Policy Research Working Paper 10446

Sectoral Productivity Shock, Regional Differences in Intersectoral Linkages, and Structural Transformation in Ghana

Saumik Paul
Dhushyanth Raju

WORLD BANK GROUP
Social Protection and Jobs Global Practice
May 2023

Policy Research Working Paper 10446

Abstract

This paper studies the effect of a local sectoral productivity shock on subnational structural transformation. The analysis is based on regional input-output tables constructed for 2004 and 2013 and available censuses of firms in 2003 and 2013 for Ghana. Based on the data, the analysis confirms the occurrence of a mining productivity shock. Between 2004 and 2013, mining grew dramatically as a share of gross domestic product. The mining shock occurred primarily in the south of Ghana with much larger increases in mining's share in regional output, the number of mining firms, and mining employment than in the north of the country. The findings show that the mining productivity shock led to growing regional (north-south) differences in intersectoral linkages, with greater intermediate use of mining output and a larger sectoral total factor productivity ratio between mining and manufacturing in the south than in the north. Informed by international evidence of strong intersectoral linkages between mining and heavy manufacturing industries, the paper examines the performance of heavy manufacturing in response to the mining productivity shock. The elasticity of heavy manufacturing to mining employment growth is 50 percent larger in the south than in the north, generated by an increase in both average firm employment and the entry of new firms. These north-south differences are interpreted as possibly due to weak interregional production linkages.

This paper is a product of the Social Protection and Jobs Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at at saumik.paul@newcastle.ac.uk and draju2@worldbank.org.

Sectoral Productivity Shock, Regional Differences in Intersectoral Linkages, and Structural Transformation in Ghana*

Saumik Paul[1]

Dhushyanth Raju[2]

Keywords: Structural transformation, intersectoral linkages, propagation of productivity shock, subnational areas, mining, Ghana

JEL codes: L14, L22, O11, O14, R11, R15

[1] Newcastle University and IZA, saumik.paul@newcastle.ac.uk.
[2] World Bank, draju2@worldbank.org.

* This paper is a substantially revised version of a previous paper titled "Regional Differences in Intersectoral Linkages and Diverse Patterns of Structural Transformation," published as IZA Discussion Paper 15461. We thank Emanuele Ferrari for guidance on the construction of input-output tables from supply and use tables for Ghana. We also thank Al-Mouksit Akim, Andrew Dabalen, Giorgio Fazio, K. N. Harilal, Marco Lorusso, Sunil Mani, Rayaprolu Nagraj, M. Parameswaran, and seminar participants at the Centre for Development Studies (Trivandrum, India), Newcastle University, and the Centre for the Study of African Economies (CSAE) Conference 2023 on Economic Development in Africa (Oxford University, UK) for helpful comments.

1. Introduction

Local sectoral productivity shocks can lead to fluctuations in economic activity at various levels. The literature on production networks describes conditions by which intersectoral and interregional linkages can help to propagate a local sectoral productivity shock to the aggregate level (Acemoglu et al. 2012; Oberfield 2018; Carvalho et al. 2021; Caliendo et al. 2018; among others).[1] Many low-income countries have weak linkages across subnational regions, presumably due to the high cost of doing trade (WTO 2018; World Bank 2022).[2] As the existing literature on production networks is dominated by research on high-income countries, it offers little insight into the propagation of local sectoral productivity shocks in the presence of weak interregional linkages. Weak interregional linkages could restrict the propagation of a local sectoral productivity shock in one region to other regions, and thus to the aggregate level. In line with this thinking, we seek to understand if a sector- and region-specific productivity shock produces regional differences in intersectoral linkages, and hence leads to regional differences in the sectoral composition of economic activities. In this study, we examine how a positive mining shock alters the course of regional structural transformation in Ghana.

One indication of the mining shock can be seen in the dramatic increase in the sector's contribution to the country's export earnings: In Ghana, mining products as a share of export earnings rocketed from 10 percent in 2006 to 70 percent in 2018 (The Growth Lab at Harvard University). Among the country's diverse mineral resources, gold and more recently, oil and natural gas, have accounted for the bulk of output. As Ghana's oldest extraction industry, gold mining dates back to the mid-15th century, but commercial production started only after 2003. By 2017, Ghana had become the second-largest producer of gold in Sub-Saharan Africa, accounting for 4 percent of global production (Corathers 2019). Gold has also made up a growing share of the country's export earnings, increasing from 4.3 percent in 2006 to 40 percent in 2018. In 2010, Ghana emerged as a new oil and gas producer in Sub-Saharan Africa (OEF 2019), with cumulative oil production surging from 1.2 million barrels in 2010 to 508.4 million barrels in 2021 (PIAC 2021). Petroleum products have steadily increased as a share of Ghana's export earnings, rising from 17 percent in 2012 to nearly 25 percent in 2018.

[1] A growing number of studies also examines the effect of sectoral productivity shock on economic outcomes at the local level (for example, see Kline and Moretti 2014; Feyrer et al. 2017; Toews and Vezina 2020).
[2] Trade costs (due to tariffs, transport, infrastructure, and logistic hurdles) are five times higher in Sub-Saharan Africa than in high-income countries (WTO 2018).

Notably, the intensification of mining activities has primarily occurred in the south of Ghana. Between 2003 and 2013, gold mines spread from a handful of districts in the Ashanti region to many districts in the Ashanti, Western, and Central regions in the south. Ghana's oil and gas fields are also located off the south coast. Between 2003 and 2013, the increase in the number of mining firms and in mining employment in the south is larger than in the north by 14 and 62 times, respectively.

We test two predictions related to the positive mining shock in Ghana, by combining the literature on production networks (Acemoglu et al. 2012; Carvalho and Tahbaz-Salehi 2019) with that on mining-led local development (Feyrer et al. 2017; Toews and Vezina 2020). First, we examine whether the mining output shock that primarily occurred in the south of Ghana led to a growing regional (north-south) difference in intersectoral linkages between 2003 and 2013. Second, we examine whether regional differences in intersectoral linkages following the mining shock led to regional differences in the sectoral composition of regional output during the same period.

To estimate regional differences in intersectoral linkages and the composition of sectoral outputs, we use statistics at the sector level (output, productivity, and employment elasticities in other sectors with respect to mining) and at the firm level (rate of firm entry and average firm-level employment in heavy manufacturing industries). Region-level sectoral data come from aggregate and regional five-sector input-output (I-O) tables for 2004 and 2013 that we construct from supply and use tables for Ghana. The five sectors are agriculture, mining, "other industry" (that is, industrial subsectors other than mining), wholesale and retail trade (WRT) services, and "other services" (that is, services subsectors other than WRT services). For firm-level data, we use two rounds of censuses of firms for Ghana: the 2003 National Industrial Census (NIC) and the 2014 Integrated Business Establishment Survey (IBES).

We examine the spatial and temporal pattern of the mining shock by exploiting the variation in the intensity of mining activities between the north and the south and between 2003 and 2013. Differences in regional intersectoral linkages are measured using the I-O tables for the north and the south in 2004 and 2013. Between 2004 and 2013, mining's output as a share of gross domestic product (GDP) or the Domar weight increased by 16 percentage points, and the increase in the Domar weight for mining was 1.7 times larger in the south than in the north. The sectoral total factor productivity (TFP) ratio between mining and "other industry" in the south (0.532) is more than twice the size of that in the north (0.204). We also find larger growth in the share of intermediate use in mining and the downstreamness index for mining in the south than in the north. Input downstreamness is measured as the average distance from primary inputs suppliers (Antras et al. 2012). Overall, we find stronger intersectoral linkages with mining in the south than in the north.

For the second prediction, i.e., whether regional differences in intersectoral linkages led to regional differences in sectoral composition of regional output between 2003 and 2013, to identify the counterfactual, we distinguish between heavy manufacturing industries (chemicals, machinery, metals, and nonmetallic minerals) and light manufacturing industries (such as food, textiles, paper, and wood). Based on world input-output data for 43 countries, we find that heavy manufacturing and mining show strong intersectoral linkages, as more than 85 percent of mining intermediate inputs in manufacturing are used in heavy manufacturing. We test if employment growth in heavy manufacturing industries occurs in mining districts (districts with at least one mining firm). The elasticity of employment for heavy manufacturing with respect to employment in mining (an elasticity of 0.31) is almost 50 percent larger than the corresponding elasticity for light manufacturing (0.21).

In our subsequent empirical model, the intensity of intersectoral networks is identified jointly by the location of a mining firm and the year in which it was established. We interpret the effect of the mining shock on intersectoral linkages as causal if the contemporaneous and lagged effects are positive and strong, and lead effects (placebo) are weak and negative. Constructing a district-year panel with 119 districts and 24 years (1990–2013) based on data on the location and the year of establishment of a firm collected in the 2014 IBES, we find stronger intersectoral linkages between mining and heavy manufacturing in the south than in the north. The relationship between mining and heavy manufacturing firms in the south appears to be causal, based on the placebo tests.

Finally, we test if average firm-level employment (in different sectors) is higher in mining districts in the south and if average employment in a manufacturing firm is higher in 2013 (compared to 2003) if it is located in a mining district in the south. On average, employment size in heavy manufacturing located in a mining district in the south (compared to the rest) is higher by 23.2 percent. We also find that average employment size of heavy manufacturing firms grew by more than three times in mining districts in the south between 2003 and 2013 (compared to light manufacturing firms). Overall, the variation in the mining employment shock across districts explains employment growth particularly in heavy manufacturing in the south. The evidence strongly suggests that this process of structural transformation was facilitated by the entry of new firms in heavy manufacturing in mining districts as well as an increase in average employment in heavy manufacturing firms in mining districts.

This study contributes to three broad strands of the literature. First, we contribute to the literature on the drivers of structural transformation. Structural transformation is broadly understood as a process driven by both demand-side factors (Kongsamut et al. 2001; Comin et al. 2017) and supply-side factors (Baumol 1967; Ngai and Pissarides 2007). A handful of studies examine the spatial disparity in structural transformation and show that it is linked to the geographic mobility of workers (Caselli and Coleman II 2001; Allen and Arkolakis 2014; Desmet and Rossi-Hansberg 2014). At the same time, interest has grown in understanding the role of changes in input-output flows behind the process of structural transformation (Herrendorf and Valentinyi 2012; Herrendorf et al. 2013; Caliendo et al. 2018; Liu 2019; Fadinger et al 2022). We combine these two subfields to show that changes in the pattern of input-output flows resulting from local sectoral productivity shocks could produce a diverging process of structural transformation across regions.

Second, we contribute to a growing body of research on the roles of intersectoral and interregional linkages governing the propagation of sectoral productivity shocks to the aggregate level (Acemoglu et al. 2012; Atalay 2017; Caliendo et al. 2018; Carvalho et al. 2021). As noted earlier, given that the existing literature on production networks tends to be focused on high-income countries, and takes as an analytical starting point the economic structure and performance of these countries, such studies offer little insight into the propagation mechanisms for low-income countries where trade costs can be much higher than in high-income countries. We show that a local sectoral productivity shock could lead to regional differences in intersectoral linkages and in the pattern of structural transformation. Although we do not provide direct evidence, we interpret this result as possibly due to weak interregional linkages limiting the scope of sectoral productivity shocks amplifying from one region to another in the context of low-income countries.

Finally, we contribute to the literature focusing on the role that mining can play in development in Ghana. Like many other countries in Sub-Saharan Africa, Ghana is blessed with diverse natural resources. Following decades of deindustrialization and growth-inhibiting structural transformation, the country’s emergence as an oil and gas producer in 2010 coincided with a national industrialization drive (Fosu 2017; Osei et al. 2020; Paul and Raju 2021, PIAC 2021). The prospects of place-based development through mining (Aragon and Rud 2013; Fafchamps et al. 2017) and the socioeconomic benefits arising from stronger intersectoral linkages between mining and other sectors have already been pointed out by

Aryeetey et al. (2014). We make further refinements to this line of research by underscoring the need for policies that could propel aggregate productivity from growing north-south differences in intersectoral linkages and regional specialization.

The remainder of the paper is organized as follows. Section 2 provides an overview of the mining productivity shock and national and regional trends in structural transformation for Ghana. Section 3 discusses how the mining productivity shock in the south of Ghana leads to growing regional differences in the pattern of intersectoral linkages based on regional I-O tables. Section 4 shows how spatial differences in intersectoral linkages affect sectoral output and productivity based on census data for firms. Section 5 concludes.

2. Overview of Mining Shock and Structural Transformation in Ghana

We begin with a brief account of the recent mining productivity shock in Ghana, followed by an overview of the annual and spatial trends in mining and manufacturing based on statistics from the GGDC-UNU-WIDER economic transformation database (ETD)[3] and district-level data from two censuses on Ghana firms: the 2003 National Industrial Census (NIC) and the 2014 Integrated Business Establishment Survey (IBES).[4]

The 2003 NIC and 2014 IBES were administered by the Ghana Statistical Service (GSS). The 2003 NIC covered only industrial sectors (mining, manufacturing, public utilities, and construction), whereas 2014 IBES covered industrial as well as all services sectors (wholesale and retail trade, transport, communications, finance, real estate, government services, and private services). Both censuses were conducted in two phases. Phase II involved a detailed questionnaire, capturing workforce, wages and salaries, stocks, value of fixed assets, quantity and cost of inputs purchased, other operating costs, and sales and other income. We use the data from phase II for both surveys. The reference year for phase II of the 2003 NIC is the calendar year 2003 and the reference year for phase II of the 2014 IBES is the calendar year 2013.[5]

---

[3] The ETD is a joint initiative of the Groningen Growth and Development Centre (GGDC) and United Nations University-World Institute for Development Economics Research (UNU-WIDER). It is publicly available at https://www.wider.unu.edu/project/etd-economic-transformation-database, along with documentation on its contents and construction.

[4] For survey design and implementation details, see GSS (2006) and (2018).

[5] Phase II of 2003 NIC was fielded between December 2004 and February 2005, and phase II of 2014 IBES was fielded between November 2015 and April 2016.

Growth of Mining Activities in Ghana

Ghana boasts a wide range of mineral resources including gold, manganese, bauxite, diamonds, and oil and gas. Gold is its oldest extraction industry, starting in the mid-15th century during the country's colonial era. In 2017, Ghana became the world's second-largest producer of gold, accounting for 4 percent of global production (Corathers 2019). Even as overall production has increased steadily, short-term output often fluctuated, sometimes dramatically, between 1995 and 2003 (figure 1, panel a). Production initially peaked in the late 1990s, before dropping in the early 2000s. Output picked up again in 2003 and continued to increase since then. Since 2003, gold mining activities have shifted from the Ashanti region, as many mines there closed, primarily to the Central, Eastern, and Western regions (Fafchamps et al. 2017).

The first discovery of oil and gas in Ghana dates back to the 1970s. As the volume of extraction was modest until the turn of the 21st century, the production of oil and gas during this period was classified as noncommercial. After decades of more comprehensive exploration, Ghana discovered oil in large quantities in the oil fields in the Deep Water Tano and West Cape Three Points blocks in 2007. In November 2010, the Jubilee partners (comprising Tullow Oil, Kosmos Energy, Anardako Petroleum Corporation, Sabre Oil and Gas, E.O. Group, and Ghana National Petroleum Company) started extracting and producing oil in commercial quantities. Several other oil fields were discovered between 2010 and 2020. Ghana started drilling in TweneboaEnyenra Ntomme in 2016 and in Sankofa Gye Nyame the following year. The country's volume of cumulative oil production increased from 1.2 million barrels in 2010 to 508.4 million barrels in 2021 (PIAC 2021) (figure 1, panel b). With offshore mining continuing to thrive in the south, Ghana is now aiming to explore onshore mines across several locations in the Voltaian basin in the north (Skaten 2019).

The growing importance of minerals is reflected in Ghana's export basket (appendix figure A1). In 2006, gold accounted for a mere 4.3 percent of export earnings. In 2012, after the country started producing oil and gas on a commercial basis, that sector constituted almost 17 percent of total export earnings. The same year, the contribution of gold to total export earnings rose to 25 percent. Within the next six years, the composition of Ghana's export earnings changed dramatically, with 70 percent of export earnings deriving from minerals in 2018, including 40 percent from gold and 25 percent from crude petroleum.

National Trends in Sectoral Employment and Value-Added Shares

Figure 2 depicts trends in each sector's share of employment and value-added, which reflect structural transformation, based on ETD statistics. Ghana did not exhibit any strong signs of structural transformation until 2000. Between 2000 and 2010, structural transformation gained momentum, but the changes were mostly limited to agriculture's share of employment declining and services' share of employment increasing. Industry's share of employment grew from 16 percent in 2010 to 20 percent in 2018, driven primarily by manufacturing. Meanwhile, agriculture's share of employment declined from 55 percent to 33 percent, and services' share of employment grew from 30 percent to 47 percent over the same period.

The sectoral shares of value-added followed somewhat different trends. Between 1990 and 2018, services' share of value-added hovered at about 50 percent. Both agriculture's and industry's shares of value-added remained close to 25 percent until 2010. Since then, the two sectors' shares of value-added diverged, with industry's share rising above that of agriculture. Within industry, mining's share of value-added increased from 3 percent in 2000 to 12 percent in 2018 (9 percentage points). Construction's share of industry value-added has increased moderately since 2005, whereas manufacturing's share has been declining since the mid-2000s.

Regional Trends in Industry and Services in the North and the South

Trends in employment and value-added shares at a more detailed sectoral level are not available in the ETD. As an alternative, we use 2014 IBES summary statistics from GSS (2016) on the number of firms in industry and services, categorized by district and year of establishment, to describe the evolution of sectoral activities at the regional level. We follow the classification of Ghanaian regions prior to the 2018 referendum, which expanded the number of regions from 10 to the 16 in effect today. We define the north as comprising the Brong Ahafo, Northern, Upper East, Upper West, and Volta regions, and the south as comprising the Ashanti, Central, Eastern, Greater Accra, and Western regions (figure 3, panel a). We retain this definition of the north and south of Ghana throughout the paper.

From approximately 1975 to the early 2010s, the numbers of firms in industry and in services increased steadily in both the north and the south, but the total number of firms (for both sectors) in the south has far exceeded that in the north (appendix figure A2, panel a). The growth rate in terms of the number of firms (referred to herein as "growth in firms") in industry has always been higher in the north than in the south (appendix figure A2, panel b).

A similar trend is observed for firms in services, with the number of such firms in the north gradually converging with that in the south except between 2005 and 2014.

Regional Trends in Mining and Manufacturing in the North and the South

We look at regional trends for subsectors within industry, specifically mining and manufacturing. For this, we use data from 2003 NIC and 2014 IBES. The 2003 NIC only surveyed industrial firms. Given this, it is not feasible to examine the number of firms and employment in agriculture or services over time.

Table 1 reports the numbers of firms and employees in 2003 and 2013 at the national level, in the north, and in the south. At the national level, the number of firms engaged in mining increased from 125 in 2003 to 294 in 2013 and the number of firms engaged in manufacturing increased from 23,797 in 2003 to 101,789 in 2013. The numbers of firms and employees remain overwhelmingly large in the south in both manufacturing and mining, compared to numbers for the north. The change in the number of mining firms and of employment in the south is higher than in the north by 14 times and 62 times, respectively. The south's share of mining firms increased from 82 percent (103 out of 125) in 2003 to 89 percent (261 out of 294) in 2013, and its share of mining employment continued to dominate, totalling an overwhelming 98 percent in both years. This is also evident from figure 3 (panels b and c). On the other hand, the north's share of manufacturing firms grew from 19 percent (4,623 out of 23,797) in 2003 to 31 percent (31,281 out of 101,789) in 2013. Similarly, its share of manufacturing employment grew from 9 percent (10,386 out of 116,774) in 2003 to 16 percent (44,507 out of 271,863) in 2013. The evidence suggests manufacturing employment in the north has partially converged with that in the south over time.[6]

We next look at regional trends in manufacturing subsectors. We distinguish between heavy manufacturing and light manufacturing.[7] Given the importance of food and clothing, we also examine them separately in selected analyses. Table A1 compares growth of firms and growth in the number of employees ("growth of employees") at the district level between

[6] Data are not available for nonindustrial sectors in NIC 2003. However, based on comparable national household sample surveys for 2005/06, 2012/13, and 2016/17 (rounds of the Ghana Living Standards Survey), services employment in the north grew faster than that in the south, with the north's share of services employment increasing from 43 percent to 45 percent; in comparison, manufacturing-employment growth was much slower in the north (Paul and Raju 2021).

[7] Heavy manufacturing refers to manufacturing of coke and refined petroleum, chemicals, basic metals and fabricated metal, machinery and equipment, motor vehicles, and other transport vehicles, among others. Light manufacturing includes manufacturing of wood, paper, printing and reproduction of recording, pharmaceuticals, rubber and plastic, other nonmetallic items, computers, electronics, electrical equipment, furniture, food, and clothing.

2003 and 2013 in manufacturing as a whole and in four subcategories of manufacturing, namely heavy manufacturing, light manufacturing, clothing, and food.[8] The rate of growth of firms and employees in the clothing industry is significantly higher in the north than in the south. Figure 3 (panels d, e, and f) provides corroboratory evidence based on district maps. District hubs for heavy and light manufacturing activities are scattered evenly between the north and the south. However, the top one-third of districts experiencing employment growth in the clothing sector between 2003 and 2013 are predominantly located in the north. Overall, the growth of manufacturing employment in the north is predominantly led by the clothing sector.

3. Spatial Differences in Intersectoral Linkages

To estimate spatial differences in intersectoral linkages, we construct five-sector national I-O tables based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021). The five sectors are agriculture; mining; "other industry," which includes industrial subsectors other than mining; wholesale and retail trade (WRT) services; and "other services," comprising services subsectors other than WRT services.[9] This five-sector classification allows us to examine the changing patterns of intersectoral linkages between mining and other sectors. Table 2 reports five-sector national I-O tables for 2004 and 2013. The unit for inputs and outputs are in billion 2004 cedis for 2004 and million 2013 cedis for 2013. In 2007, due to inflation, the Ghana cedi was devalued. The current cedi is 10,000 times the old cedi (before 2007). We converted the figures to million cedis in both years, and then applied the sector-level deflators from the ETD to have them in 2004 constant prices. In addition, GSS rebased Ghana's national accounts series from the 1993 base year to 2006. In our analysis, both 2004 and 2013 I-O tables use the rebased figures. For robustness, we compare the value-added shares from our I-O tables against the ones available from the ETD. The values closely match for "other industry" and WRT services but appear somewhat different for the rest of the sectors. This is mainly because several adjustments have been made to ensure consistency over time of sectoral value-added and employment shares in the ETD.

Appendix B discusses how we constructed national I-O tables from the supply and use tables for Ghana. To construct I-O tables for the north and the south of Ghana for 2004

[8] Since independence in 1960, Ghana's district boundaries have changed multiple times. NIC 2003 follows a classification of 138 districts, and IBES 2014 follows a classification of 216 districts.
[9] In our five-sector classification, "other industry" encompasses manufacturing, construction, and utilities, and "other services" include transport, communications, finance, commerce, government services, and private services.

and 2013 from the national I-O tables, we applied a nonsurvey-based method (Miller and Blair 2009; Flegg and Tohmo 2011; Kowalewski 2013). Appendix C discusses how we constructed the regional I-O tables.

Sectoral Domar Weights and Value-Added Shares

Appendix figure A3 (panel a) shows changes in Domar weights, which is the ratio of sectoral output to GDP, between 2004 and 2013. In the south, production activities primarily shifted from agriculture and "other services" to mining and "other industry." The Domar weight increased the most for mining (17 percentage points), followed by "other industry" (6 percentage points). In the north, the Domar weight for agriculture decreased by 36 percentage points. "Other industry" experienced the largest increase in the Domar weight (by 16 percentage points), followed by mining (10 percentage points) and WRT services (10 percentage points).

Appendix figure A3 (panel b) shows the change in value-added shares for each sector between 2004 and 2013. The regional pattern of the change in sectoral value-added shares is comparable to the regional pattern of the change in Domar weights. In the north, the gain in the value-added share in "other industry" (23 percentage points) is larger than the change in the Domar weight in "other industry" (16 percentage points). At the same time, the gain in the value-added share in mining in the south (13 percentage points) is lower than the Domar weight in mining (17 percentage points). The implications of changes in the Domar weight and the sectoral value-added share for intersectoral linkages are twofold. First, "other industry" continues to be the most important sector in the production network of the north. Second, mining plays a dominant role in the production network, especially in the south.

Intermediate Input Use and Input Downstreamness Index

We compute the intermediate use share as the percentage of sectoral output used as intermediate inputs for other sectors, and its change between 2004 and 2013. Appendix figure A4 (panel a) compares the change in the intermediate share across sectors. In both the north and the south, the share of intermediate use in mining has increased by 11 and 13 percentage points, respectively. In the south, the change in the intermediate use in WRT services (by 32 percentage points) is more the four times the same in the north (by 7 percentage points).

We next compute downstreamness (Miller and Blair 2009; Antras et al. 2012; Antras and Chor 2013) at the sector level for 2004 and 2013 using the national and regional I-O tables. The downstreamness index measures the average distance from primary input suppliers (Antras et al. 2012). Appendix C discusses the derivation of these indices and the procedure for calculating them. Appendix figure A4 (panel b) shows the change in sectoral input downstreamness between 2004 and 2013. The change in the downstreamness for mining is higher in the south (18 percentage points) than in the north (15 percentage points). Overall, regional variation in the change in downstreamness and the intermediate input use share point to mining's stronger role as a downstream industry in the south than in the north. The relevance of mining in the supply chain has gradually increased over time. While the large-scale production of oil and gas in Ghana since 2010 has directly contributed to it, it is undeniable that a stronger intersectoral linkage between "other industry" and mining has also played a major role in growing importance of mining in the supply chain.

Final Remarks on Intersectoral Linkages and Structural Transformation

As a final step, we estimate sectoral TFP using the I-O tables. This technique is based on Jorgenson et al. (1987), a standard reference in the literature for the estimation of TFPs. Since we only have I-O tables for two points in time, 2004 and 2013, we can only calculate TFP for one period (2004 to 2013). As reported in appendix table A2, the TFP ratio between mining and agriculture is much larger in the south (12.088) than in the north (–9.594). The south experienced a much larger productivity shock in mining than in the north—the TFP ratio between mining and "other industry" is larger in the south (0.532) than in the north (0.204). On the other hand, the TFP ratio between mining and WRT services in the south (–1.785) is much smaller than that in the north (21.434).

Table 3 summarizes the main findings on regional differences in intersectoral linkages between 2004 and 2013 using the I-O tables for the north and the south. Simple difference-in-differences calculations (between 2004 and 2013, between the north and the south) for value-added share, Domar weights, and the TFP, suggest a larger mining output and productivity shock in the south than in the north. Correspondingly, the TFP in "other industry" is also larger in the south than in the north. In addition, the difference-in-differences outcomes on the intermediate use share, and input downstreamness index point to the prominence of mining in supply chain growing at a faster rate in the south than in the north, which in turn produces differences in intersectoral linkages with mining between the south and the north. To recapitulate, we find support for the link between the mining productivity shock and differences in intersectoral linkages between the south and the north. Several factors could explain this result, including a weak productivity shock in mining and limited intermediate use by other sectors in the north.

4. Intersectoral Linkages and Sectoral and Firm Performance

In the previous section, we presented evidence on the role of the mining output shock in shaping regional differences in intersectoral linkages. We now aim to understand the mechanisms that link production networks and structural transformation but at a more granular level. We use 2003 NIC and 2014 IBES data to examine (1) how the positive mining employment shock relates to employment growth in other sectors across districts and (2) how the positive mining employment shock across time and geographic areas affects the entry of new firms and the growth of firm employment in different sectors.

District-Level Analysis

We first examine the sensitivity of changes in employment in other sectors to changes in employment in mining across districts. Propagation of the mining employment shock to other sectors is identified based on the assumption that employment growth in sectors that have stronger linkages to mining (for example, heavy manufacturing industries) predominantly takes place in mining districts, that is, districts with at least one mining firm. The regression model is as follows:

$$\begin{aligned}&\Delta\log(Emp_d)^s_{03-13} = \alpha + \sigma\Delta\log(MEmp_d)_{03-13} + \phi\Delta\log(MEmp_{r,d'\neq d})_{03-13} + \\ &\beta_1\Delta\log(IFirm_d)_{93-03} + \beta_2\Delta\log(IFirm_d)_{83-93} + \beta_3\Delta\log(SFirm_d)_{93-03} + \\ &\beta_4\Delta\log(SFirm_d)_{83-93} + \varepsilon_d,\end{aligned} \tag{1}$$

where $\Delta\log(Emp_d)^s_{03-13}$ and $\Delta\log(MEmp_d)_{03-13}$ measure changes in log employment in sector s in district d between 2003 and 2013 and changes in the mining sector in district d between 2003 and 2013, respectively. To capture the effect of mining activities in neighboring and other districts within the same region, we control for changes in log mining employment in region r less mining employment in district d denoted as $\Delta\log(MEmp_{r,d'\neq d})_{03-13}$. The elasticity of sectoral employment with respect to mining employment at the district level is denoted by σ, and ϕ is the elasticity of sectoral employment at the district level with respect to mining employment at the region level.

Industrial productivity in district d over the past decades may have driven employment growth in sector s and district d between 2003 and 2013. In such a case, any systematic variation in past employment growth across districts could confound the effect of mining employment growth on employment growth in other sectors. To filter out this confounding effect, we control for the growth of firms in industry between 1993 and 2003

($\Delta\log(IFirm_d)_{93-03}$), and between 1983 and 1993 ($\Delta\log(IFirm_d)_{83-93}$), and the growth of firms in services between 1993 and 2003 ($\Delta\log(SFirm_d)_{93-03}$) and between 1983 and 1993 ($\Delta\log(SFirm_d)_{83-93}$). We estimate equation 1 using district-level employment figures that we construct from firm-level data.

Table 3 reports the regression results for equation 1, separately for light and heavy manufacturing, at the national level, and separately for the north and the south. Overall, the association between changes in employment in both heavy and light manufacturing and changes in employment in mining is positive. The elasticity of heavy manufacturing employment with respect to mining employment (.31) is almost 50 percent larger than the elasticity of light manufacturing employment with respect to mining employment (.21). The difference in the results between the north and the south supports a stronger production network between heavy manufacturing and mining in the south than in the north. The aggregate employment effect at the region level, however, is stronger for light manufacturing than heavy manufacturing in the south. Lastly, industrial development in the previous decades appears to play a less significant role compared to the growth in mining employment in explaining employment growth in manufacturing between 2003 and 2013.

Identification of intersectoral linkages in equation 1 relies only on geographic proximity to a mining firm. As such, it is not sensitive to the time lag between the establishment of a mining firm and a manufacturing firm. In our next model, production networks are identified jointly by the location of a mining firm and the year in which it was established, as follows:

$$\begin{aligned}NewFirm^s_{d,t} &= \alpha + \beta_1 NewMFirm_{d,t} + \beta_2 NewMFirm_{d,t-1} + \delta_1 NewMFirm_{r(d'\neq d),t} + \\ &\delta_2 NewMFirm_{r(d'\neq d),t-1} + \varepsilon_{d,t}.\end{aligned} \quad (2)$$

$NewFirm^s_{d,t}$ is an indicator variable, which takes the value of one, if at least one new firm enters in sector *s*, in district *d*, and in year *t*, and zero otherwise. β_1 and β_2 denote the immediate and lagged (by one year) effect of the number of new mining firms established in district *d* on the probability of having a new firm in sector *s* and district *d*. To estimate equation 2, we use a district-year panel comprising 119 districts and 24 years (1990–2013) based on the location and the year of establishment of a firm, using 2014 IBES data. Since employment and other firm characteristics are available only for the census year, we use the number of firms to measure the outcome variable. For the same reason, the explanatory variables are also measured using the number of firms established in different years. Similar to equation 1, we control for the aggregate effect at the region level.

Table 4 reports the regression results for equation 2 separately for light manufacturing, heavy manufacturing, "other industry," WRT services, and "other services," and by north versus south. To establish the causal effect of the growth of firms in mining on the growth of firms in other sectors, we conduct placebo tests. We consider the lead effects of new mining firms for two periods, $NewMFirm_{d,t+1}$ and $NewMFirm_{d,t+2}$. In the north (panel a), we find weak evidence of the relationship between the entry of new firms in other sectors and in mining, as the results are mostly statistically insignificant. This is primarily due to the limited expansion of mining in the north. In the south (panel b), both contemporaneous and lagged effects of new mining firms on the entry of heavy manufacturing firms are positive and statistically significant. The entry of mining and heavy manufacturing firms in the south appears causal based on the results of the placebo tests, as the lead effects are statistically insignificant for heavy manufacturing. For other sectors, the placebo test results do not support a causal interpretation for the increase in the number of firms due to an increase in the number of mining firms. Appendix table A4 reports the regression results for equation 2 at the national level. For heavy manufacturing, the results at the national level reflect a combination of the results obtained at the regional level.

To conclude, the district-level results reinforce the results in Section 3 based on regional I-O tables that mining has a stronger effect on heavy manufacturing through production networks in the south than in the north.

Firm-Level Analysis

The district-level evidence suggests that employment in heavy manufacturing has grown in mining districts between 2003 and 2013. An increase in the number of heavy manufacturing firms could generate this result, without an increase in average employment in heavy manufacturing firms in mining districts. We test whether average log employment in different sectors (heavy manufacturing, in particular) is higher in mining districts in the south, based on the following model:

$$\log Emp_i = \alpha + \phi South_i + \gamma MDist_i + \delta_{DD} South_i \times MDist_i + \theta' X_i + \varepsilon_{i.} \quad (3)$$

We estimate the double-difference parameter (δ_{DD}) in equation 3 using 2014 IBES data, controlling for various firm characteristics (X_i) including informality status, type of ownership, and legal organization.

Table 5 reports the regression results for equation 3, separately for light manufacturing, heavy manufacturing, "other industry," WRT services, and "other services." An increase in the size of employment in an average firm in heavy manufacturing if it is located in a mining district in the south (compared to firms in other districts) is higher by 23.2 percent, followed by 13.7 percent higher in "other industry," 12.1 percent higher in "other services" and 6.2 percent higher in WRT services. The result is statistically significant only for heavy manufacturing and "other services."

Finally, we extend our model in equation 3 to include the effect of changes in the mining employment shock over time, as follows:

$$\log ManEmp_{i,t} = \alpha + \phi South_i + \gamma MDist_i + \beta Year_t + \delta_{DDD} South_i \times MDist_i \times Year_t + \theta' X_{i,t} + \varepsilon_{i,t}. \quad (4)$$

Equation 4 estimates the difference in average employment of a firm in the manufacturing sector if it is located in a mining district in the south compared to other manufacturing firms between 2003 and 2013. Since we use both 2003 NIC and 2014 IBES data, to estimate δ_{DDD}, the sample is restricted to only manufacturing firms. $X_{i,t}$ in equation 4 controls for various firm-level characteristics other than employment.

Table 6 reports the results of the regression results for equation 4 separately for light and heavy manufacturing. We do not find a significant difference in employment in light manufacturing firms that are located in mining districts in the south and light manufacturing firms located in other districts between 2003 and 2013. Among light manufacturing industries, average firm employment in the food industry grew by almost 26 percent in mining districts in the south over this period compared to those in other districts. Meanwhile, average firm employment in the paper industry fell by 22 percent in mining districts in the south compared to those in other districts during the same period.

Average employment size in heavy manufacturing firms in mining districts in the south grew by 31 percent compared to firms in other districts between 2003 and 2013. The firm-level evidence suggests that firm growth in heavy manufacturing over this period is primarily driven by chemical firms, registering a growth of 61 percent in average firm employment size, followed by nonmetal (30 percent), machinery (28 percent), and metal (23 percent). Overall, the growth in average employment size in heavy manufacturing firms is more than three times larger than that for light manufacturing firms in mining districts in the south between 2003 and 2013.

Summarizing the results from the analysis at the district and firm levels, the variation in the mining employment shock across districts corresponds to employment growth particularly in heavy manufacturing sectors in the south between 2003 and 2013. This process of structural transformation was facilitated by the entry of new firms in the heavy manufacturing sector in the mining districts as well as by an increase in the average size of employment in heavy manufacturing firms in the mining districts over time.

5. Conclusion

Evidence based on regional I-O tables and census data for firms supports the occurrence of a mining shock in the south of Ghana. We find evidence that the mining productivity shock drove the differentiation of production networks and the structural transformation process in the north and the south of the country. We interpret the regional difference in the sectoral composition of economic activities to be possibly due to weak interregional linkages which prevent the propagation of the local sectoral productivity shock from the south to the north.

Regional differences in intersectoral linkages and the pattern of structural transformation have several implications for aggregate productivity growth in Ghana. First, a large mining output shock in the south creates scope for policy interventions to sustain productivity growth by maintaining a strong production network in the region. Industrial policies aimed at fostering stronger linkages between mining and other sectors can help not only to secure greater economic gains from mining in the south but also to redress the lack of access to modern energy services in other sectors, particularly in manufacturing, as suggested by Aryeetey and Ackah (2018). Second, allocating resources to strengthen intersectoral linkages in the north also appears crucial as geological preconditions for oil and gas deposits have been found in the Voltaic basin located in the north of the country (Skaten 2018).

Third, divergent patterns of structural transformation across regions promote regional specialization (for example, clothing industry in the north, heavy manufacturing in the south), which, with lower trade costs, could enhance aggregate productivity growth through stronger interregional linkages (Caliendo et al. 2018). Finally, with Ghana's upstream mining activities and petroleum revenues starting to recover in the first half of 2021 in the wake of the pandemic, followed by a negative oil price shock, the country is better positioned to pursue placed-based development (Kline and Moretti 2014)—a strategy that has already been emphasized in the context of Ghana (Aragon and Rud 2013; Fafchamps et al. 2017).

Our study suggests two areas for further research. First, similar studies on other emerging oil and gas producers including Kenya, Mozambique, Tanzania, and Uganda could provide insight into the role of mining in structural transformation and productivity growth in the presence of weak interregional linkages. Second, further examination of changes in intersectoral linkages and reallocation of sectoral output arising from productivity shocks in manufacturing and wholesale and retail trade services could help inform policy makers on how to make the ongoing process of industrialization in Sub-Saharan Africa sustainable (McMillan and Zeufack 2022).

References

Acemoglu, Daron, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. 2012. "The Network Origins of Aggregate Fluctuations." *Econometrica* 80 (5): 1977–2016.

Aragon, Fernando M., and Juan Pablo Rud. 2015. "Polluting Industries and Agricultural Productivity: Evidence from Mining in Ghana." *Economic Journal* 126: 1980–2011.

Allen, Treb, and Costas Arkolakis. 2014. "Trade and the Topography of the Spatial Economy." *Quarterly Journal of Economics* 129 (3): 1085–140.

Antras, Pol, and Davin Chor. 2013. "Organizing the Global Value Chain." *Econometrica* 81 (6): 2127–204.

Antras, Pol, Davin Chor, Thibault Fally, and Russell Hillberry. 2012. "Measuring the Upstreamness of Production and Trade Flows." *American Economic Review Papers & Proceedings* 102 (3): 412–16.

Aryeetey, Ernest, and Ishmael Ackah. 2018. "The Boom, the Bust, and the Dynamics of Oil Resource Management in Ghana." WIDER Working Paper 2018/89, United Nations University World Institute for Development Economic Research, Helsinki, Finland.

Aryeetey, Ernest, Robert D. Osei, and Peter Quartey. 2014. "Managing Ghana's Oil Boom: Summary of Key Finding and Policy Lessons." In *Managing Ghana's Oil Boom for Structural Transformation,* edited by Ernest Aryeetey, Robert D. Osei, and Peter Quartey, 1–7. Accra: Institute of Statistical, Social and Economic Research.

Atalay, Enghin. 2017. "How Important Are Sectoral Shocks?" *American Economic Journal: Macroeconomics* 9: 254–80.

Baumol, William J. 1967. "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis." *American Economic Review* 57: 415–26.

Brand, Steven, Stephen Hills, and Max Munday. 2000. "Assessing the Impact of Foreign Manufacturing on Regional Economics: The Case of Wales, Scotland and the West Midlands." *Regional Studies* 34: 343–55.

Breisinger, Clemens, and James Thurlow, eds. 2006. *A 2005 Social Accounting Matrix (SAM) For Ghana.* Accra, Ghana: Ghana Statistical Service.

Caliendo, Lorenzo, Fernando Parro, Esteban Rossi-Hansberg, and Pierre-Daniel Sarte. 2018. "The Impact of Regional and Sectoral Productivity Changes on the U.S. Economy." *Review of Economic Studies* 85: 2042–96.

Carvalho, Vasco M., Makoto Nirei, Yukiko U. Saito, and Alireza Tahbaz-Salehi. 2021. "Supply Chain Disruptions: Evidence from the Great East Japan Earthquake." *Quarterly Journal of Economics* 136 (2): 1255–321.

Caselli, Francesco, and Wilbur John Coleman II. 2001. "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation." *Journal of Political Economy* 109 (3): 584–616.

Comin, Diego, Danial Lashkari, and Marti Mestieri. 2021. "Structural Change with Long-Run Income and Price Effects." *Econometrica* 89 (1): 311–74.

Corathers, Lisa A. 2019. "Maganese." In *Mineral Commodity Summaries 2019*, prepared by the National Minerals Information Center104–5. Reston, VA: U.S. Geological Survey.

Desmet, Klaus, and Esteban Rossi-Hansberg. 2014. "Spatial Development." *American Economic Review* 104 (4): 1211–43.

Eurostat. 2008. "Eurostat Manual of Supply, Use and Input-Output Tables." Eurostat Methodologies and Working Papers, Luxembourg.

Fafchamps, Marcel, Michael Koelle, and Forhad Shilpi. 2017. "Gold Mining and Proto-Urbanization: Recent Evidence from Ghana." *Journal of Economic Geography* 17 (5): 975–1008.

Feyrer, James, Erin T. Mansur, and Bruce Sacerdote. 2017. “Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution.” *American Economic Review* 107 (4): 1313–34.

Flegg, Anthony T., and Timo Tohmo. 2011. “Regional Input-Output Tables and the FLQ Formula: A Case Study of Finland.” *Regional Studies* 47 (5): 703–21.

Flegg, Anthony T., and C. D. Webber. 2000. “Regional Size, Regional Specialization and the FLQ Formula.” *Regional Studies* 34: 563–9.

Flegg, Anthony T., C. D. Webber, and M. V. Elliott. 1995. “On the Appropriate Use of Location Quotients in Generating Regional Input-Output Tables.” *Regional Studies* 29: 547–61.

Fosu, Augustin Kwasi. 2017. “Oil and Ghana’s Economy.” In *The Economy of Ghana Sixty Years After Independence,* edited by Ernest Aryeetey and Ravi Kanbur, 137. Oxford: Oxford University Press.

Kowalewski, Julia. 2013. “Regionalization of National Input–Output Tables: Empirical Evidence on the Use of the FLQ Formula.” *Regional Studies* 49 (2): 1–11.

GSS (Ghana Statistical Service). 2006. *2003 National Industrial Census Report, Background and Results.* Accra, Ghana: Ghana Statistical Service.

GSS (Ghana Statistical Service). 2016. *Integrated Business Establishment Survey: Regional Spatial Business Report*. Accra, Ghana: Ghana Statistical Service.

GSS (Ghana Statistical Service). 2018. *Integrated Business Establishment Survey Phase II: Comprehensive Sectoral Report*. Accra, Ghana: Ghana Statistical Service.

GSS (Ghana Statistical Service). 2021. *The Supply and Use Tables, Year 2013*. Accra, Ghana: Ghana Statistical Service.

Harrigan, Frank J., and James McGilvray. 1988. “The Measurement of Interindustry Linkages.” *Ricerche Economiche* 42: 325–43.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2013. “Two Perspectives on Preferences and Structural Transformation.” *American Economic Review* 103 (7): 2752–89.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2014. “Growth and Structural Transformation.” *Handbook of Economic Growth*, Vol. 2B (Amsterdam and New York): 855–941.

Herrendorf, Berthold, and Akos Valentinyi. 2012. “Which Sectors Make Poor Countries So Unproductive?” *Journal of the European Economic Association* 10: 323–41.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. 1987. *Productivity and U.S. Economic Growth*. Cambridge, MA: Harvard University Press.

Jorgenson, Dale W., and Kevin J. Stiroh. 2001. “Raising the Speed Limit: U.S. Economic Growth in the Information Age.” In *Industry-Level Productivity and International Competitiveness Between Canada and the United States*, edited by Dale W. Jorgenson and Frank Chung Lee, 2–75. Ottawa: Industry Canada.

Kline, Patrick, and Enrico Moretti. 2014. “People, Places and Public Policy: Some Simple Welfare Economics of Local Economic Development Programs.” *Annual Review of Economics* 6.

Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie. 2001. “Beyond Balanced Growth.” *Review of Economic Studies* 68 (4): 869–82.

Kowalewski, Julia. 2013. “Regionalization of National Input–Output Tables: Empirical Evidence on the Use of the FLQ Formula.” *Regional Studies* 49 (2): 1–11.

Lin, Boqiang, Presley K. Wesseh Jr., and Micheal Owusu Appiah. 2014. “Oil Price Fluctuation, Volatility Spillover and the Ghanaian Equity Market: Implication for Portfolio Management and Hedging Effectiveness.” *Energy Economics* 42: 172–82.

Liu, Ernest. 2019. “Industrial Policies in Production Networks.” *Quarterly Journal of Economics* 134: 1883–948.
McMillan, Margaret, and Albert Zeufack. 2022. “Labor Productivity Growth and Industrialization in Africa.” *Journal of Economic Perspectives* 36 (1): 3–32.
McNerney, James, Charles Savoie, Francesco Caravelli, Vasco M. Carvalho, and J. Doyne Farmer. 2022. “How Production Networks Amplify Economic Growth.” *Proceedings of the National Academy of Sciences* 119 (1).
Miller, Ronald E., and Peter D. Blair. 2009. *Input-Output Analysis: Foundations and Extensions*, Second Edition. Cambridge, UK: Cambridge University Press.
Miller, Ronald E., and Umed Temurshoev. 2017. “Output Upstreamness and Input Downstreamness of Industries / Countries in World Production.” *International Regional Science Review* 40: 443–75.
Ngai, L. Rachel, and Christopher A. Pissarides. 2007. “Structural Change in a Multisector Model of Growth.” *American Economic Review* 97 (1): 429–43.
Oberfield, Ezra. 2018. “A Theory of Input-Output Architecture.” *Econometrica* 86: 559–89.
OEF (Oxford Energy Forum). 2019. “Africa’s Oil and Gas Scene After the Boom.” *The Oxford Institute for Energy Studies* January 117: 1–31.
Osei, Robert Darko, Richmond Atta-Ankomah, and Monica Lambon-Quayefio. 2020. “Structural Transformation and Inclusive Growth in Ghana.” WIDER Working Paper 2020/36, United Nations University World Institute for Development Economic Research, Helsinki, Finland.
Paul, Saumik, and Dhushyanth Raju. 2021. “Barriers to Growth-Enhancing Structural Transformation: The Role of Subnational Differences in Intersectoral Productivity Gaps.” Policy Research Working Paper 9683, World Bank, Washington, DC.
PIAC (Public Interest and Accountability Committee). 2021. “Semi-Annual Report on the Management and Use of Petroleum Revenues for the Period January–June, 2021.” https://www.piacghana.org/portal/files/downloads/piac_reports/piac_2021_semi-annual_report_p.pdf.
Skaten, Monica. 2018. “Ghana’s Oil Industry: Steady Growth in a Challenging Environment.” WPM 77, The Oxford Institute for Energy Studies, University of Oxford, Oxford, UK.
Toews, Gerhard, and Pierre-Louis Vezina. 2022. “Resource Discoveries, FDI Bonanzas, and Local Multipliers: Evidence from Mozambique.” *Review of Economics and Statistics* 104 (5): 1046–58.
World Bank. 2022. *Africa in the New Trade Environment: Market Access in Troubled Times.* Washington DC: World Bank.
WTO (World Trade Organization). 2018. *World Trade Statistical Review*. Geneva: WTO.

Table 1: Firms and Employees, Mining and Manufacturing, 2003 and 2013

		2003 (number) (1)	2013 (number) (2)	Change, 2003 to 2013 (number) (3)	South/north in (3) (ratio) (4)
a. Firms					
Mining	National	125	294	169	14.4
	North	22	33	11	
	South	103	261	158	
Manufacturing	National	23,797	101,789	77,992	1.9
	North	4,623	31,281	26,658	
	South	19,174	70,508	51,334	
b. Employees					
Mining	National	14,869	40,120	25,251	62.4
	North	247	645	398	
	South	14,622	39,475	24,853	
Manufacturing	National	116,774	271,863	155,089	3.5
	North	10,386	44,507	34,121	
	South	106,388	227,356	120,968	

Source: Authors' estimates based on data from the 2003 National Industrial Census and the 2014 Integrated Business Establishment Survey.

Table 2: Input-Output Tables, 2004 and 2013

a. 2004 (in billion 2004 cedis)

		AGR	MIN	O-IND	WRT	O-SER	Intermediate share of output	Final demand	Output
2004 (in 2004 prices)	AGR	0.077	0.000	0.117	0.016	0.000	0.211	32,513	41,195
	MIN	0.000	0.000	0.066	0.000	0.000	0.066	4,472	4,790
	O-IND	0.031	0.036	0.201	0.025	0.070	0.362	14,141	22,174
	WRT	0.272	0.010	0.194	0.092	0.000	0.567	5,433	12,562
	O-SER	0.070	0.011	0.017	0.129	0.252	0.479	20,915	40,135

b. 2013 (in billion 2013 cedis)

		AGR	MIN	O-IND	WRT	O-SER	Intermediate share of output	Final demand	Output
2013 (in 2013 prices)	AGR	0.136	0.000	0.068	0.018	0.041	0.263	30,944	41,959
	MIN	0.000	0.053	0.138	0.001	0.004	0.195	21,913	27,227
	O-IND	0.039	0.026	0.099	0.145	0.080	0.388	45,247	73,906
	WRT	0.010	0.090	0.001	0.003	0.180	0.284	38,534	39,654
	O-SER	0.072	0.019	0.042	0.073	0.119	0.325	38,703	57,364

Source: Authors' elaboration based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021).

Note: AGR = agriculture. MIN = mining. O-IND = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. O-SER = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services.

Table 3: Change in Intersectoral Linkages, 2004–2013

	Change in X [2013–2004] in the south – change in X [2013–2004] in the north				
X =	Value-added share	Domar weight	Total factor productivity	Intermediate use share	Input downstreamness index
	(1)	(2)	(3)	(4)	(5)
AGR	0.181	0.162	–0.021	0.005	0.005
MIN	**0.067**	**0.070**	**0.004**	**0.019**	**0.033**
O-IND	–0.118	–0.092	0.355	–0.007	–0.025
WRT	0.026	–0.058	0.067	–0.248	–0.308
O-SER	–0.155	–0.253	–0.065	–0.023	–0.116

Source: Authors' elaboration based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021).

Note: TFP = total factor productivity. AGR = agriculture. MIN = mining; O-IND = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. O-SER = services other than wholesale and retail trade; they include transport, communication, finance, commerce, government services, and private services.

Following Antras et al. (2012), input downstreamness is measured as $D_i = 1 \times \frac{V_i}{X_i} + 2 \times \frac{\sum_j^5 V_j A_{ji}}{X_i} + 3 \times \frac{\sum_j^5 \sum_k^5 V_j A_{jk} A_{ki}}{X_i} + 4 \times \frac{\sum_j^5 \sum_k^5 \sum_s^5 V_j A_{jk} A_{ks} A_{si}}{X_i} + \cdots$.

Table 4: Sectoral Employment Elasticities

	$\Delta\log(Emp_d)^s_{03-13}$					
	National		North		South	
	Light manufacturing (1)	Heavy manufacturing (2)	Light manufacturing (3)	Heavy manufacturing (4)	Light manufacturing (5)	Heavy manufacturing (6)
$\Delta\log(MEmp_d)_{03-13}$	0.210**	0.312***	0.558***	0.259	0.164	0.355***
	(0.087)	(0.105)	(0.156)	(0.323)	(0.106)	(0.111)
$\Delta\log(MEmp_{r,d'\neq d})_{03-13}$	0.451***	0.254*	–0.219	–0.172	1.109***	0.554*
	(0.147)	(0.132)	(0.272)	(0.360)	(0.326)	(0.282)
$\Delta\log(IFirm_d)_{93-03}$	–0.403	–0.032	–0.353	–0.086	–0.891	0.204
	(0.625)	(0.966)	(0.966)	(1.411)	(1.180)	(1.045)
$\Delta\log(IFirm_d)_{83-93}$	–0.225	–0.970	–0.237	–1.006	0.282	–0.936
	(0.706)	(0.843)	(0.780)	(1.206)	(1.269)	(1.245)
$\Delta\log(SFirm_d)_{93-03}$	–1.214	1.945	–3.546	–0.173	–0.932	2.822
	(1.679)	(1.688)	(3.058)	(3.468)	(2.698)	(2.933)
$\Delta\log(SFirm_d)_{83-93}$	3.569*	3.240*	0.565	2.313	6.719*	3.760
	(1.933)	(1.855)	(2.433)	(2.888)	(3.977)	(4.078)
Constant	–1.853	–2.792**	3.197	0.489	–6.849***	–5.569***
	(1.261)	(1.135)	(2.209)	(2.320)	(1.617)	(1.676)
N	136	136	67	67	69	69
R^2-statistic	0.167	0.175	0.188	0.052	0.400	0.331

Source: Authors' estimates based on data from the 2003 National Industrial Census, the 2014 Integrated Business Establishment Survey, and GSS (2016).

Note: This table reports estimates for equation 1. Dependent variable = district-level employment in the given sector. Standard errors are reported in parentheses. Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 5: Firm Creation, North and South

	$NewFirm^{s}_{d,t}$				
	Light manufacturing (1)	Heavy manufacturing (2)	Other industry (3)	WRT services (4)	Other services (5)
a. North					
$NewMFirm_{d,t-1}$	0.111	0.059	0.143	0.242	0.633***
	(0.206)	(0.131)	(0.148)	(0.221)	(0.100)
$NewMFirm_{d,t}$	0.679*	0.046	0.130	–0.001	0.034
	(0.359)	(0.095)	(0.104)	(0.112)	(0.267)
$NewMFirm_{d,t+1}$	0.419*	0.406	0.032	0.058	–0.263
	(0.226)	(0.293)	(0.046)	(0.249)	(0.161)
$NewMFirm_{d,t+2}$	–0.429***	–0.128	–0.050	0.322	0.007
	(0.106)	(0.085)	(0.049)	(0.213)	(0.232)
Constant	0.366***	0.153***	0.110***	0.425***	0.538***
	(0.028)	(0.022)	(0.016)	(0.026)	(0.029)
N	1,407	1,407	1,407	1,407	1,407
R^2-statistic	0.036	0.018	0.007	0.019	0.027
b. South					
$NewMFirm_{d,t-1}$	0.012	0.123***	0.239***	0.117*	0.058
	(0.053)	(0.044)	(0.067)	(0.064)	(0.071)
$NewMFirm_{d,t}$	-0.042	0.163***	-0.003	0.123*	0.049
	(0.047)	(0.047)	(0.045)	(0.073)	(0.056)
	(0.030)	(0.025)	(0.014)	(0.032)	(0.025)
$NewMFirm_{d,t+1}$	0.167***	0.067	0.105***	0.213***	0.109***
	(0.051)	(0.044)	(0.032)	(0.045)	(0.036)
$NewMFirm_{d,t+2}$	0.060	0.080	-0.030	0.189***	0.046
	(0.041)	(0.051)	(0.038)	(0.056)	(0.053)
Constant	0.409***	0.211***	0.116***	0.384***	0.583***
	(0.030)	(0.028)	(0.023)	(0.029)	(0.032)
N	1,449	1,449	1,449	1,449	1,449
R^2-statistic	0.027	0.019	0.027	0.050	0.028

Source: Authors' estimates based on data from the 2014 Integrated Business Establishment Survey.

Note: This table presents estimates for equation 2. The dependent variable is an indicator variable indicating entry of at least one new firm in year *t* in district *d* in the given sector. The database used consists of a district-year panel comprising 119 districts and 24 years (1990–2013) based on the location and year of entry of the firm. Other industry = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. Other services = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services. Standard errors are reported in parentheses. Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 6: Changes in Average Firm-Level Employment across Districts

	$\log Emp_i$				
	Light manufacturing (1)	Heavy manufacturing (2)	Other industry (3)	WRT services (4)	Other services (5)
$MDist \times South$	–0.007	0.209**	0.128	0.060	0.114***
	(0.059)	(0.086)	(0.198)	(0.042)	(0.042)
$MDist$	0.019	0.033	0.130	0.040	–0.027
	(0.041)	(0.066)	(0.129)	(0.026)	(0.031)
$South$	0.333***	0.308***	0.112	0.453***	0.349***
	(0.070)	(0.115)	(0.271)	(0.052)	(0.055)
Constant	4.053***	3.498***	3.117***	2.598***	2.689***
	(0.197)	(0.330)	(0.249)	(0.226)	(0.053)
N	3,851	1,560	814	5,618	10,903
R^2-statistic	0.356	0.484	0.264	0.345	0.290

Source: Authors' estimates based on data from the 2014 Integrated Business Establishment Survey.

Note: This table presents estimates for equation 3. Dependent variable = log employment in manufacturing. Other industry = those industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. Other services = those services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services. All regressions control for the informality status of a firm, the type of ownership, the type of legal organization, and region. Standard errors are reported in parentheses. Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table 7: Changes in Firm-Level Employment, 2003–2013

a. Light manufacturing

	$\log ManEmp_{i,t}$				
	Light	Food	Clothing	Paper	Other
	(1)	(2)	(3)	(4)	(5)
$MDist \times Year \times South$	0.089	0.229**	0.062	–0.224	0.159*
	(0.080)	(0.116)	(0.105)	(0.183)	(0.082)
$MDist$	0.076	–0.054	0.085	0.254*	0.070
	(0.057)	(0.079)	(0.068)	(0.132)	(0.044)
$Year$	–0.644***	–0.494***	–0.712***	–0.421***	–0.756***
	(0.043)	(0.080)	(0.060)	(0.154)	(0.051)
$South$	–0.035	0.181**	–0.141**	0.056	–0.125***
	(0.039)	(0.085)	(0.056)	(0.123)	(0.042)
Constant	4.695***	4.915***	4.293***	4.427***	3.497***
	(0.176)	(0.311)	(0.228)	(0.342)	(0.280)
N	5,895	1,398	2,224	874	1,399
R^2-statistic	0.358	0.457	0.250	0.392	0.318

b. Heavy manufacturing

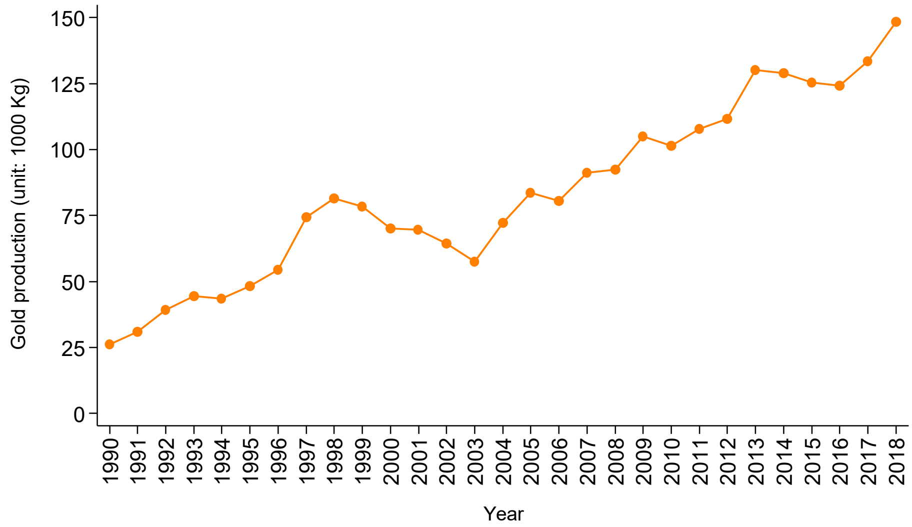
	$\log ManEmp_{i,t}$				
	Heavy	Chemical	Nonmetallic mineral	Metal	Machinery
$MDist \times Year \times South$	0.267***	0.482*	0.257	0.209*	0.247
	(0.076)	(0.270)	(0.172)	(0.116)	(0.156)
$MDist$	0.047	–0.425***	–0.001	0.185***	0.114
	(0.053)	(0.146)	(0.109)	(0.064)	(0.110)
$Year$	–0.564***	–0.530**	–0.388***	–0.686***	–0.465***
	(0.055)	(0.212)	(0.109)	(0.093)	(0.106)
$South$	–0.078	–0.041	–0.023	–0.124	–0.145
	(0.048)	(0.205)	(0.113)	(0.082)	(0.101)
Constant	4.258***	5.236***	4.474***	4.199***	3.385***
	(0.283)	(0.446)	(0.452)	(0.373)	(0.258)
N	2,206	378	400	1,050	378
R^2-statistic	0.454	0.546	0.301	0.419	0.433

Source: Authors' estimates based on data from the 2003 National Industrial Census and the 2014 Integrated Business Establishment Survey.

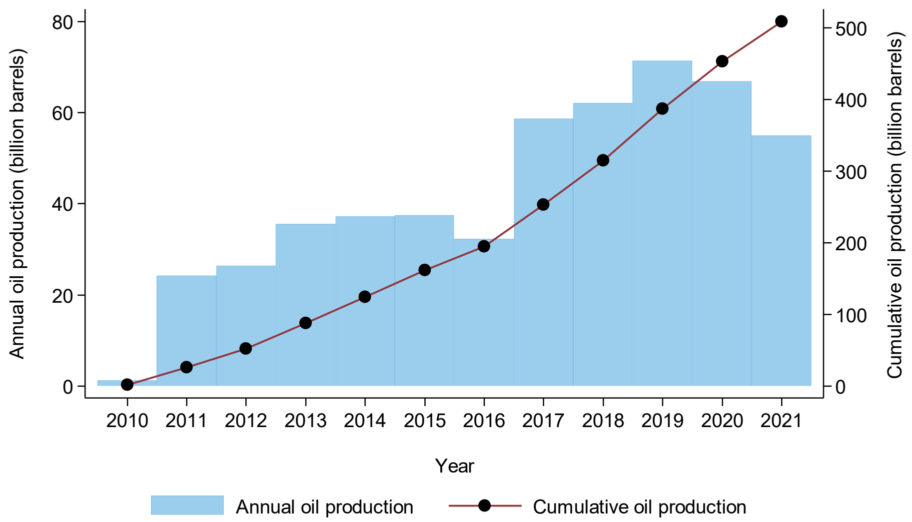
Note: This table reports estimates for equation 4. Dependent variable = log employment in firm *i* at time *t*. All regressions control for the informality status of a firm, the type of ownership, the type of legal organization, and region. Standard errors are reported in parentheses. Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Figure 1: Gold and Oil Production in Ghana

a. Gold production, 1990–2018



b. Natural oil and gas production, 2010–2021



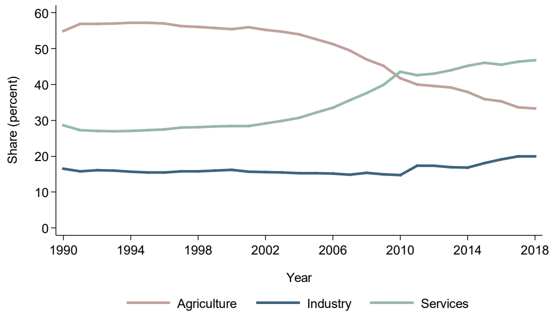
Source: Authors' estimates based on information obtained from PIAC (2021) and the United States Geological Survey (USGS) Database. https://www.usgs.gov/.

Note: Gold production figures include reported artisanal and small-scale output.

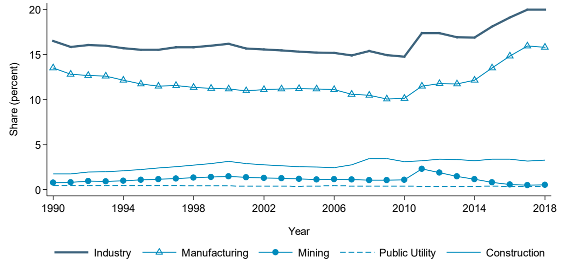
Figure 2: Trends in Sectoral Shares, for Employment and Value-Added, 1990–2018

Sectoral share of employment

a. Broad sectors

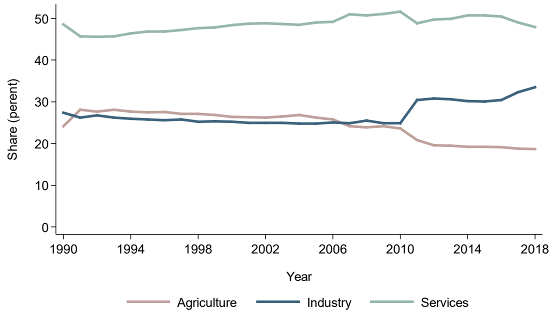


b. Subsectors within industry

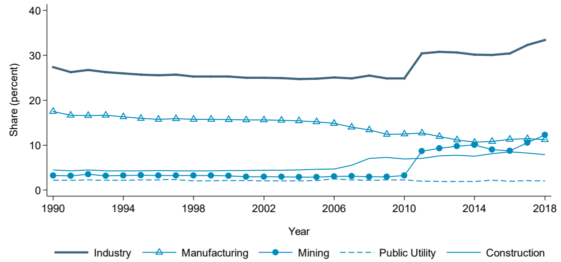


Sectoral share of value-added

c. Broad sectors



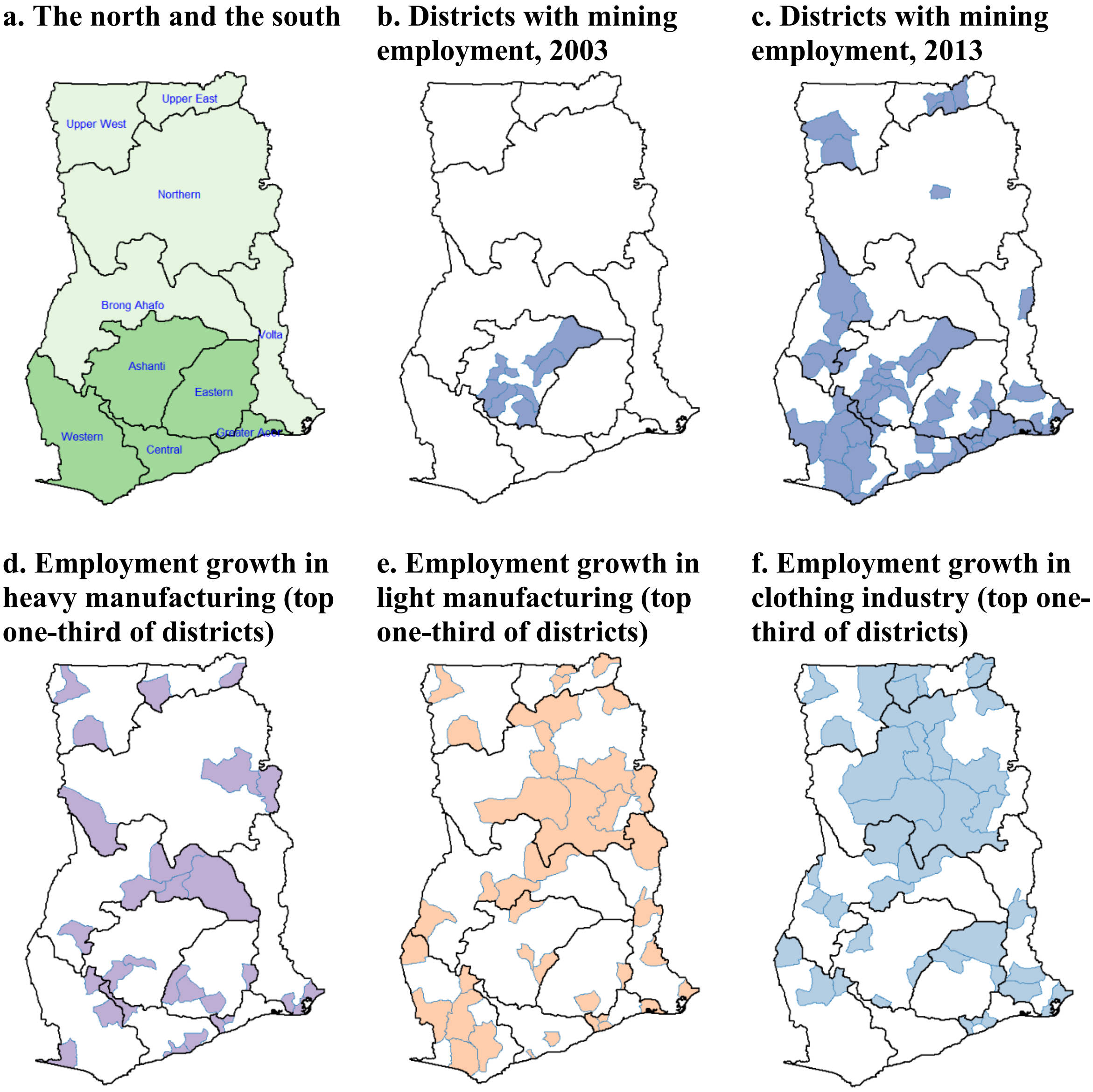
d. Subsectors within industry



Source: Authors' estimates based on statistics for Ghana from the Economic Transformation Database.

Note: Agriculture includes forestry and fisheries; industry includes mining, manufacturing, public utilities, and construction; and services include wholesale and retail trade, transportation and storage, financial and real estate activities, government services, and private services. Almost 95 percent of industrial employment is in mining and manufacturing.

Figure 3: Spatial Growth of Sectoral Employment, 2003–2013



Source: Authors' estimates based on data from the 2003 National Industrial Census and the 2014 Integrated Business Establishment Survey.

Note: In panel a, light green regions refer to the north and dark green regions refer to the south of Ghana. Panels b and c show the prevalence of mining activities at the district level. A district is shaded in grey if it has mining employment. Panel d highlights districts that are in the top one-third in terms of growth in employment in heavy manufacturing sectors between 2003 and 2013. Panel e highlights districts that are in the top one-third in terms of growth in employment in light manufacturing industries between 2003 and 2013. Panel f highlights districts that are in the top 33rd percentile in terms of growth in employment in the clothing sector between 2003 and 2013. Growth in $X = 100 \times (\log [X \text{ in } 2013] - \log [X \text{ in } 2003])$.

Appendix A

Supplemental Tables and Figures

Table A1: Spatial Disparity in Industrial Performance, 2003–2013

Industry	North			South			South–North	
	Districts *N*	Mean	SD	Districts *N*	Mean	SD		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
a. District-level growth in the number of firms								
Manufacturing	58	149	72	61	106	85	–42	***
Heavy manufacturing	40	263	109	47	268	136	5	
Light manufacturing	58	137	74	61	109	87	–27	*
Food	58	165	107	55	148	115	–18	
Clothing	58	130	135	61	78	133	–53	**
b. District-level growth in the number of employees								
Manufacturing	58	46	84	61	33	102	–13	
Heavy manufacturing	40	217	131	47	208	161	–9	
Light manufacturing	58	36	83	61	32	101	–4	
Food	58	43	141	55	75	139	33	
Clothing	58	44	158	61	–15	152	–58	**

Source: Authors' estimates based on data from the 2003 National Industrial Census and the 2014 Integrated Business Establishment Survey.

Note: Heavy manufacturing = manufacturing of coke and refined petroleum, chemicals, basic metals and fabricated metal, machinery and equipment, motor vehicles, and other transport vehicles. Light manufacturing = including wood, paper, printing and reproduction of recordings, pharmaceuticals, rubber and plastic, other nonmetallic items, computers, electronics, electrical equipment, furniture, heavy manufacturing items, food, clothing, and other manufacturing activities not classified elsewhere. Food = manufacturing of food products and beverages. Clothing = manufacturing of textiles, apparel, and leather-related products. SD = standard deviation. Growth in X = 100×(log [X in 2013] – log [X in 2003]). Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A2: Total Factor Productivity Ratios Between Sectors

	National (1)	North (2)	South (3)
Mining to agriculture	–9.221	–9.594	12.088
Mining to other industry	0.173	0.204	0.532
Mining to WRT services	–0.972	21.434	–1.785
Mining to other services	–0.266	–0.467	–0.612

Source: Authors' elaboration based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021).

Note: Other industry = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. Other services = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services.

Table A3: Firm Creation, National

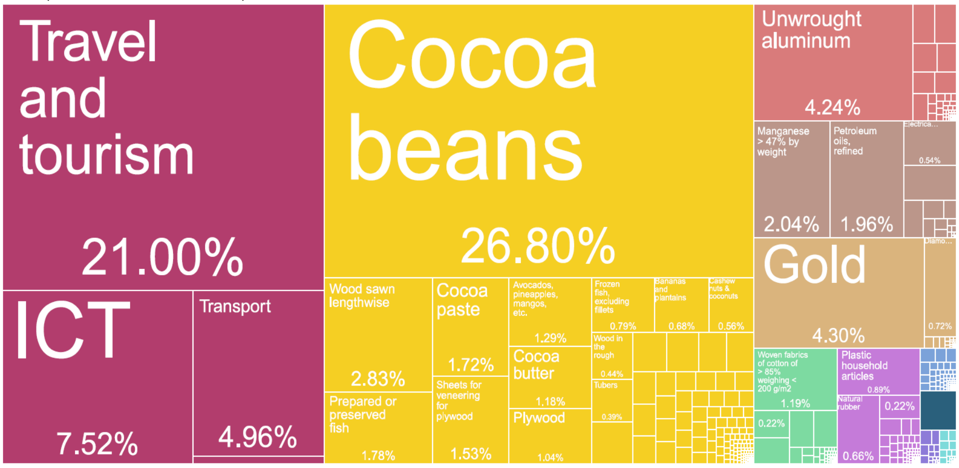
	$NewFirm^{s}_{d,t}$				
	Light manufacturing (1)	Heavy manufacturing (2)	Other industry (3)	WRT services (4)	Other services (5)
$NewMFirm_{d,t-1}$	0.043	0.131***	0.228***	0.124**	0.136*
	(0.060)	(0.045)	(0.056)	(0.061)	(0.078)
$NewMFirm_{d,t}$	0.044	0.145***	0.021	0.100	0.041
	(0.098)	(0.048)	(0.048)	(0.074)	(0.066)
$NewMFirm_{r(d'\neq d),t-1}$	0.128***	0.050**	0.024	0.112***	0.090***
	(0.025)	(0.024)	(0.018)	(0.028)	(0.026)
$NewMFirm_{r(d'\neq d),t}$	0.129***	0.047*	0.022	0.059**	0.072***
	(0.031)	(0.024)	(0.014)	(0.030)	(0.024)
$NewMFirm_{d,t+1}$	0.201***	0.116*	0.099***	0.188***	0.067
	(0.054)	(0.070)	(0.027)	(0.054)	(0.051)
$NewMFirm_{d,t+2}$	–0.012	0.049	–0.018	0.200***	0.019
	(0.063)	(0.038)	(0.035)	(0.057)	(0.059)
$NewMFirm_{r(d'\neq d),t+1}$	–0.002	–0.004	0.034*	0.089***	0.063*
	(0.027)	(0.017)	(0.017)	(0.029)	(0.033)
$NewMFirm_{r(d'\neq d),t+2}$	0.057*	0.018	0.041**	0.100***	0.100***
	(0.031)	(0.022)	(0.018)	(0.025)	(0.024)
Constant	0.393***	0.184***	0.114***	0.409***	0.566***
	(0.021)	(0.018)	(0.014)	(0.020)	(0.021)
N	2,856	2,856	2,856	2,856	2,856
R^2-statistic	0.025	0.018	0.017	0.027	0.024

Source: Authors' estimates based on data from the 2014 Integrated Business Establishment Survey.

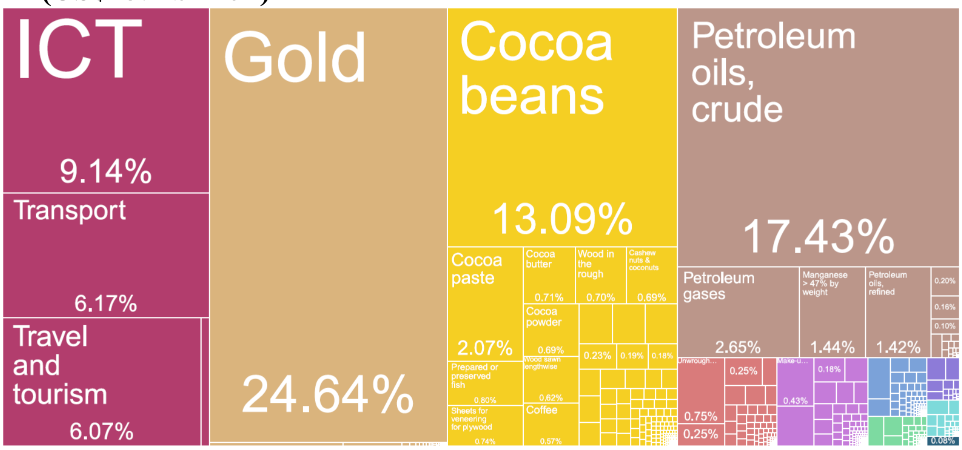
Note: This table presents estimates of the variants of the regression specification in equation 2. The dependent variable is an indicator variable indicating entry of at least one new firm in year *t* and district *d* in respective sectors. Other industry = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. Other services = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services. Standard errors are reported in parentheses. Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Figure A1: Growing Importance of Minerals in Ghana's Export Basket, 2006–2018

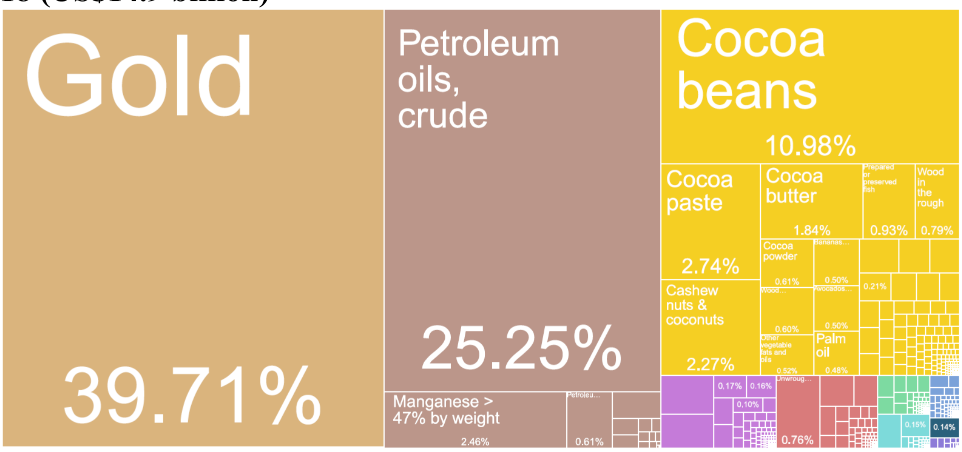
a. 2006 (US$4.1 billion)



b. 2012 (US$15.1 billion)



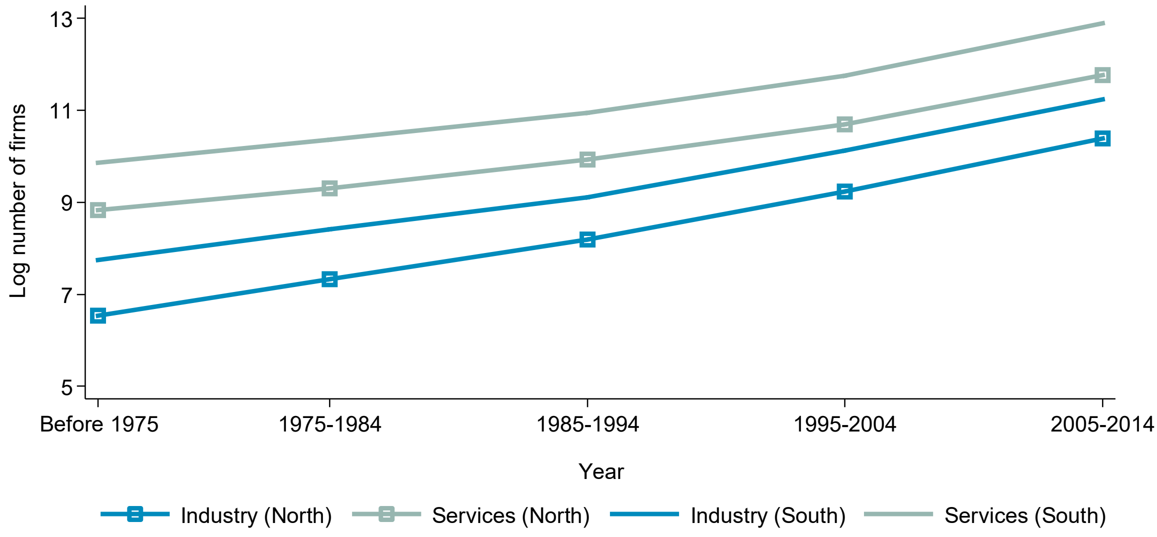
c. 2018 (US$14.9 billion)



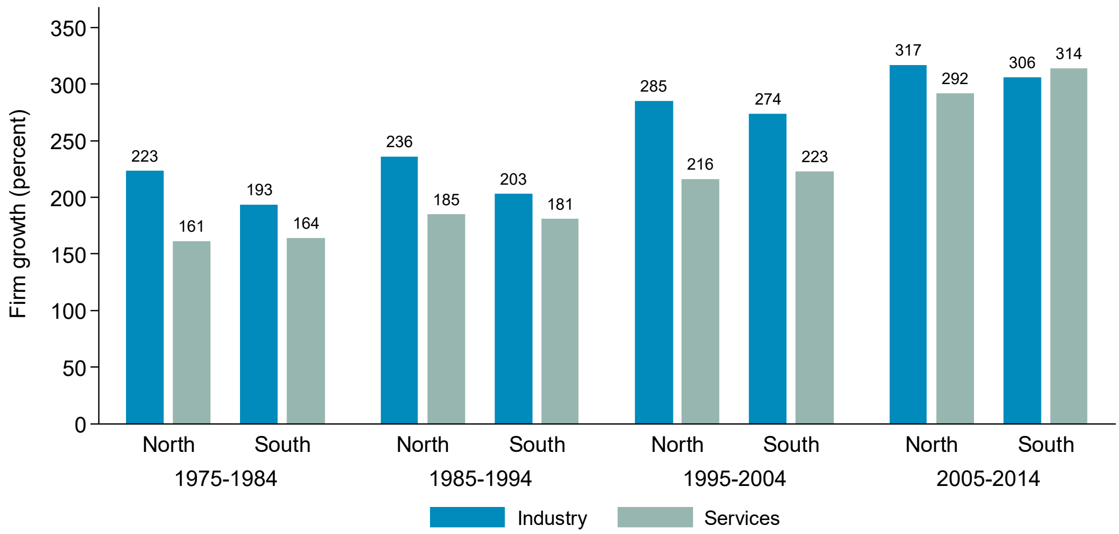
Source: Authors' estimates based on information from the Atlas of Economic Complexity by the Growth Lab at Harvard University (https://atlas.cid.harvard.edu/).

Figure A2: Firms in Industry and Services, 1975–2014, North and South

a. Number of firms



b. Growth in number of firms

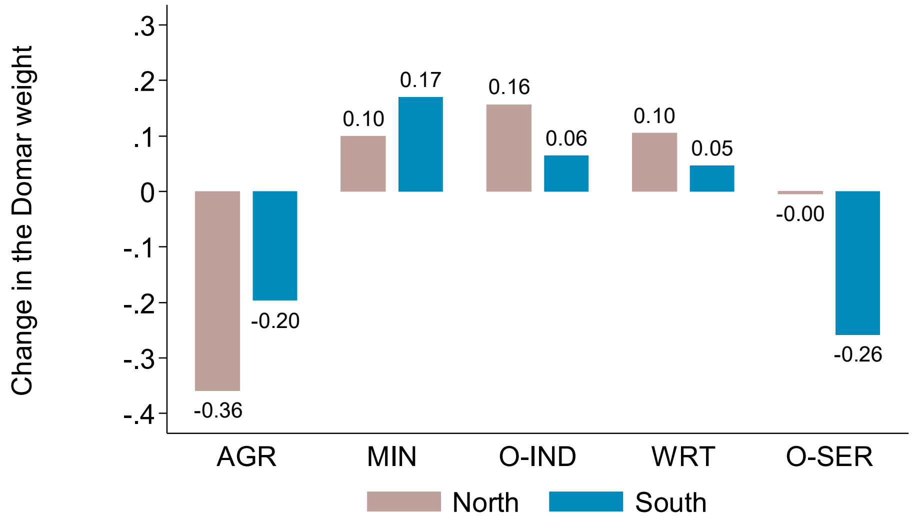


Source: Authors' estimates based on statistics obtained from GSS (2016).

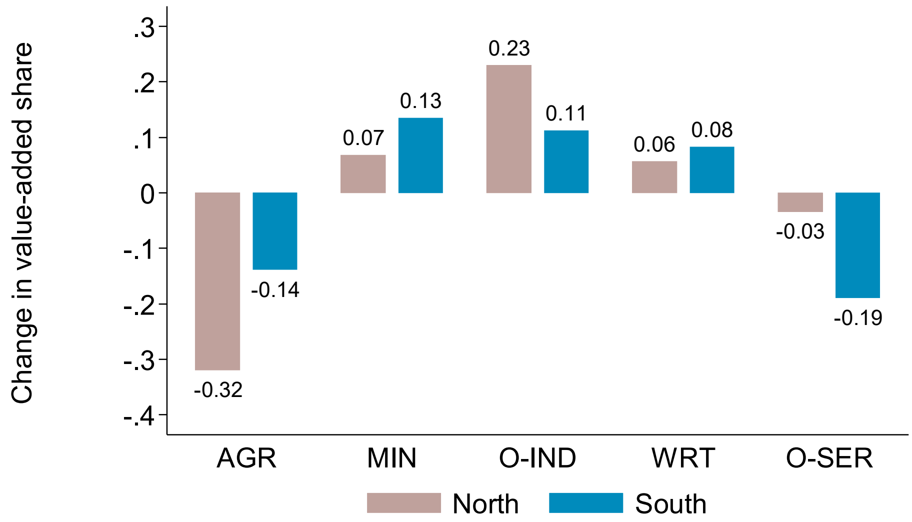
Note: Industry = mining, manufacturing, public utilities, and construction. Services = wholesale and retail trade, transportation and storage, financial and real estate activities, government services, and private services.

Figure A3: Change in the Sectoral Domar Weight and Value-Added Share, 2004-2013

a. Sectoral Domar weight



b. Value-added share

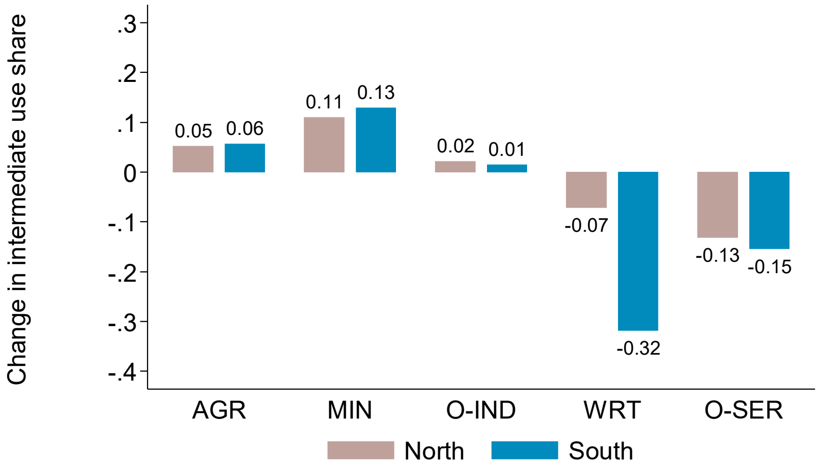


Source: Authors' elaboration based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021).

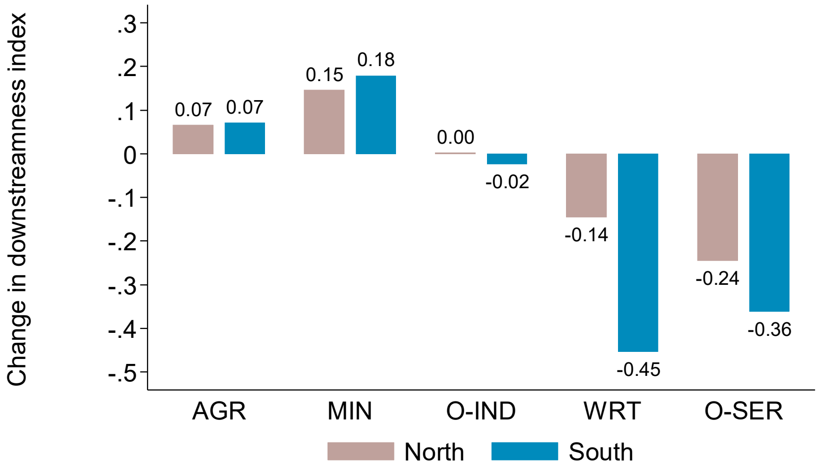
Note: AGR = agriculture. MIN = mining. O-IND = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. O-SER = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services.

Figure A4: Change in Intermediate Input Use and Input Downstreamness Index, 2004-2013

a. **Intermediate input use**



b. **Input downstreamness index**



Source: Authors' elaboration based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021).

Note: AGR = agriculture. MIN = mining. O-IND = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. O-SER = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services. See appendix C for a discussion of the methodology that we use to compute input downstreamness.

Appendix B

Construction of Input-Output Tables from Supply and Use Tables

The system of supply and use tables is constructed as two main tables: the supply table and the use table. The supply table (table B1) shows the supply of goods and services by type of product in an economy for a given time period. It consists of a production matrix (which is divided into domestic production and imports of goods and services), a matrix of transport and trade margins, and a matrix of net taxes (taxes less subsidies on products). The values of the domestically produced products and imports in the supply table are shown initially in basic prices while they are transformed to purchasers' prices in the final columns, where for each product, the net taxes on products (taxes less subsidies on products), and trade and transport margins, are added.

Table B1: Supply Table

	Industries	Supply
Products	V^T	s
Output	o^T	

Note: V^T = supply matrix (product by activities). o^T = column vector of industry output. s = column vector of product output. The capital letters denote matrices. Transpose matrices are written as matrices with the attachment of a superscript (T). Vectors are written as column vectors and row vectors are written as transposed column vectors.

The use table (table B2) shows the use of products by domestic industry and by final demand. Final demand is composed of consumption by households, general government and nonprofit organizations serving households, capital formation by firms, general government and households, changes in inventories, and exports. The use table shows the input structure of each industry (by column) and describes the use of different products and services (by row).

Table B2: Use Table

	Industries	Final demand	Use
Products	U	Y	s
Value added	W		w
Output	o^T	y	

Note: U = use matrix for intermediates. W = value-added matrix (components by industry). Y = final demand matrix (product by category). y = vector of final demand. w = vector of value-added. The small letters denote vectors. The table also shows the components of gross value added by industry.

All information of supply and use tables and I-O tables can be integrated into one matrix (table B3). The system is balanced if total input of products (s^T) equals total output of products (s) and total input of industries (o^T) equals total output of industries (o). If this is the case, total value added (w) equals total net final expenditure (y).

Table B3: An Integrated I-O Framework

	Products	Industries	Final demand	Total
Products		U	Y	s
Industries	V			o
Value added		W		w
Total	s^T	o^T	y	

Note: The typical element of the I-O matrix, in rows i and column j, represents the amount of product i used up in the production of industry j.

There are different methods through which supply and use tables can be converted into I-O tables. We follow the industry-by-industry I-O table based on the assumption of a fixed product sales structure, which means each product has its own specific sales structure, irrespective of the industry where it is produced (table B4).[10]

Table B4: I-O Table (Industry by Industry)

	Industries	Final demand	Output
Industries	A	F	o
Value added	W		w
Input	o^T	y	

Note: A = intermediate matrix (industry by industry). F = final demand matrix (industries by category).

Valuations of different entities in the supply and use tables are measured in different prices. For example, the supply table values are based on basic prices whereas the use table values are based on purchasers' prices. The relationship between the different types of prices are as follows:

[10] See Eurostat (2008), the Eurostat manual of supply and use tables and I-O tables at https://ec.europa.eu/eurostat/documents/3859598/5902113/KS-RA-07-013-EN.PDF/b0b3d71e-3930-4442-94be-70b36cea9b39 for a detailed discussion on other methods to convert supply and use tables to I-O tables.

$$Basic\ prices$$
$$= Purchasers'\ prices\ (excluding\ any\ deductible\ VAT)$$
$$-\ Nondeductible\ VAT - Trade\ and\ transport\ margin - Taxes\ on\ products\ (excl. VAT)$$
$$+\ Subsidies\ on\ product$$

Purchasers' price is the price the purchaser actually pays for the products at the time of purchase. It includes any taxes (less subsidies) on the products and any transport charges paid separately; it excludes deductible taxes like VAT on the products. Basic price is the price receivable by the producer from the purchaser for a unit of a good or service produced as output, minus any tax payable on that unit as a consequence of its production or sale (i.e., taxes on products), plus any subsidies receivable on that unit as a consequence of its production or sale (i.e., subsidies on products). The difference between the purchasers' price and the basic price relates to trade and transport margins and taxes less subsidies.

To convert purchasers' prices into basic prices using the above formula, we need supply-side valuation matrices; and we need use-side valuation matrices to convert the basic prices to purchasers' prices. I-O table values are based on basic prices. Since we do not have the use-side valuation table for the supply table, we use the proportion of purchasers' prices to basic prices for each sector (except trade) to obtain supply table values in basic prices.[11]

Let us define $\emptyset_1 = V * inv[diag(s)]$, where $diag(s)$ = diagonal matrix of product output. $\emptyset_1$ calculates the market shares matrix (the contribution of each industry to the output of a product). Similarly, $\emptyset_2 = U * inv[diag(o)]$, where $diag(o)$ = diagonal matrix of industry output. $\emptyset_2$ calculates input requirements for products per unit of output of an industry (intermediates).

We can calculate each element of table B4 based on the following equations:

(B1) $A = \emptyset_1 \times \emptyset_2$ (for intermediate input coefficients).

(B2) $o = inv[I - \emptyset_1 \times \emptyset_2] \times \emptyset_1 \times \emptyset_2 \times y$, where I= identity matrix (for output).

(B3) $F = \emptyset_1 \times y$ (for final demand).

The 2004 supply and use tables follow a classification of 13 products and activities: (1) agriculture, (2) cocoa, (3) forestry, (4) fisheries, (5) manufacturing, (6) mining, (7) electricity, (8) construction, (9) trade, (10) transport, (11) business, (12) public services, and (13) private services.

[11] For a detailed discussion on the method to convert purchasers' prices to basic prices, see http://www.saarcstat.org/sites/default/files/training/onsite/Supply_and_Use_Table/Session%206%20The%20Valuation%20Matrices.pdf.

Applying equations B1–B3, we construct a 13 × 13 I-O table with values in 2004 million cedis. We then convert it into a 5 × 5 I-O table using the following mapping: agriculture = (1) + (2) + (3) + (4), "other industry" = (5) + (7) + (8), mining = (6), WRT services = (9), and "other services" = (10) + (11) + (12) + (13).

The 2013 supply and use tables follow a classification of 20 products and activities: (1) agriculture, hunting, and livestock; (2) forestry and logging products; (3) fish and other fishing; (4) ores and minerals; (5) crude petroleum and natural gas; (6) electricity, town gas, steam, and hot water; (7) natural water, sewage and waste collection, treatment and disposal, and other environmental protection services; (8) manufacturing products; (9) construction and construction services; (10) distributive trade services; (11) accommodation and food- and beverage-serving services; (12) transport services; (13) financial and related services; (14) real estate services; (15) business and production services; (16) telecommunications, broadcasting, and information supply services; (17) public administration and other services provided to the community as a whole; compulsory social security services; (18) education services; (19) human health and social care services; and (20) community, social, and personal services.

Applying equations B1–B3, we construct a 20 × 20 I-O table with values in 2013 million cedis. We then convert it into a 5 × 5 I-O table using the following mapping: agriculture = (1) + (2) + (3), mining = (4) + (5), "other industry" = (6) + (7) + (8) + (9), WRT services = (10) + (11), and "other services" = (12) + (13) + (14) + (15) + (16) + (17) + (18) + (19) + (20).

Appendix C

Derivation of Subnational Regional Input-Output Tables

General Equilibrium Framework

Consider a general equilibrium model with labor (l) as the single factor of production for N goods. The aggregate demand is achieved through maximization of a constant-returns aggregator of final demand for N goods $(C_1, C_2, .., C_N)$:

$$Y = max\ \aleph(C_1, C_2, .., C_N)$$

$$\text{subject to } \textstyle\sum_i^N P_i C_i = w\bar{l} + \sum_i^N \pi_i, \qquad \text{(C1)}$$

where C_i is the consumption good i, P_i is its price, w is wages, and π_i is the profit for the producers of consumption good i. Labor is fixed in supply and is given by $\bar{l}$. The left-hand side of the budget constraint in equation C1 shows nominal GDP from the expenditure side, which equals the nominal GDP from the income side including wages and profits on the right-hand side. Each good is produced by competitive firms in the following manner:

$$y_i = \ A_i F_i(K_i, L_i, x_{i1}, x_{i2}.., x_{iN}), \qquad \text{(C2)}$$

where A_i is a Hick-neutral technology, K_i and L_i are capital and labor used for the production of good i, and x_{ij} are intermediate inputs from sector j used for the production of sector i. The Domar weight, the proportion of output in sector i to GDP, becomes y_i/Y. Profits for the producers of good i can be written as

$$\pi_i = P_i y_i - \ w_i l_i - \textstyle\sum_j^N P_j\, x_{ij}. \qquad \text{(C3)}$$

Market-clearing conditions are $y_i = \sum_j^N x_{ji} + C_i$, and $\bar{l} = \sum_i^N l_i$. Markets for every good and labor clear, and all agents take prices as given. From the market-clearing conditions, the intermediate consumption share (φ_i) for goods (sector) i can be written as

$$\varphi_i = \frac{\sum_j^N x_{ji}}{y_i}. \qquad \text{(C4)}$$

National Input-Output Tables

To examine the spatial patterns of intersectoral linkages, we construct I-O tables at the subnational level. As a first step, we build five-sector (agriculture, “other industry,” mining, wholesale and retail trade (WRT) services, and “other services”) national I-O tables for 2004 and 2013. In our five-sector classification, mining is separated from other industrial activities (manufacturing, construction, and utilities) that are grouped into “other industry.” Similarly, wholesale and retail trade services are separated from “other services,” which includes transport, communications, finance, commerce, government services, and private services. This five-sector classification allows us to examine the changing patterns of intersectoral linkages between mining and other sectors.

We create five-sector national I-O tables using supply and use tables. The 2004 supply and use table is obtained from 2005 Ghana Social Accounting Matrices (SAM) (GSS 2006). SAMs provide a comprehensive and economy-wide database representing all transactions (economic and social) carried out among the agents of a specific economy in a year. Chapter 11 in Miller and Blair (2009) provides a detailed discussion on the relationships between SAMs and I-O tables. GSS (2006) contains detailed descriptions of Ghana's SAM 2005. The 2013 supply and use table is obtained from GSS (2021).[12] The supply and use tables can be transformed to I-O tables using multiple alternative methods, each of which is tied to a set of assumptions related to the structure of the economy. We follow the industry-by-industry I-O table based on the assumption of a fixed product sales structure, which means each product has its own specific sales structure, irrespective of the industry in which it is produced.

In 2007, due to inflation, the Ghana cedi was devalued. The current cedi is 10,000 times the old cedi (before 2007). This affects our study as we compare cedis between 2004 and 2013. We converted the figures to million cedis in both years, and then applied the sector-level deflators from the GGDC-UNU-WIDER economic transformation database (ETD) to have them in 2004 constant prices. In Appendix B, we provide a detailed description of the steps that we follow to construct I-O tables from supply and use tables. Table C1 reports five-sector national I-O tables for 2004 and 2013. The unit for inputs and outputs are in constant 2004 million cedis. The Ghana Statistical Service rebased Ghana's national accounts series from the 1993 base year to 2006. Both 2004 and 2013 I-O tables use the rebased figures. For robustness, we compare the value-added shares from our I-O tables against the ones available from the ETD. The values closely match for "other industry" and WRT services but appear somewhat different for the rest of the sectors. This is mainly because several adjustments have been made to ensure consistency over time of sectoral value-added and employment shares in the ETD.[13]

[12] See https://statsghana.gov.gh/nationalaccount_macros.php?Stats=MTY4OTA1MDkwNC4wOTY=/webstats/2s1p460rn5 (accessed May 30, 2022).
[13] More information on these methods is available at https://www.wider.unu.edu/sites/default/files/Publications/Technical-note/PDF/tn2021-2-ETD-content-sources-methods.pdf.

Subnational Regional Input-Output Tables

The features of a regional economy that characterize the subnational I-O analysis are (1) different (or identical) structure of production at the subnational level compared to the same at the national level and (2) possibilities of greater regional interdependence (through the supply of inputs and outputs) and relatively higher level of specialization because of the smaller size of the subnational economy. Regional I-O tables have long been used to understand the evolution of key economic sectors at the subnational level by comparing their forward and backward linkage effects, which are not feasible using a national I-O table.

We apply a nonsurvey-based method to construct five-sector I-O tables for the north and the south of Ghana in 2004 and 2013. Survey-based or semi-survey-based methods rely more on national I-O tables (Brand et al. 2000). However, the substantial time and budgetary cost to administering surveys have encouraged researchers over the past two decades to refine nonsurvey-based methods in order to minimize discrepancies arising from regional differences in employment and output. See Miller and Blair (2009), Flegg and Tohmo (2011), and Kowalewski (2013) for further discussion. To present the procedure, we rewrite the market-clearing conditions for sectors from the previous section as a five-sector national I-O table for Ghana as follows:

$$\boldsymbol{x} = A\boldsymbol{x} + \boldsymbol{f}, \qquad \text{(C5)}$$

where $\boldsymbol{x}$ is a 5×1 vector of sectoral output, $\boldsymbol{f}$ is a 5×1 vector of final domestic demand excluding net exports, and A is a 5×5 Leontief matrix, all measured at the national level. We define A_{ij} as input coefficients, which display the value of goods and services from sector i purchased by sector j. Let ${A_{ij}}^R$ be the input coefficients in the subnational Leontief I-O matrix. Since ${A_{ij}}^R$ is not directly observed from national I-O tables, our goal here is to establish a mapping from A_{ij} to ${A_{ij}}^R$.

We define the *location quotient* for sector i as $LQ_i = \frac{E_i^R / E^R}{E_i / E}$, where E_i^R denotes regional employment in sector i (selling sector), E^R total regional employment, E_i total employment in sector i (selling sector), and E total national employment. The location quotient measures the ability of a sector in a given region to supply the demands for its outputs by other sectors and final consumption needs in that region. Thus, $LQ_i \geq 1$ for a region implies regional specialization in sector i.

We apply the location quotient method following the recent literature that argues this method is superior to other existing nonsurvey-based techniques to estimate subnational input and output multipliers (Flegg and Webber 2000; Kowalewski 2013). A commodity balance approach and iterative procedures are among other nonsurvey-based techniques applied by researchers to construct regional I-O tables. See, for example, Miller and Blair (2009) for a discussion. Using LQ_i, the *cross-sector location quotient* (SLQ) can be defined as a proportion of LQ_i and LQ_j: $SLQ_{ij} = \frac{LQ_i}{LQ_j}$, where i and j refer to two different sectors. SLQ compares LQ for both selling and purchasing sectors, which allows for each sector to simultaneously export and import across regions (Harrigan and McGilvray 1988).

Flegg and co-authors (Flegg et al. 1995; Flegg and Webber 2000) modified the SLQ formula to accommodate the size of the purchasing region. *Flegg's location quotient* (FLQ) is defined as

$$FLQ_{ij} = SLQ_{ij} \times \left[log_2(1 + \frac{E^R}{E})\right]^{\delta}, \tag{C6}$$

where the exponent δ adds more flexibility by altering the convexity of the adjustment quotient in FLQ. A higher value of δ lowers the size of $\left[log_2(1 + \frac{E^R}{E})\right]$; as a result, a greater adjustment to regional imports is considered. The choice of the value for δ remains an empirical matter. The literature suggests that a value of $\delta = 0.3$ works well in different circumstances (Miller and Blair 2009). As a further refinement, Kowalewski (2013) offers a regression-based method to estimate δ_j for each of the purchasing sectors. Due to data constraints, we are unable to estimate δ_j for each purchasing region and consider a constant $\delta(= .3)$ for all sectors. We apply the following formula to calculate ${A_{ij}}^S$ from A_{ij}:

$${A_{ij}}^R = \begin{cases} A_{ij} & if\ FLQ_{ij} \geq 1 \\ FLQ_{ij}.A_{ij} & if\ FLQ_{ij} < 1 \end{cases} \tag{C7}$$

Table C1 presents the Leontief inverse matrices for all-Ghana (national), the north, and the south in 2004 and 2013.

Downstreamness

We rewrite equation C5, where the value of gross output (X_i) in sector i equals the sum of its use as intermediate inputs to other sectors and its use in final consumption (F_i), as follows:

$$X_i \ = \ \sum_j^5 A_{ij} X_j \ + \ F_i. \tag{C8}$$

Through the iteration of terms for sector i's intermediate use, the value of gross output (X_i) can be expressed as a function of multiple terms, each reflecting the use of X_i in different positions in the value chain, starting with its use in final consumption as follows:

$$X_i \ = \ F_i + \sum_j^5 A_{ij} F_j \ + \ \sum_j^5 \sum_k^5 A_{ik} A_{kj} F_j + \sum_j^5 \sum_k^5 \sum_s^5 A_{ik} A_{ks} A_{sj} F_j + \cdots. \qquad \text{(C9)}$$

Following Antras et al (2012), we divide both sides by X_i, and multiply each term on the right-hand side of equation C9 by their distance from final use plus one, to obtain the following measure of upstreamness for sector i:

$$U_i \ = \ 1 \times \frac{F_i}{X_i} + 2 \times \frac{\sum_j^5 A_{ij} F_j}{X_i} + 3 \times \frac{\sum_j^5 \sum_k^5 A_{ik} A_{kj} F_j}{X_i} + 4 \times \frac{\sum_j^5 \sum_k^5 \sum_s^5 A_{ik} A_{ks} A_{sj} F_j}{X_i} + \cdots. \qquad \text{(C10)}$$

By construction, $U_{1i} \geq 1$. A larger value of U_{1i} indicates a higher level of upstreamness. The downstreamness measures the average distance from primary inputs suppliers (Miller and Temurshoev 2017). An expression for downstreamness (equation C8) looks similar to equation C10, except for sectoral final consumption (F_i) is replaced by sectoral value-added (V_i).

$$D_i \ = \ 1 \times \frac{V_i}{X_i} + 2 \times \frac{\sum_j^5 V_j A_{ji}}{X_i} + 3 \times \frac{\sum_j^5 \sum_k^5 V_j A_{jk} A_{ki}}{X_i} + 4 \times \frac{\sum_j^5 \sum_k^5 \sum_s^5 V_j A_{jk} A_{ks} A_{si}}{X_i} + \cdots. \qquad \text{(C11)}$$

A sector with large D_i has a large share of intermediate input in gross input and has strong intermediate input supply links with industries that have large downstreamness. These two indices jointly constitute the entire production process, and as such are crucial for understanding any changes in the production network.

Table C1: Leontief Inverse Matrices, 2004 and 2013

a. 2004

National	AGR	MIN	O-IND	WRT	O-SER
AGR	1.098	0.169	0.006	0.027	0.016
MIN	0.068	1.281	0.048	0.054	0.119
O-IND	0.004	0.085	1.003	0.004	0.008
WRT	0.343	0.325	0.023	1.121	0.030
O-SER	0.163	0.103	0.020	0.197	1.346

North	AGR	MIN	O-IND	WRT	O-SER
AGR	1.089	0.165	0.006	0.026	0.015
MIN	0.023	1.265	0.047	0.047	0.118
O-IND	0.000	0.003	1.000	0.000	0.000
WRT	0.120	0.226	0.019	1.112	0.021
O-SER	0.043	0.049	0.017	0.126	1.341

South	AGR	MIN	O-IND	WRT	O-SER
AGR	1.091	0.093	0.002	0.014	0.007
MIN	0.063	1.273	0.032	0.046	0.099
O-IND	0.004	0.084	1.002	0.003	0.007
WRT	0.340	0.301	0.015	1.115	0.023
O-SER	0.162	0.091	0.014	0.195	1.344

b. 2013

National	AGR	MIN	O-IND	WRT	O-SER
AGR	1.168	0.093	0.008	0.040	0.070
MIN	0.064	1.130	0.050	0.175	0.141
O-IND	0.010	0.165	1.063	0.027	0.025
WRT	0.031	0.029	0.102	1.024	0.214
O-SER	0.101	0.068	0.035	0.097	1.166

North	AGR	MIN	O-IND	WRT	O-SER
AGR	1.161	0.090	0.007	0.038	0.069
MIN	0.025	1.120	0.049	0.171	0.137
O-IND	0.002	0.068	1.058	0.011	0.010
WRT	0.010	0.015	0.101	1.017	0.210
O-SER	0.034	0.041	0.031	0.071	1.155

South	AGR	MIN	O-IND	WRT	O-SER
AGR	1.163	0.053	0.003	0.021	0.038
MIN	0.062	1.124	0.037	0.151	0.116
O-IND	0.010	0.164	1.061	0.023	0.021
WRT	0.029	0.024	0.081	1.020	0.188
O-SER	0.100	0.063	0.027	0.094	1.160

Source: Authors' elaboration based on 2004 and 2013 supply and use tables for Ghana (GSS 2006, 2021).

Note: AGR = agriculture. MIN = mining. O-IND = industries other than mining; they include manufacturing, construction, and utilities. WRT = wholesale and retail trade. O-SER = services other than wholesale and retail trade; they include transport, communications, finance, commerce, government services, and private services.