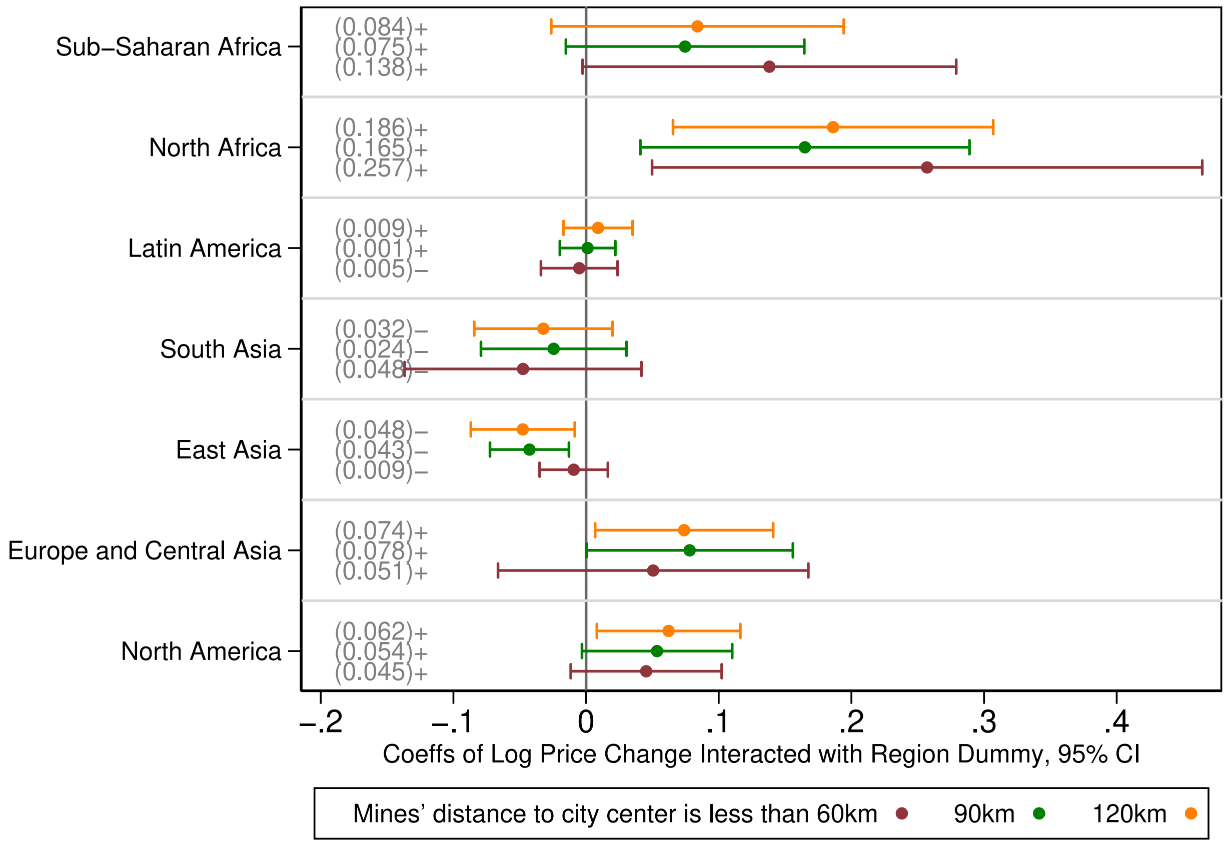
Notes: Figure A4 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta log population density within a radius of 60km of the city. All the regressions control for initial log population density in the city, log number of mines within the radius of 60km (Red), 90km (Green) or 120km (Orange) of the city, country group × period fixed effects, and country fixed effects. Standard errors are clustered at the city level.

Figure A5: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 30KM, Cities with and without Mines



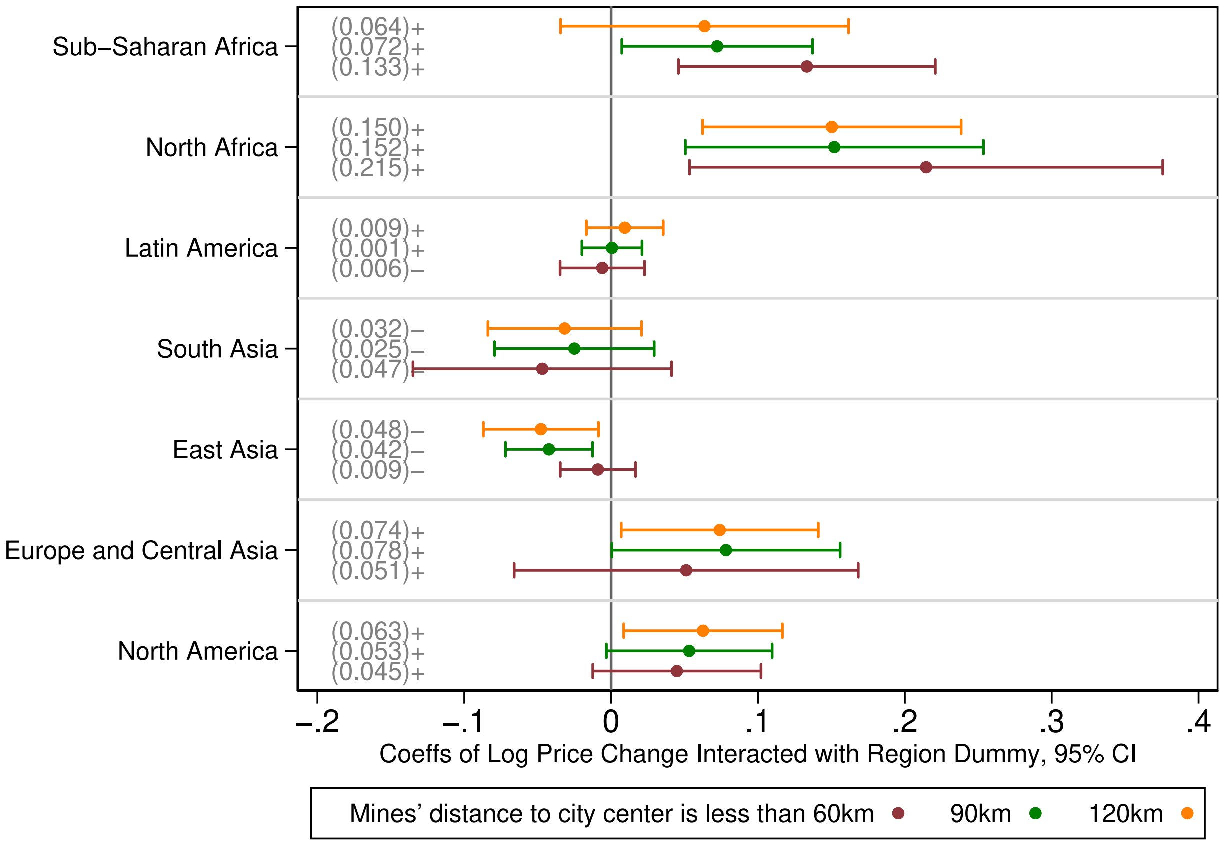
Notes: Figure A5 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample includes cities without mines in their nearby areas. The dependent variables are delta log population density within a radius of 30km of the city. All the regressions control for initial log population density in the city, log number of mines (plus 1) within the radius of 60km (Red), 90km (Green), or 120km (Orange) of the city, country group × period fixed effects, and country fixed effects. Standard errors are clustered at the city level.

Figure A6: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 30KM, Only Cities from WUP 2018



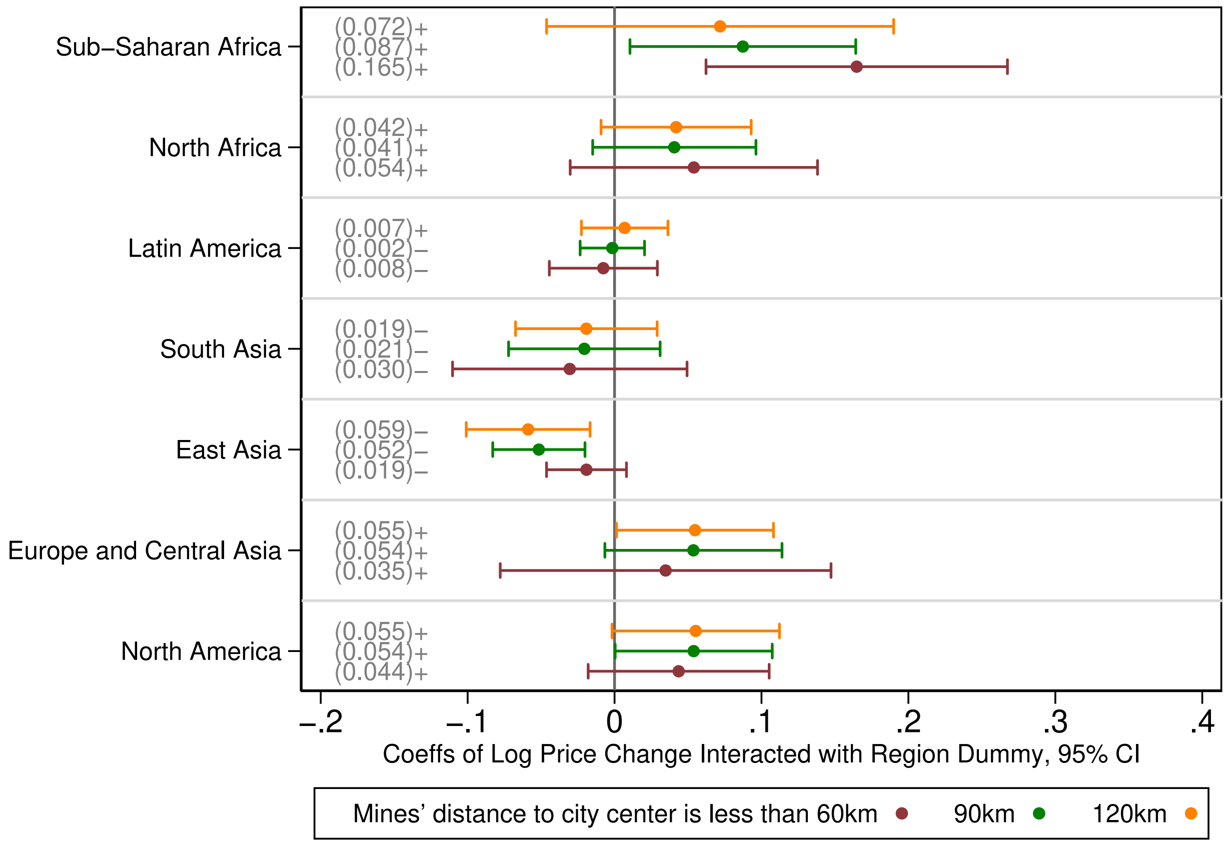
Notes: Figure A6 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample only includes cities from WUP 2018. The dependent variables are delta log population density within a radius of 30km of the city. All the regressions control for initial log population density in the city, log number of mines within the radius of 60km (Red), 90km (Green), or 120km (Orange) of the city, country group × period fixed effects, and country fixed effects. Standard errors are clustered at the city level.

Figure A7: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 30KM, Cities from WUP 2018 and African Cities with Population Threshold Above 100K



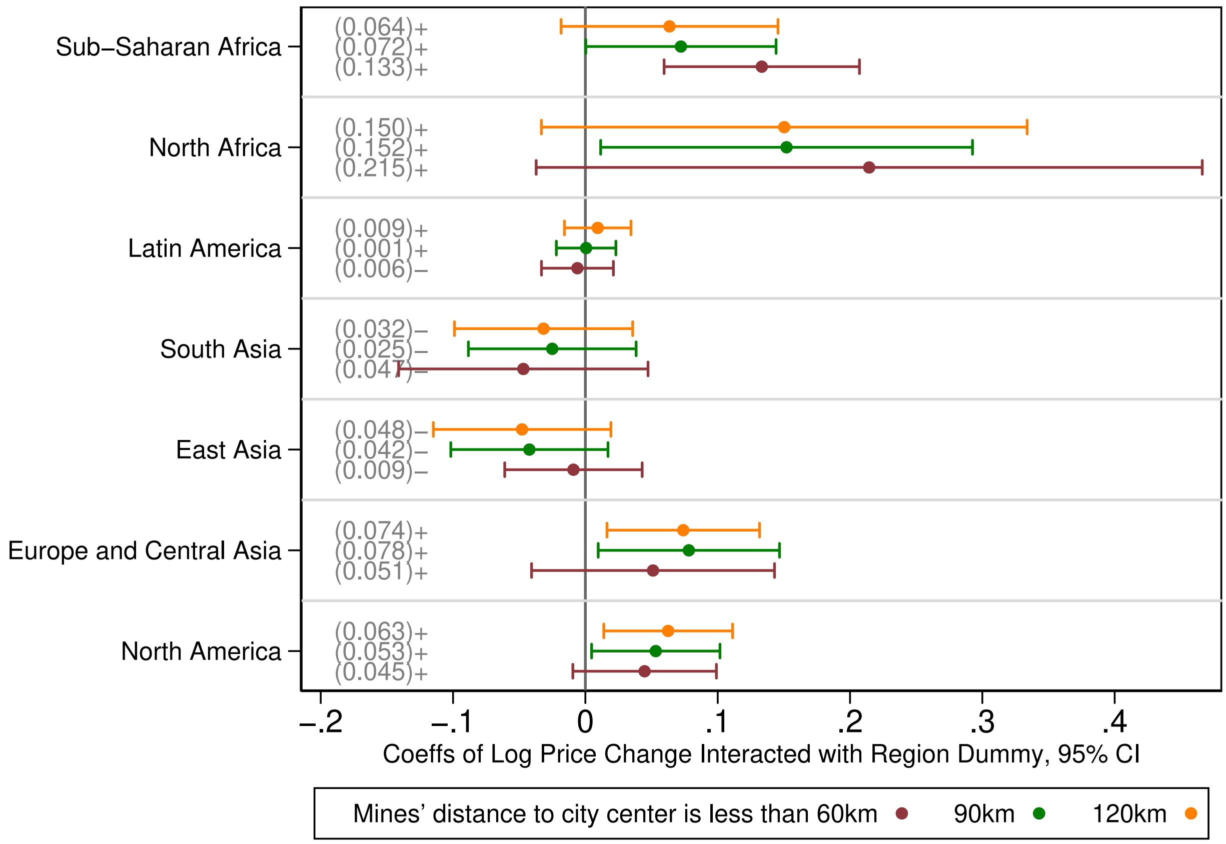
Notes: Figure A7 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample includes cities from WUP 2018 and African cities with a population threshold above 300K. The dependent variables are delta log population density within a radius of 30km of the city. All the regressions control for initial log population density in the city, log number of mines within the radius of 60km (Red), 90km (Green), or 120km (Orange) of the city, country group × period fixed effects, and country fixed effects. Standard errors are clustered at the city level.

Figure A8: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 30KM, Country*Period FE



Notes: Figure A8 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta log population density within a radius of 30km of the city. All the regressions control for initial log population density in the city, log number of mines within the radius of 60km (Red), 90km (Green), or 120km (Orange) of the city, and country × period fixed effects. Standard errors are clustered at the city level.

Figure A9: The Effect of Price Change on Population Change: Regional Heterogeneity, City Buffer Zone = 30KM, Spatial Correlation



Notes: Figure A9 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta log population density within a radius of 30km of the city. All the regressions control for initial log population density in the city, log number of mines within the radius of 60km (Red), 90km (Green), or 120km (Orange) of the city, country group × period fixed effects, and country fixed effects. Standard errors are Conley (1999) style allowing for spatial correlation within a 500 km radius and for infinite serial correlation.

C.2.3 Mining Boom and Structural Transformation: Global

Table A6: Price Shock and Change in Employment Shares Within Cities: Global Analysis, City Buffer Zone = 30KM, Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Outcome = Delta Change in Employment Share of									
	Agriculture		Manufacture		High-Skilled Services		Other Services		Not Recorded	
Mines' largest distance to city center	60km	120km	60km	120km	60km	120km	60km	120km	60km	120km
Panel A Cities With and Without Mines										
Price Change	-0.012***	-0.016***	0.005***	0.004*	0.002***	0.002**	0.027***	0.032***	-0.021***	-0.021***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
N	3,598	3,598	3,598	3,598	3,598	3,598	3,598	3,598	3,598	3,598
Panel B Only Cities from WHP 2018										
Price Change	-0.012***	-0.015***	0.001	0.003	0.002**	0.002**	0.029***	0.031***	-0.019***	-0.021***
	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
N	1,894	2,815	1,894	2,815	1,894	2,815	1,894	2,815	1,894	2,815
Panel C Cities from WHP 2018 and African Cities With Population Threshold Above 100K										
Price Change	-0.014***	-0.017***	0.001	0.003	0.002**	0.002**	0.028***	0.032***	-0.017***	-0.019***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
N	2,063	3,086	2,063	3,086	2,063	3,086	2,063	3,086	2,063	3,086
Panel D Country * Period FE										
Price Change	-0.014***	-0.017***	0.001	0.001	0.001**	0.001	0.017***	0.022***	-0.005**	-0.007***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.003)	(0.002)
N	1,909	2,872	1,909	2,872	1,909	2,872	1,909	2,872	1,909	2,872
Panel E Spatial Correlation										
Price Change	-0.014**	-0.016***	0.001	0.003	0.002	0.002	0.029***	0.032***	-0.018***	-0.020***
	(0.006)	(0.006)	(0.003)	(0.004)	(0.001)	(0.001)	(0.008)	(0.007)	(0.006)	(0.006)
N	1,954	2,926	1,954	2,926	1,954	2,926	1,954	2,926	1,954	2,926
Panel F Drop Canada										
Price Change	-0.015***	-0.016***	0.002	0.002	0.001	0.001	0.032***	0.034***	-0.019***	-0.020***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
N	1,899	2,862	1,899	2,862	1,899	2,862	1,899	2,862	1,899	2,862
Panel G Drop Census with Only Geolev1 Available										
Price Change	-0.015***	-0.018***	0.002	0.003	0.001	-0.000	0.035***	0.038***	-0.021***	-0.022***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.004)	(0.005)	(0.003)
N	1,833	2,725	1,833	2,725	1,833	2,725	1,833	2,725	1,833	2,725

Notes:Table A6 reports coefficients of equation 14. The dependent variables are delta changes in employment shares by industry within a radius of 30km of the city. All the regressions control for the log number of mines (buffer zone same as it for price shock) and initial employment share of agriculture, manufacturing, and mining (buffer zone same as it for dependent variable). All regressions control for country group × period fixed effects and country fixed effects, except in Panel D which controls for country × period fixed effects. Standard errors in parentheses are clustered at the city level, except in Panel E which is Conley (1999) standard errors in parentheses allowing for spatial correlation within a 500 km radius and for infinite serial correlation. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

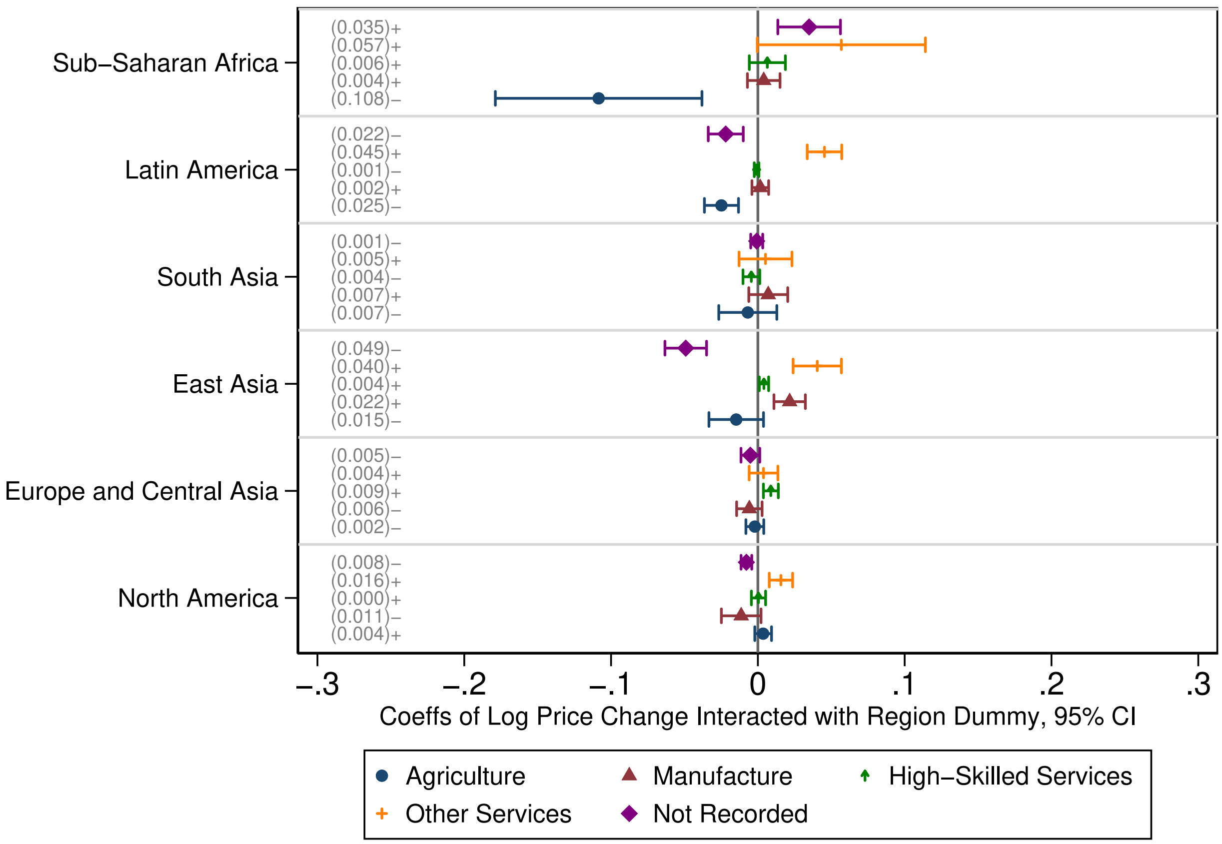
Table A7: Price Shock and Change in Employment Shares Within Cities: Global Analysis, City Buffer Zone = 60KM, Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Outcome = Delta Change in Employment Share of									
	Agriculture		Manufacture		High-Skilled Services		Other Services		Not Recorded	
Mines' largest distance to city center	60km	120km	60km	120km	60km	120km	60km	120km	60km	120km
Panel A Cities With and Without Mines										
Price Change	-0.012***	-0.016***	0.003**	0.002	0.003***	0.003***	0.027***	0.031***	-0.020***	-0.019***
	(0.004)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.003)	(0.002)
N	3,796	3,796	3,796	3,796	3,796	3,796	3,796	3,796	3,796	3,796
Panel B Only Cities from WHP 2018										
Price Change	-0.009**	-0.015***	0.001	0.001	0.003**	0.003***	0.027***	0.030***	-0.021***	-0.019***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.004)	(0.003)
N	1,976	2,947	1,976	2,947	1,976	2,947	1,976	2,947	1,976	2,947
Panel C Cities from WHP 2018 and African Cities With Population Threshold Above 100K										
Price Change	-0.013***	-0.020***	0.001	0.002	0.003**	0.003***	0.027***	0.033***	-0.018***	-0.017***
	(0.004)	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.003)	(0.002)
N	2,177	3,256	2,177	3,256	2,177	3,256	2,177	3,256	2,177	3,256
Panel D Country * Period FE										
Price Change	-0.006	-0.013***	-0.001	-0.001	0.002*	0.002**	0.012***	0.019***	-0.006***	-0.007***
	(0.005)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.003)	(0.002)	(0.002)
N	1,979	2,997	1,979	2,997	1,979	2,997	1,979	2,997	1,979	2,997
Panel E Spatial Correlation										
Price Change	-0.011	-0.017***	0.001	0.002	0.003*	0.003*	0.027***	0.031***	-0.020***	-0.018***
	(0.007)	(0.006)	(0.003)	(0.004)	(0.002)	(0.002)	(0.008)	(0.007)	(0.006)	(0.005)
N	2,034	3,060	2,034	3,060	2,034	3,060	2,034	3,060	2,034	3,060
Panel F Drop Canada										
Price Change	-0.011**	-0.017***	0.002	0.001	0.001	0.001	0.029***	0.033***	-0.020***	-0.018***
	(0.005)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.005)	(0.003)	(0.004)	(0.003)
N	1,974	2,985	1,974	2,985	1,974	2,985	1,974	2,985	1,974	2,985
Panel G Drop Census with Only Geolev1 Available										
Price Change	-0.011**	-0.019***	0.001	0.002	0.000	-0.000	0.031***	0.036***	-0.021***	-0.019***
	(0.005)	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.005)	(0.004)	(0.004)	(0.003)
N	1,903	2,836	1,903	2,836	1,903	2,836	1,903	2,836	1,903	2,836

Notes:Table A7 reports coefficients of equation 14. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. All the regressions control for the log number of mines (buffer zone same as it for price shock) and initial employment share of agriculture, manufacturing, and mining (buffer zone same as it for dependent variable). All regressions control for country group × period fixed effects and country fixed effects, except in Panel D which controls for country × period fixed effects. Standard errors in parentheses are clustered at the city level, except in Panel E which is Conley (1999) standard errors in parentheses allowing for spatial correlation within a 500 km radius and for infinite serial correlation. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

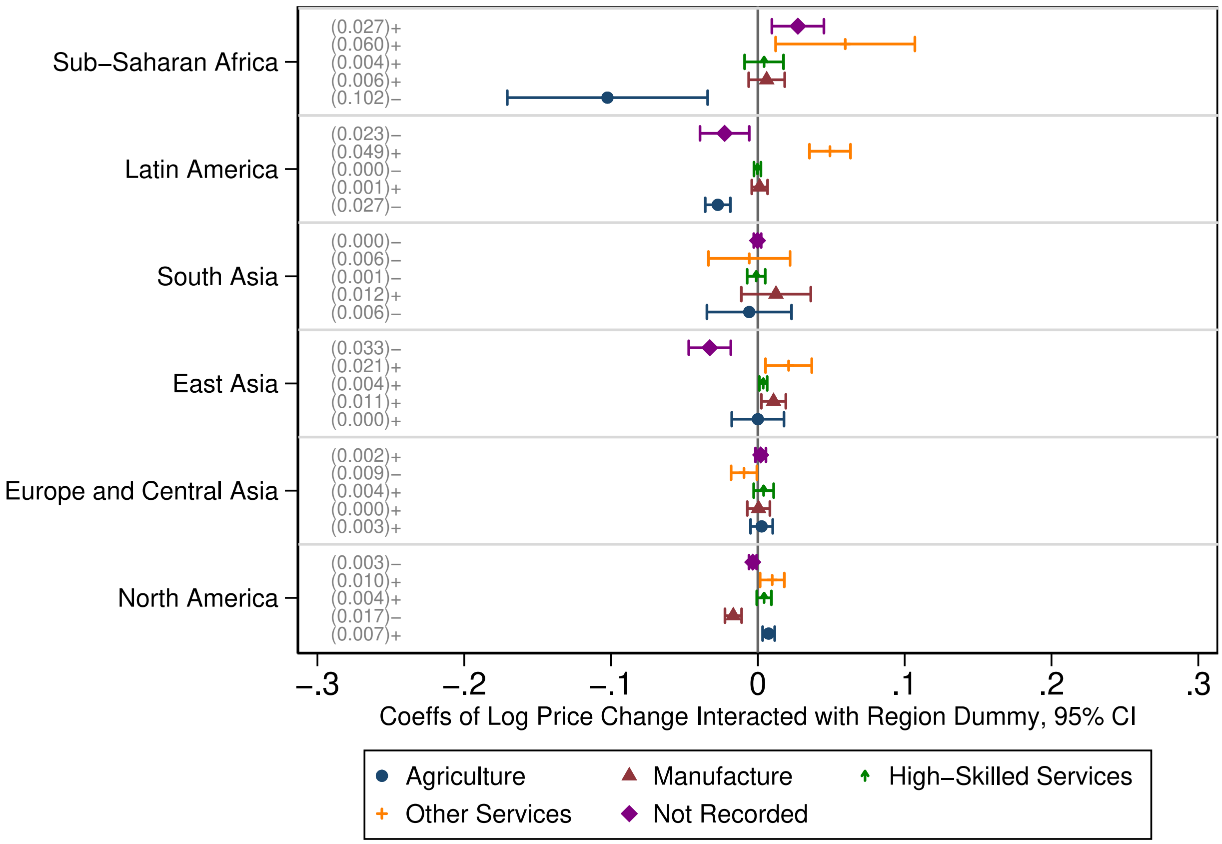
C.2.4 Mining Boom and Structural Transformation: Regional

Figure A10: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 30km, Mine Buffer Zone = 120km



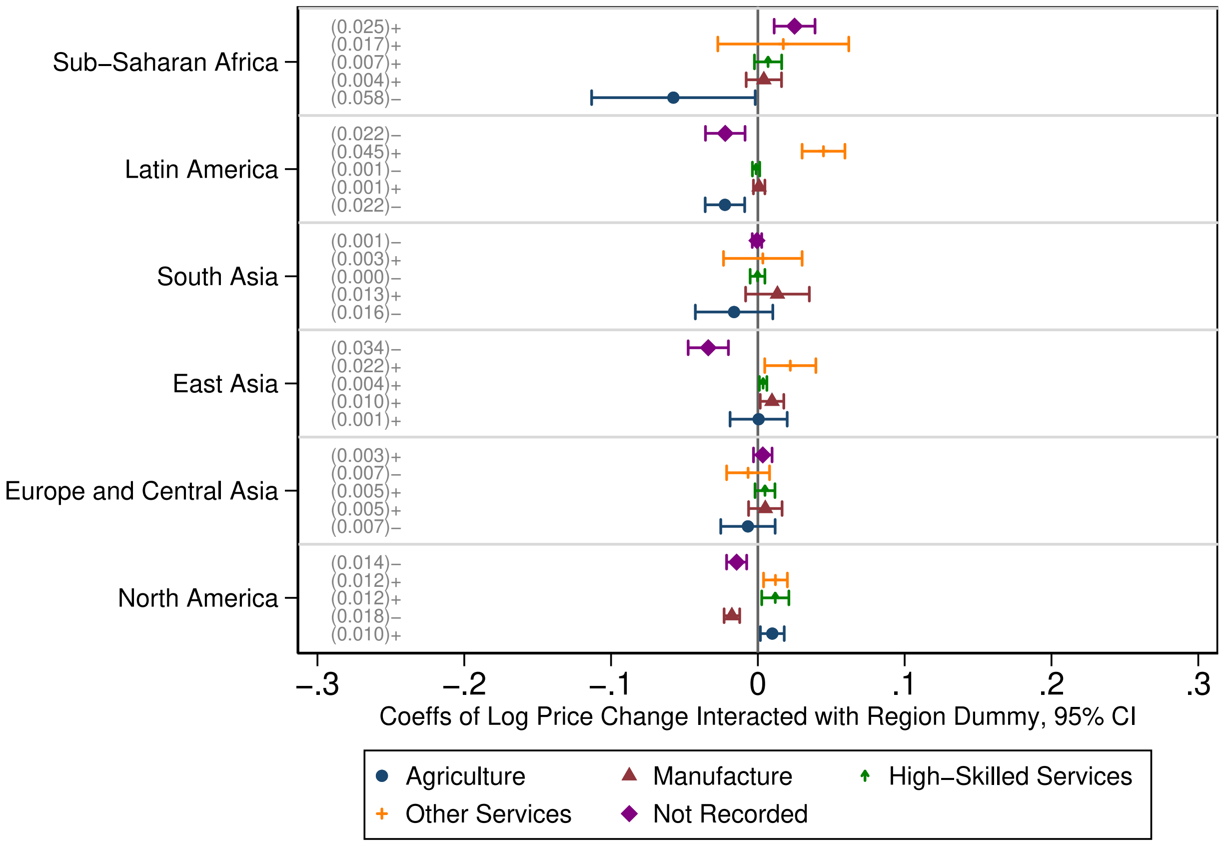
Notes: Figure A10 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta changes in employment shares by industry within a radius of 30km of the city. The price change is the average log price change of mines located within a radius of 120km of the city. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the radius of 30km of the city, log number of mines within the radius of 120km of the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A11: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 30km, Mine Buffer Zone = 60km



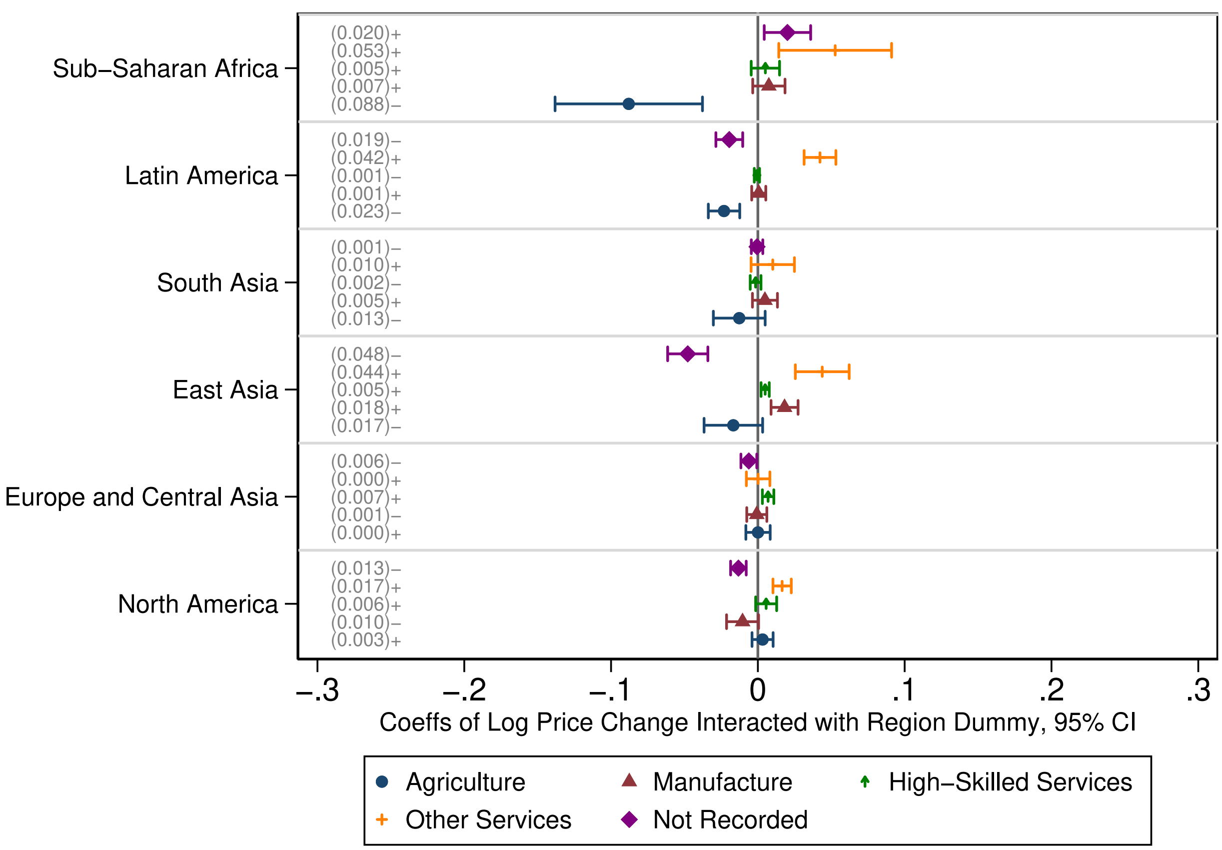
Notes: Figure A11 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta changes in employment shares by industry within a radius of 30km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 60km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A12: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 60km



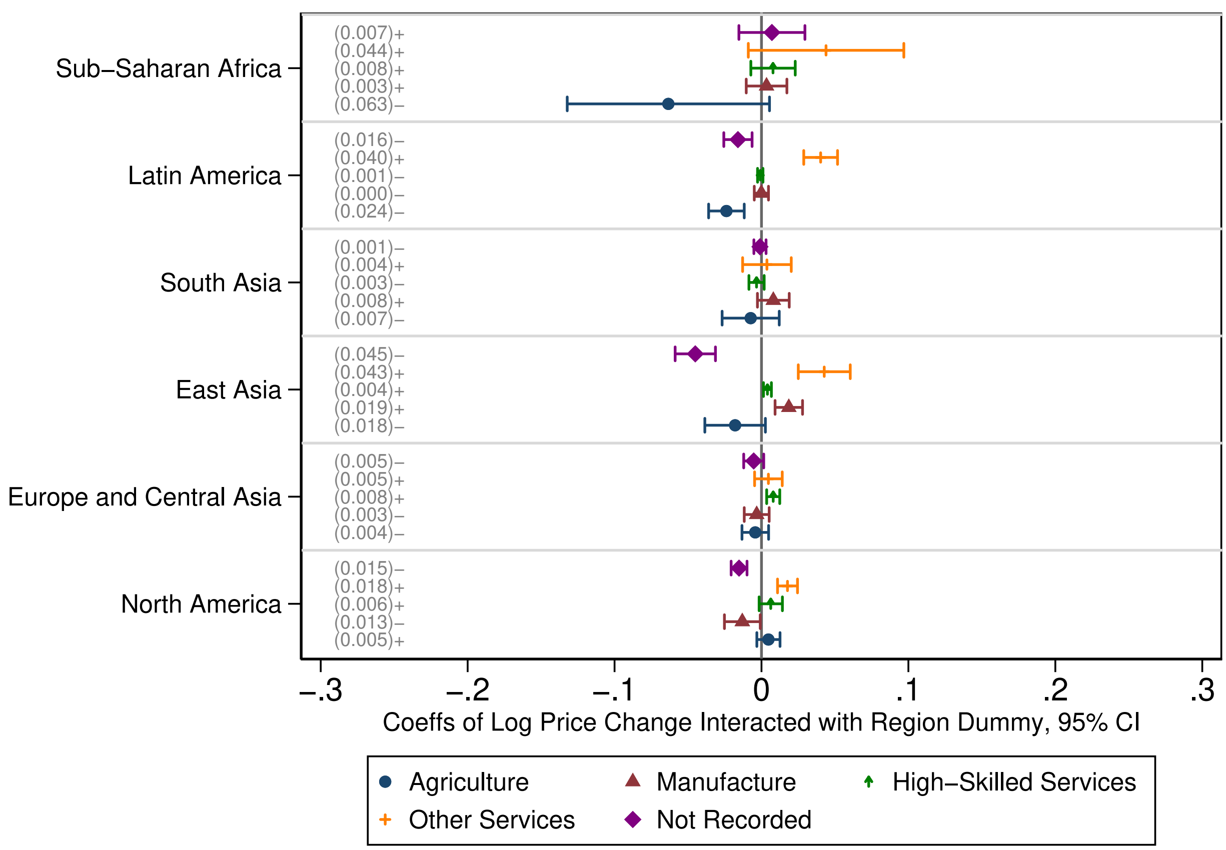
Notes: Figure A12 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 60km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A13: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Cities with and without Mines



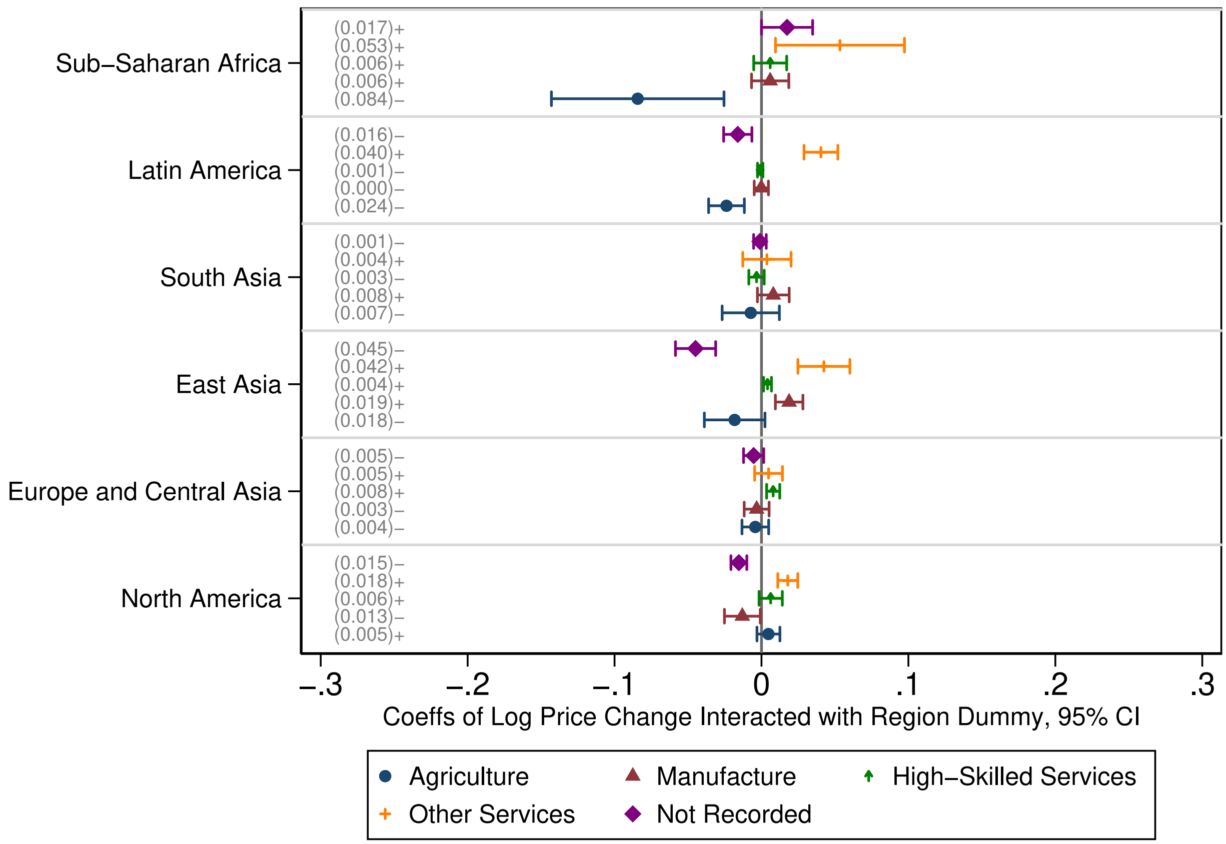
Notes: Figure A13 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample includes cities without mines in their nearby areas. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A14: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Only Cities from WUP 2018



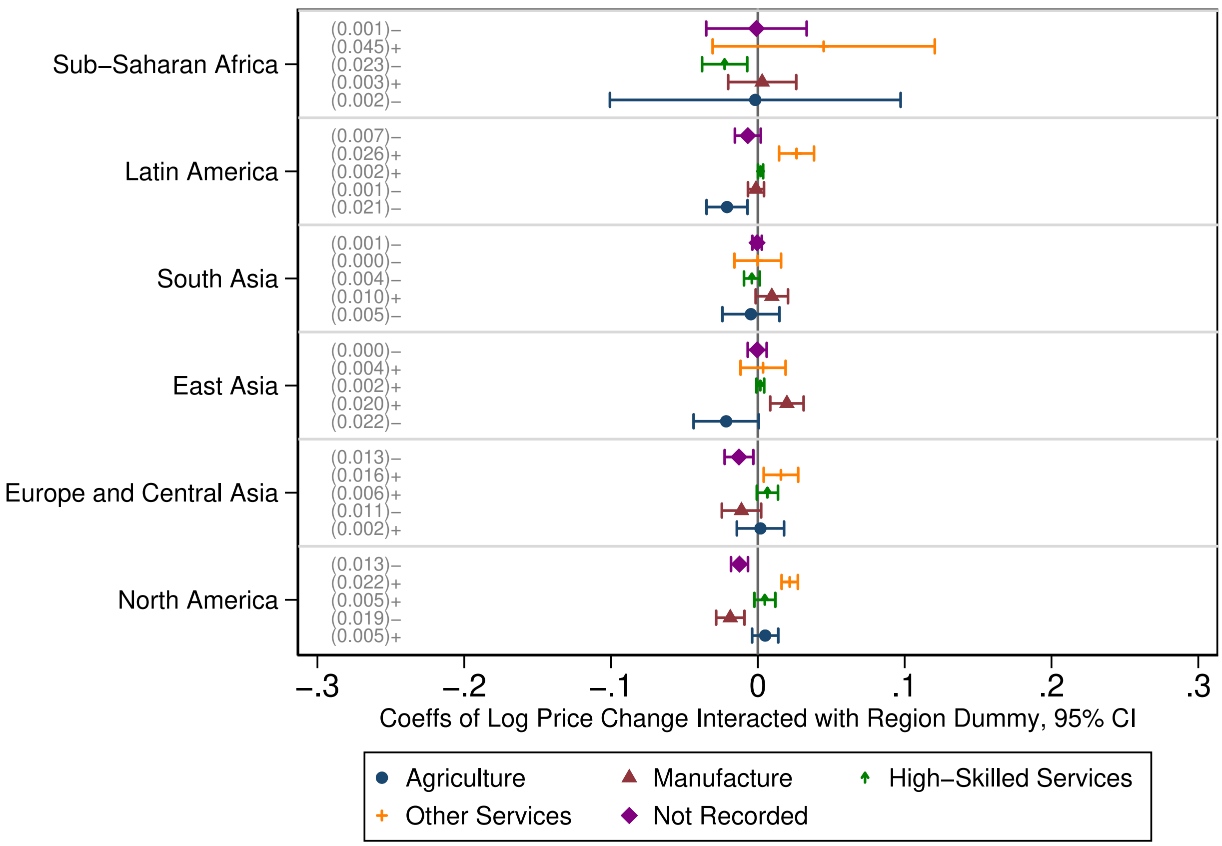
Notes: Figure A14 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample only includes cities from WUP 2018. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A15: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Cities from WUP 2018 and African Cities with Population Threshold Above 100K



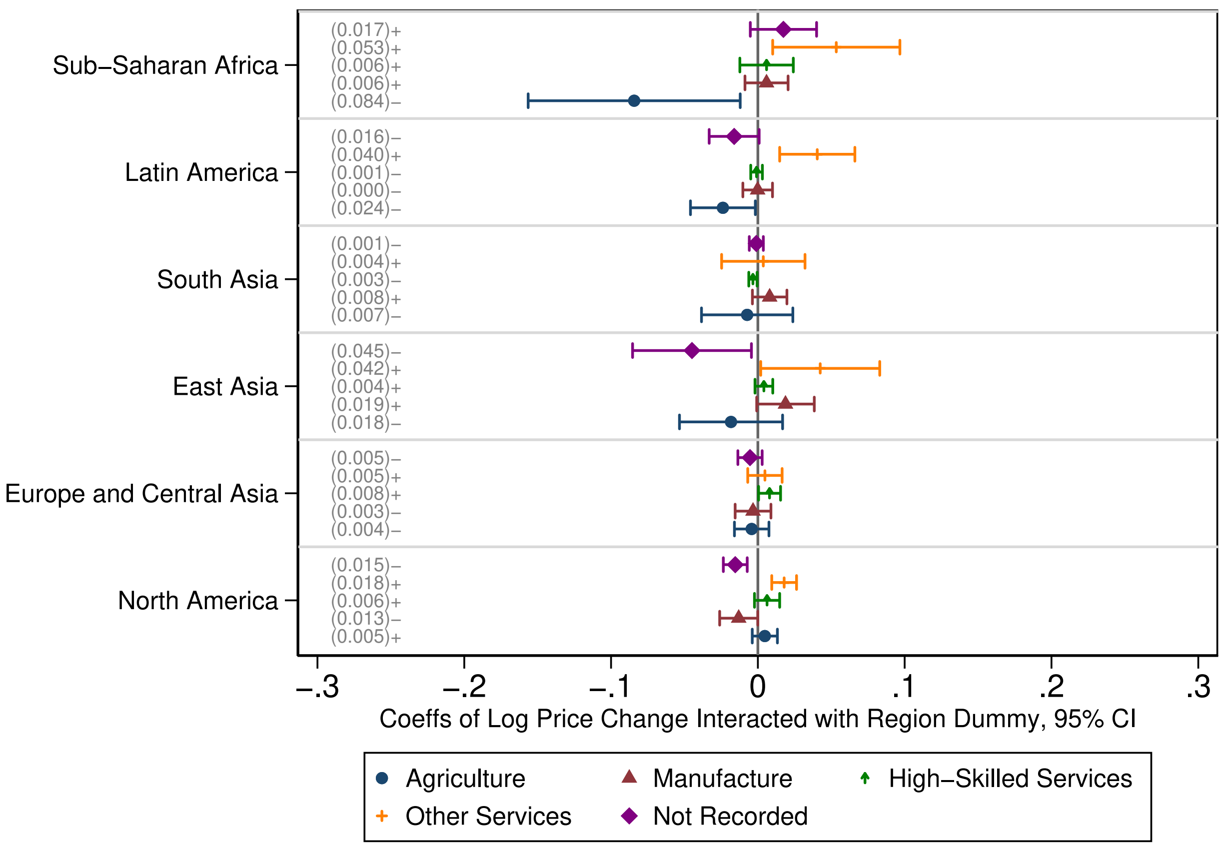
Notes: Figure A15 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample includes cities from WUP 2018 and African cities with a population threshold above 300K. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A16: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Country*Period FE



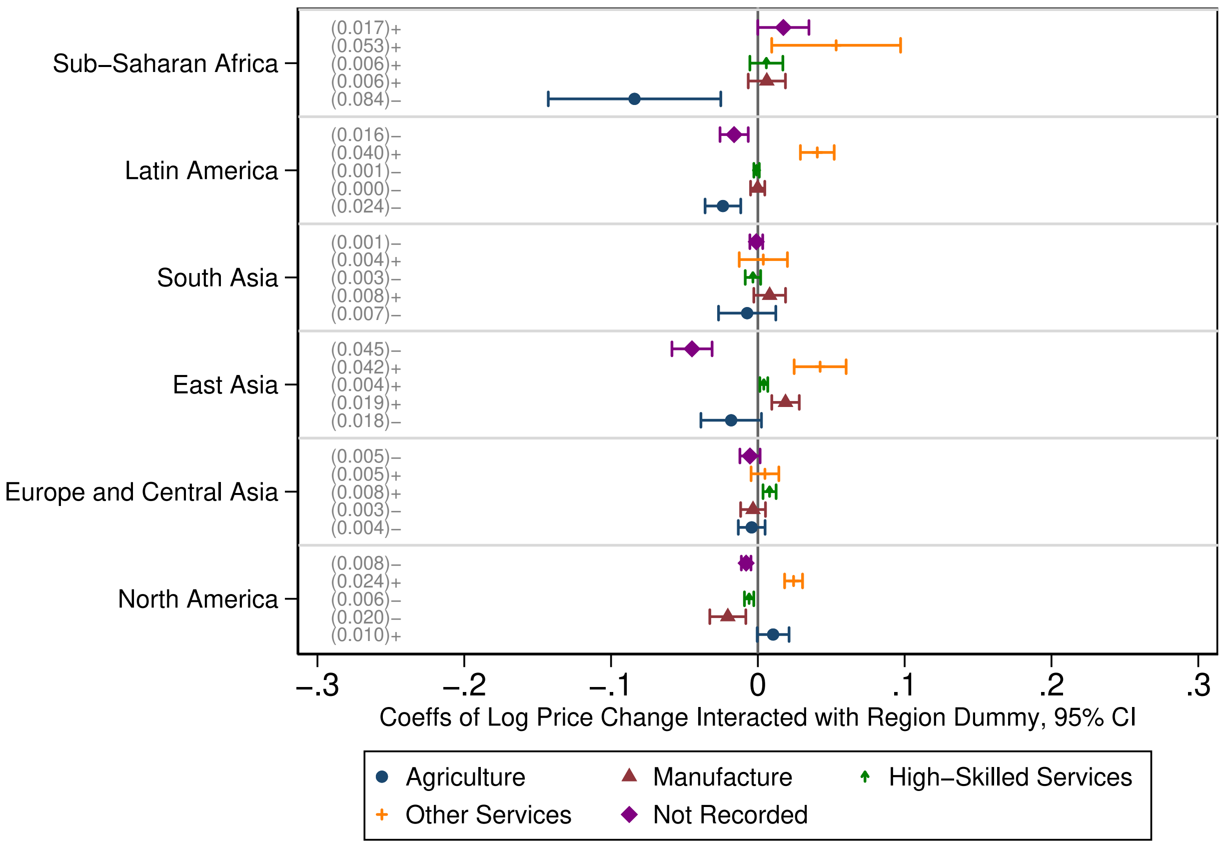
Notes: Figure A16 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, and country × period fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A17: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Spatial Correlation



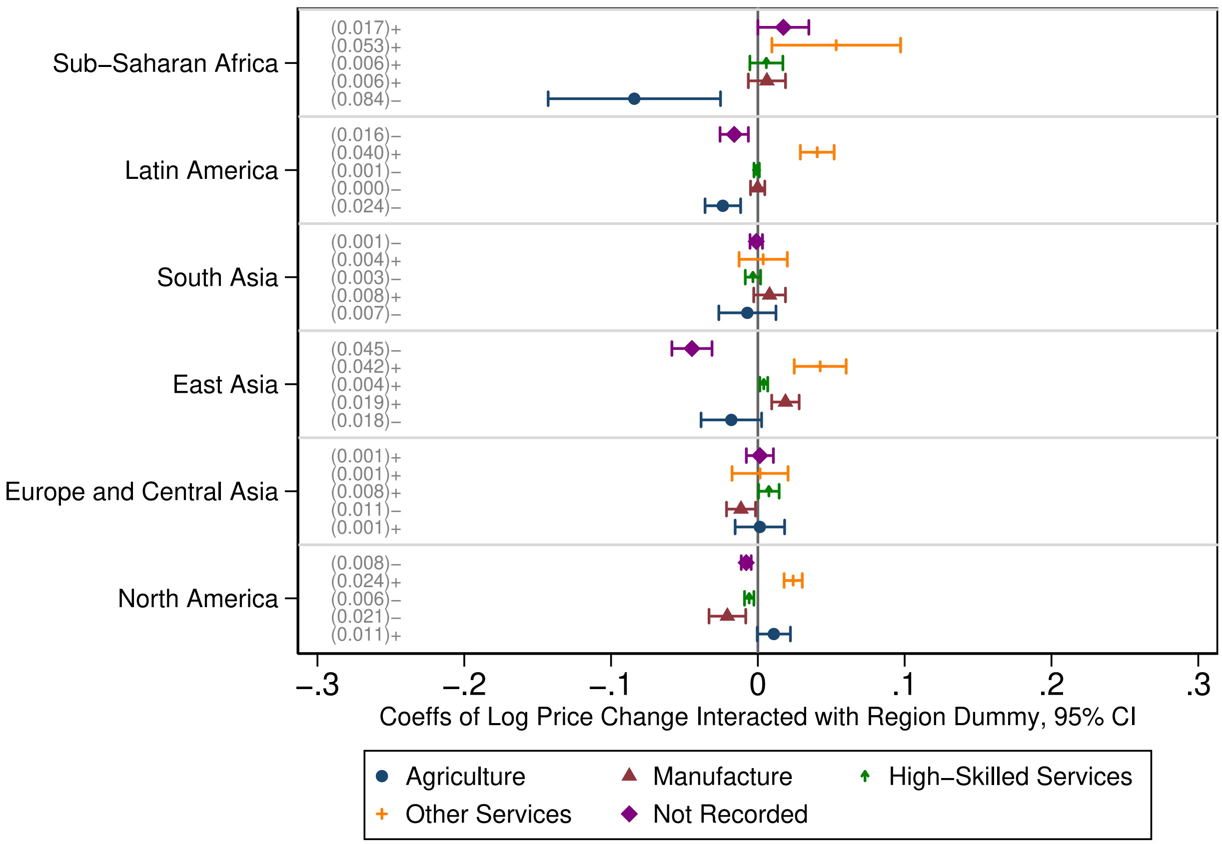
Notes: Figure A17 plots the estimated coefficients of price change interacted with region dummy by equation 15. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are Conley (1999) style allowing for spatial correlation within a 500 km radius and for infinite serial correlation.

Figure A18: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Drop Canada



Notes: Figure A17 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample does not include Canada. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

Figure A19: The Effect of Price Change on Change in Employment Share Within Cities: Regional Heterogeneity, City Buffer Zone = 60km, Mine Buffer Zone = 120km, Drop Countries with only Geolev1 Available



Notes: Figure A17 plots the estimated coefficients of price change interacted with region dummy by equation 15. The sample does not include countries that only have geolev1 available. These countries are Armenia, Belarus, Botswana, Canada, Palestine, Portugal, Puerto Rico, Romania, Russia, France, Germany, Slovak Republic, Suriname, Switzerland, Trinidad and Tobago, Ireland, Italy, and Jamaica. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The buffer zone of cities of the independent variable (price change) and control variable (log number of mines) is 120km. All the regressions control for initial employment share of agriculture, manufacturing, and mining within the city, country group × period fixed effects, and country fixed effects. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors are clustered at the city level.

C.3 Complementary Results: Mechanism Analysis

Table A8: Price Shock and Population Change Within Cities: Mechanisms, City Buffer Zone = 60 KM

	(1)	(2)	(3)	(4)	(5)	(6)
Mechanism	Baseline	Resource Intensity	Natural Resource Export	Agricultural Productivity	Access to Electricity	Human Capital
Panel A Mines' distance to city c <= 60KM						
Price Change * North Africa	0.230***	0.232***	0.277***	0.209**	0.228***	0.071**
	(0.083)	(0.083)	(0.094)	(0.082)	(0.083)	(0.033)
Price Change * sub-Saharan Africa	0.095**	0.095**	0.088**	0.054	0.070	0.094
	(0.042)	(0.043)	(0.041)	(0.042)	(0.043)	(0.061)
Price Change	0.000	-0.000	0.003	0.020*	0.007	-0.002
	(0.010)	(0.010)	(0.010)	(0.011)	(0.012)	(0.010)
Price Change * Mechanism		0.001	0.015**	-0.032***	-0.012	0.007
		(0.004)	(0.006)	(0.006)	(0.010)	(0.006)
N	3,201	3,201	3,132	3,174	3,168	2,835
Panel B Mines' distance to city c <= 90KM						
Price Change * North Africa	0.159***	0.167***	0.172***	0.151***	0.159***	0.047**
	(0.050)	(0.050)	(0.053)	(0.049)	(0.050)	(0.021)
Price Change * sub-Saharan Africa	0.046	0.044	0.039	0.019	0.028	0.044
	(0.030)	(0.031)	(0.030)	(0.032)	(0.035)	(0.039)
Price Change	-0.008	-0.008	-0.005	0.003	-0.004	-0.010
	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)	(0.009)
Price Change * Mechanism		0.008***	0.012**	-0.021***	-0.009	0.005
		(0.003)	(0.005)	(0.005)	(0.009)	(0.005)
N	4,113	4,113	4,035	4,077	4,074	3,630

Notes: Table 6 reports estimated coefficients of equation 16. The dependent variables are delta log population density within a radius of 60km of the city. All mechanisms are measured in the baseline year and normalized to have a mean of 0 and a standard deviation of 1. All the regressions control for the initial log population density in the city, and the log number of mines. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.

Table A9: Price Shock and Change in Employment Shares Within Cities: Mechanisms, City Buffer Zone = 60km, Mine Buffer Zone = 120km

	(1)	(2)	(3)	(4)	(5)	(6)
Mechanism	Baseline	Resource Intensity	Natural Resource Export	Agricultural Productivity	Access to Electricity	Human Capital
Panel A Delta Change in Emp. Share of Agriculture						
Price Change * sub-Saharan Africa	-0.070**	-0.065**	-0.061*	-0.052*	-0.088***	-0.083***
	(0.030)	(0.030)	(0.036)	(0.031)	(0.032)	(0.028)
Price Change	-0.014***	-0.014***	-0.015***	-0.020***	-0.010**	-0.015***
	(0.004)	(0.003)	(0.004)	(0.005)	(0.005)	(0.004)
Price Change * Mechanism		-0.009***	-0.005	0.014**	-0.008	0.005
		(0.003)	(0.007)	(0.005)	(0.007)	(0.004)
N	2,963	2,963	2,956	2,963	2,961	2,905
Panel B Delta Change in Emp. Share of Manufacture						
Price Change * sub-Saharan Africa	0.004	0.002	0.003	-0.003	0.005	0.003
	(0.007)	(0.007)	(0.008)	(0.008)	(0.009)	(0.007)
Price Change	0.002	0.002	0.002	0.004*	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Price Change * Mechanism		0.005***	0.001	-0.005	0.001	-0.003
		(0.001)	(0.002)	(0.003)	(0.003)	(0.002)
N	2,963	2,963	2,956	2,963	2,961	2,905
Panel C Delta Change in Emp. Share of High-Skilled Services						
Price Change * sub-Saharan Africa	0.004	0.003	-0.008	-0.002	0.001	0.008
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)
Price Change	0.002**	0.002**	0.004***	0.004***	0.003***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Price Change * Mechanism		0.001	0.007***	-0.004**	-0.001	0.003**
		(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
N	2,963	2,963	2,956	2,963	2,961	2,905
Panel D Delta Change in Emp. Share of Other Services						
Price Change * sub-Saharan Africa	0.023	0.015	0.034	-0.011	0.025	0.046**
	(0.023)	(0.023)	(0.027)	(0.024)	(0.028)	(0.021)
Price Change	0.030***	0.031***	0.029***	0.042***	0.030***	0.029***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.006)	(0.004)
Price Change * Mechanism		0.015***	-0.007	-0.025***	0.001	0.008**
		(0.003)	(0.006)	(0.006)	(0.008)	(0.004)
N	2,963	2,963	2,956	2,963	2,961	2,905

Notes: Table 7 reports estimated coefficients of equation 16. The dependent variables are delta changes in employment shares by industry within a radius of 60km of the city. The price change is the average log price change of mines located within a radius of 120km of the city. All mechanisms are measured in the baseline year and normalized to have a mean of 0 and a standard deviation of 1. All the regressions control for the initial employment share of agriculture, manufacturing, and mining within a radius of 60km of the city, and log the number of mines within a radius of 120km of the city. We drop the country group of Middle East and North Africa due to a lack of observations. Standard errors in parentheses are clustered at the city level. ***, **, * denotes statistical significance at the 1%, 5%, 10% levels, respectively.