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DISCUSSION PAPER SERIES

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ISSN: 2365-9793

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ABSTRACT

Regional Differences in Intersectoral Linkages and Diverse Patterns of Structural Transformation*

Intersectoral linkages can act as shock propagation channels and shape the pattern of structural transformation. To our knowledge, no research has examined how subnational differences in intersectoral linkages impact such spillover effects. We hypothesize that regional differences in local economic shocks diversify intersectoral linkages, and, consequently, produce divergent patterns of structural transformation across regions. Using novel regional input-output tables and existing enterprise censuses for Ghana, we test and find support for four predictions related to this hypothesis: (1) a recent, positive mining output shock that occurred in the south of Ghana leads to growing differences in intersectoral linkages between the north and the south of the country, (2) the effect of the mining output shock on output and productivity growth in other sectors differs across regions in line with changes in the patterns of intersectoral linkages, (3) the elasticity of employment in other sectors with respect to the change in employment in mining closely follows the regional patterns of intersectoral linkages, and (4) variation in the mining output shock across time and space explains the variation in the rate of firm entry and average firm-level employment in sectors (such as heavy manufacturing) that largely depend on mining for intermediate inputs.

JEL Classification: D24, F15, F43, N10, O11, O14, O47, D57, E32, L14, Q54

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

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* We thank Emanuele Ferrari for guidance on the construction of input-output tables from supply and use tables. We also thank Andrew Dabalen, K. N. Harilal, Sunil Mani, Rayaprolu Nagraj, M. Parameswaran, and seminar participants at the Centre for Development Studies, Trivandrum for helpful comments.

1. Introduction

Intersectoral linkages govern the propagation of local economic shocks to the aggregate level (Acemoglu et al. 2012; Atalay 2017; Caliendo et al. 2018; Carvalho et al. 2021). As sectors with longer production chains experience larger growth in productivity (McNerney et al. 2022), the movement of sectors along the supply chain generates differences in sectoral productivity growth; these differences consequently shape the patterns of structural transformation (Baumol 1967; Ngai and Pissarides 2007). We extend this line of thinking in a new direction. Suppose a local sectoral productivity shock alters the spatial fabric of intersectoral linkages by changing the position of sectors in production networks by a larger margin in one subnational region (hereafter, referred to as just region) compared to another. Then, do such systematic differences in the spillover of shocks produce diverse patterns of structural transformation across regions within a country? There is a growing interest in understanding the formation of production networks at the sector level (Baqaee and Farhi 2019; Paul and Raju 2022) as well as at the firm level (Carvalho and Voitlander 2015; Oberfield 2018; Taschereau-Dumouchel 2018). We instead examine how intersectoral production networks at the region level respond to variation in sectoral shocks across regions.[1] Using newly constructed datasets on input-output (I-O) flows at the region level, our study is the first to examine the relationship between spatial differences in intersectoral linkages and structural transformation.

We study the process of structural transformation in Ghana, in the wake of a boom in the mining industry in the south since 2010. Until 2010, the country's structural transformation was characterized by the reallocation of resources primarily from low-productivity agriculture to low-productivity services (Osei et al. 2018; Nxumalo and Raju 2020), which appears to have constrained overall productivity growth (Rodrik 2013; McMillan et al. 2014; Paul and Raju 2021). In 2010, Ghana emerged as a new oil and gas producer in Sub-Saharan Africa (OEF 2019), with cumulative oil production steadily increasing from 1.2 million barrels in 2010 to 508.4 million barrels in 2021 (PIAC 2021). The country's oil and gas fields are located off the south coast. Since 2010, employment in heavy manufacturing industries (chemicals, machinery, metals, and nonmetallic minerals) grew steadily in the south, whereas employment in light manufacturing industries (including food, textiles, and paper) became increasingly concentrated in the north. As more than 85 percent

[1] In a similar vein, using regional and industry data from the United States, Caliendo et al. (2018) study the impact of intersectoral and interregional trade linkages in propagating local productivity shocks to the rest of the economy. Baqaee and Farhi (2019) characterize the endogenous nonlinear response of intersectoral networks to sectoral productivity shocks.

of mining intermediate inputs typically goes to heavy manufacturing industries,[2] these trends suggest that the propagation of the mining productivity shock mainly in the south might have led to growing differences in the regional pattern of structural transformation in the country. We formally test this.

Exploiting the mining productivity shock as an exogenous source of variation in intersectoral linkages across regions, we empirically evaluate four predictions: (1) the mining output shock that occurred in the south of Ghana leads to growing differences in production networks between the north and the south, (2) the effects of the mining output shock on output and productivity growth in other sectors differ across regions in line with changes in the patterns of intersectoral linkages, (3) the elasticity of employment in other sectors with respect to changes in employment in mining closely follows the regional patterns of intersectoral linkages, and (4) the variation in the mining employment shock across time and space explains the variation in the rate of firm entry and average firm-level employment in sectors (for example, heavy manufacturing) that largely depend on mining for intermediate inputs.

We use the two latest rounds of enterprise censuses for Ghana, with 2003 and 2013 as reference periods for the data, to examine whether the mining output shock is specific to the south of the country. During this period, the numbers of firms and employees engaged in both mining and manufacturing surged in the south, especially in comparison to the north. The number of firms engaged in mining in the region increased by 153 percent over this period, from 103 in 2003 to 261 in 2013. In contrast, the north saw an increase of only 50 percent, from 22 to 33 firms. The south's share of total mining firms increased from 82 percent (103 of 125) in 2003 to 89 percent (261 of 294) in 2013, while its share of mining employment remained at a commanding 98 percent for both years. On the other hand, manufacturing employment figures for the north began to approach those for the south between 2003 and 2013, thanks mainly to steady growth in the clothing sector in the north.

To measure spatial differences in intersectoral linkages, we construct five-sector national I-O tables from 2004 and 2013 national 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). As our I-O tables are constructed using the supply and use tables from various sources, we perform a sensitivity check using an available I-O table

[2] Authors' own estimate based on world input-output data (WIOD) for 43 countries.

for Ghana for 1968 (UN 1985). The results suggest that these I-O tables are consistent and comparable over time. We also produce I-O tables for the north and the south for 2004 and 2013 from the national I-O tables, which are, respectively, six years before and three years after the start of major oil and gas production in 2010.

Based on the regional I-O tables, we test if the mining output shock is related to spatial differences in intersectoral linkages by examining upstreamness and downstreamness (Miller and Blair 2009; Antras et al. 2012; Miller and Temurshoev 2017) for other sectors between 2004 and 2013 and between the north and the south. The upstreamness index measures the average distance from final output users, whereas the downstreamness index measures the average distance from primary input suppliers. Mining is the only sector that gained both in terms of upstreamness and downstreamness between 2004 and 2013. The growing importance of mining in the supply chain is mainly driven by a higher level of downstreamness in mining in the south (1.28) compared to the north (1.15) in 2013. We also observe regional differences in the relative positions of other sectors, especially agriculture and "other services" in the supply chain. The decline in upstreamness in agriculture is six times larger in the south than in the north. The gain in upstreamness in "other services" in the north is twice the size of that in the south.

To examine the effect of the mining output shock on changes in sectoral outputs, we employ a simple multisector and multistage model to derive a relationship between changes in sectoral productivities and sectoral output shares through intersectoral linkages. We apply the "Morishima elasticity of substitution" (MES) to derive a condition for changes in the output shares between any two sectors resulting from changes in their relative sectoral productivities, which is similar to the condition for the propagation of productivity shocks shown in other studies (Atalay 2017; Baqaee and Farhi 2019; Carvalho et al. 2021; Paul and Raju 2022).[3] As Paul and Raju (2022) show, the MES can be expressed as (1) the sum of the elasticity of substitution between value-added total factor productivity (TFP) and output TFP and (2) the sum of the elasticity of substitution between value-added and output TFP.

Since regional I-O tables are available for only two points in time, 2004 and 2013, it is not feasible to calculate changes in the elasticity parameters based on TFPs at the regional level. As a second-best option, we produce two sets of nonparametric results. First, we measure the value-added ratio, the output TFP ratio, and the value-added TFP ratio to account for regional differences in sectoral productivity growth between 2004 and 2013. Second, we

[3] The MES is a natural multi-input generalization of the Hicksian two-input elasticity of substitution (Blackorby and Russell 1989).

calculate the MES using I-O tables from 1968, 2004, and 2013 to capture the changes in sectoral output ratios resulting from the mining output shock at the aggregate level.

Between 2004 and 2013, mining's output as a share of gross domestic product (GDP) 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. At the national level, value-added in mining is lower than that for other sectors in 2004. In 2013, value-added in mining becomes greater than value-added in WRT services, and almost equals the value-added in agriculture. We compute sectoral TFP at the national and regional levels based on I-O tables (Miller and Blair 2009).[4] The 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), accompanied by a larger increase in the value-added ratio between mining and "other industry" in the south (from 0.430 to 0.730) than in the north (from 0.024 to 0.250). On the other hand, the MES results at the aggregate level suggest that mining output is complementary to output in other sectors.

To examine the relationship between sectoral productivity and the change in the production network over time, we measure the change in intersectoral linkages as the log difference between 2004 and 2013 in sectoral upstreamness and downstreamness. There is a much stronger positive correlation between TFP and the change in upstreamness across sectors in the north (0.76) than in the south (0.39). Since the south of Ghana is richer than the north, this corroborates the finding from Fadinger et al. (2022) that highly interlinked sectors are more productive than less interlinked sectors, particularly in low- and middle-income countries. However, the correlation between TFP and the change in downstreamness across sectors is negative in both the north (–0.69) and the south (–0.44).

Overall, the evidence from a battery of empirical tests based on regional I-O tables strongly indicates differences in the effects of the mining output shock on output and productivity growth in other sectors across regions that are in line with regional differences in the pattern of production networks.

We next examine the impact of regional differences in intersectoral linkages on structural transformation, and the mechanisms behind it, based on enterprise census data. Specifically, we estimate the sensitivity of changes in employment in different sectors to changes in employment in mining across districts. The 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)

[4] This procedure corresponds to that of Jorgenson et al. (1987), which has been the standard reference in the literature for the calculation of TFP.

mainly occurs in districts that have at least one mining firm (mining districts). Since this identification strategy relies only on the location of a mining firm (mining district), the production network in our second model is identified jointly by the location of a mining firm and the year in which it was established. We interpret the intersectoral linkages as causal if the contemporaneous and lagged effects of new mining firms on the entry of firms in other sectors in the same district are positive, and the lead effects (our placebo test) are independent of the entry of firms in other sectors in the same district.

We also estimate employment elasticities at a more disaggregated level than the five-sector classification used for the I-O tables, based on the enterprise censuses. 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). Mining shows stronger intersectoral linkages with heavy manufacturing in the south than in the north. This supports the findings based on the I-O tables that the level of upstreamness of mining grew in the south. Both contemporaneous and lagged effects of new mining firms on the entry of heavy manufacturing firms in the mining districts are positive and statistically significant. The relationship between mining and heavy manufacturing firms in the south appears to be causal based on the results from our placebo test as the lead effects are small and statistically insignificant for heavy manufacturing. However, the corresponding estimated effects for the other sectors (light manufacturing, “other industry,” WRT services, and “other services”) do not support a causal interpretation.

Employment in heavy manufacturing grew in mining districts between 2003 and 2013. The growth in the number of heavy manufacturing firms could generate this result, without an increase in average employment in heavy manufacturing firms. We test whether average firm-level employment in different sectors (heavy manufacturing, in particular) increased in mining districts in the south between 2003 and 2013. Our findings show that average employment in heavy manufacturing firms in mining districts in the south grew by 31 percent compared to average employment in heavy manufacturing firms in other (nonmining) districts. In mining districts, the growth in average employment is more than three times larger among heavy manufacturing firms than the corresponding growth among light manufacturing firms.

Overall, the variation in the mining employment shock across districts explains employment growth particularly in heavy manufacturing in the south. 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.

Understanding regional differences in intersectoral linkages and patterns of structural transformation can generate policy-relevant insights on how to promote aggregate productivity growth in several ways. 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. 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, with divergent patterns of structural transformation across regions promoting regional specialization (for example, clothing industry in the north, heavy manufacturing in the south), stronger interregional trade linkages could enhance aggregate productivity growth (Caliendo et al. 2018). After the COVID-19 pandemic, followed by the oil price shock, Ghana's upstream mining activities started recovering in the first half of 2021. Projected petroleum revenues earmarked for development projects in 2021 totaled about US$886 million, of which 54 percent was planned for infrastructure development (PIAC 2021). The prospects of place-based development (Kline and Moretti 2014) have already been emphasized in the context of Ghana (Aragon and Rud 2013; Fafchamps et al. 2017). The availability of petroleum revenues makes it feasible for the government to realize the abovementioned goals through these place-based policies.

The remainder of the paper is organized as follows. Section 2 provides a brief survey of the broad areas that the current study contributes to. Section 3 provides an overview of national and regional trends in structural transformation for Ghana. Section 4 discusses the findings on forward and backward linkage effects, and the upstreamness of sectors across regions and over time based on the regional I-O tables. Section 5 discusses how spatial differences in intersectoral linkages affect sectoral output and productivity, based on the regional I-O tables. Section 6 discusses how spatial differences in intersectoral linkages affect employment growth and firm growth across sectors and regions, based on enterprise census data. Section 7 concludes.

2. Related literature

This study relates to three broad strands of the literature: (1) the drivers of structural transformation, (2) the role of intersectoral linkages in propagating sectoral productivity shocks, and (3) structural transformation through mining in Ghana.

Drivers of Structural Transformation

The process of structural transformation has been viewed as an integral part of long-run economic growth since the seminal contribution of Kuznets (1957). In recent years, variants of the multisectoral optimal growth theory model have been developed to explain the process of structural transformation from the demand side as well as the supply side (Herrendorf et al. 2014). The assumption of nonhomothetic preferences generates a lower income elasticity of demand for agricultural products than for nonagricultural products, which leads to falling demand for agricultural products and increasing demand for services as the level of income of a country rises (Kongsamut et al. 2001; Comin et al. 2017). On the other hand, supply-side drivers reallocate resources from high-productivity growth sectors to low-productivity growth sectors as long as productivity growth differs across sectors, and consumption demand for sectoral goods exhibits gross complementarity (Baumol 1967; Ngai and Pissarides 2007; Acemoglu and Guerrieri 2008). Available empirical evidence, however, supports both demand- and supply-side explanations (Dennis and Iscan 2009; Boppart 2014; Comin et al. 2017; Fukao and Paul 2021).

A handful of studies examine the spatial dimension of structural transformation but primarily through the channel of the geographic mobility of workers (Caselli and Coleman II 2001; Murota 2008; Allen and Arkolakis 2014; Desmet and Rossi-Hansberg 2014). We view regional specialization of sectoral activities independent of the movement of labor across space. Eckert and Peters (2018) find that spatial reallocation across labor markets in the United States accounts for almost none of the aggregate decline in agricultural employment. Since the long-run growth process is inherently uneven across space (World Bank 2009), we contend that the spatial variation in the pattern of structural transformation, and a meaningful aggregation of these forces, could add to the existing knowledge on the drivers of structural transformation.

We make two specific contributions to the literature on the drivers of structural transformation. First, our study extends the literature that aims to understand the drivers of structural transformation using I-O flows (Herrendorf and Valentinyi 2012; Herrendorf et al. 2013; Caliendo et al. 2018; Liu 2019) in a new direction by showing how regional differences in intersectoral linkages produce diverse patterns of structural transformation across regions. Second, we contribute to a subset of the structural transformation literature that aims to understand how productivity growth in one sector facilitates (or restricts) productivity growth in another sector (Huneeus and Rogerson 2020).

Role of Intersectoral Linkages in Propagating Sectoral Productivity Shocks

Our study relates to a growing literature that examines the role of intersectoral linkages in the propagation of sectoral shocks within an economy (Long and Plosser 1983; Acemoglu et al. 2012; Atalay 2017; Caliendo et al 2018; Baqaee and Farhi 2019; Liu 2019; Carvalho et al. 2021; Fadinger et al. 2022; Paul and Raju 2022). The elasticity parameters between intermediate sectoral outputs and the factors of production govern the conditions that determine the propagation of sectoral productivity shocks to the aggregate level within a country. Most of the studies in this literature assume that I-O flows are invariant to sectoral productivity shocks. However, there are a few studies that aim to understand how production networks respond to shocks (Baqaee and Farhi 2019; Paul and Raju 2022), including some studies based on firm-level analyses applying various assumptions related to firms' network formation (Carvalho and Voitlander 2015; Oberfield 2018; Taschereau-Dumouchel 2018). We contribute to this strand of the literature by studying the regional variation in the formation of intersectoral networks using novel datasets on regional I-O flows and its spillover effects on employment and firm growth across sectors.

Prospects of Structural Transformation through Mining in Ghana

Like many other countries in Sub-Saharan Africa, Ghana is blessed with diverse natural resources. After experiencing decades of deindustrialization and growth-inhibiting structural transformation (Fosu 2017; Osei et al. 2020; Paul and Raju 2021), Ghana emerged as an oil and gas producer in 2010, a development which coincided with an industrialization drive in the country. Value-added and employment shares of industry have increased since 2010 alongside a steady growth in the volume of annual oil production from 1.2 million barrels in 2010 to 481.2 million barrels in 2021 (PIAC 2021). However, to our knowledge, no studies have examined the implications of Ghana's development of oil resources for its structural transformation and productivity growth.

Several factors may help determine Ghana's prospects for economic growth through structural transformation from petroleum resources. These include Ghana's high oil-dependence ratio (Lin et al. 2014), the country's growing vulnerability to oil-price shocks following the removal of highly subsidized petroleum products in 2006 (Anokye and Tweneboah 2008; Nnadikwe 2011), and a deterioration of the social and economic infrastructure in prominent mining communities (Aryeetey et al. 2016). In addition, being an oil-based economy, Ghana is susceptible to Dutch disease (Cordon and Neary 1982; Ross

2012), which can adversely affect nontradable sectors due to any currency appreciation associated with a mining boom. Dutch disease continues to be a concern despite several attempts made by the Ghanaian government to control oil prices (Aryeetey and Ackah 2018; Osei et al. 2020).

We show that intersectoral linkages play a stronger role in promoting structural transformation in the south than in the north of Ghana, amid the emergence of mining as a prominent downstream sector in the south. Moreover, we show that regional patterns of intersectoral linkages govern the spillover effects of sectoral productivity shocks, such as with employment creation. Our findings are consistent with Aryeetey et al. (2014) and McMillan and Zeufack (2022) who argue that stronger intersectoral linkages between mining and other sectors is a means to achieve greater socioeconomic gains from the mining sector. Finally, we contribute to studies on the prospects of place-based development policies in Ghana (Aragon and Rud 2013; Fafchamps et al. 2017). Similar to Fafchamps et al. (2017), we find employment growth in manufacturing firms based in mining districts.

3. Overview of Structural Transformation in Ghana

We begin with a brief overview of the structural transformation trends across broad sectors (agriculture, industry, and services), and subsectors within industry in Ghana, based on statistics from the GGDC-UNU-WIDER economic transformation database (ETD).[5] We then describe the evolution of manufacturing and services activities in the north and south of Ghana using district-level data from the National Industrial Census (NIC) 2003 (the reference period for the data is 2003) and the Integrated Business Establishment Survey (IBES) 2014 (the reference period for the data is 2013).[6] Following this, we use data from the NIC 2003 and IBES 2014 (the enterprise censuses) to compare the growth in number of firms, employment, and productivity across sectors within manufacturing between the north and the south and before and after the large-scale production of oil and gas started in Ghana.

[5] The ETD is a joint initiative of the Groningen Growth and Development Centre (GGDC) and United Nation 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.

[6] The NIC 2003 and IBES 2014 were administered by the Ghana Statistical Service. The NIC 2003 covered only industrial sectors (mining, manufacturing, public utilities, and construction), whereas IBES 2014 covered industrial as well as all services sectors (wholesale and retail trade, transport, communications, finance, real estate, government, and private services). Both censuses were conducted in two phases. Phase II involved a detailed questionnaire. We use the data from phase II for both surveys. Phase II of NIC 2003 was fielded between December 2004 and February 2005, and phase II of IBES 2014 was fielded between November 2015 and April 2016. For survey design and implementation details, see GSS (2006) and (2016).

National Trends in Sectoral Employment and Value-Added Shares

Figure 1 depicts trends in each sector's share of employment and value-added, which capture structural transformation, based on ETD statistics. Ghana did not exhibit any strong signs of structural transformation until 2000. Between 2000 and 2010, the forces of structural transformation gained momentum but 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. Agriculture's share of employment continued to decline from 55 percent in 2010 to 33 percent in 2018, while services' share of employment grew from 30 percent in 2010 to 47 percent by 2018.

The sectoral shares of value-added followed somewhat different trends. Between 1990 and 2018, services' share of value-added hovered at about 50 percent. Agriculture's and industry's shares of value-added both remained close to 25 percent until 2010. Since then, the two sectors' shares of value-added diverged sharply, with industry's share rising above that of agriculture. Within industry, the value-added share of mining increased from 3 percent in 2000 to 12 percent in 2018 (9 percentage points). Construction's share of industry value-added 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 statistics from GSS (2016)—based on the IBES 2014 data—on the number of firms in industry and services 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. The south of the country is defined as the Ashanti, Central, Eastern, Greater Accra, and Western regions, while the north is defined as the Brong Ahafo, Northern, Upper East, Upper West, and Volta regions (figure 2, panel a).[7] 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 south and the north, but the total number of firms (for

[7] Note that our classification of the regions into south and north differs somewhat from that applied by the Ghana Statistical Service (GSS). The GSS classifies Northern, Upper East, and Upper West regions to be the north, and the remainder as the south (GSS 2016).

both sectors) in the south has far exceeded those in the north (figure A1). 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. A similar trend is observed for firms in services, with the number of such firms in the north gradually converging with that for the south except between 2005–14.

Districts in the south tend to have more firms in industry than those in the north (figure A2). But growth rates of firms in industry tend to be greater in districts in the north than those in the south. In terms of the number of firms in services, the districts in the south clearly dominate over districts in the north (figure A3). That being said, some of the districts in the north have also experienced steady growth in the number of firms in services over time.

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

We take a closer look at the performance of subsectors within industry, specifically mining and manufacturing. We use data from the 2003 and 2013 enterprise censuses. The 2003 census 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, persons engaged,[8] and employees in 2003 and 2013 at the national level, in the north, and in the south. At the national level, we find a 2.4-fold increase in the number of firms engaged in mining (from 125 in 2003 to 294 in 2013) and a 4.3-fold increase in the number of firms engaged in manufacturing (from 23,797 in 2003 to 101,789 in 2013). Similarly, persons engaged increased 3.2-fold (from 15,254 in 2003 to 48,977 in 2013) and 2.6-fold (from 221,953 in 2003 to 570,327 in 2013) in mining and manufacturing, respectively. Finally, the number of direct employees increased 2.7-fold (from 14,869 in 2003 to 40,120 in 2013) and 2.3-fold (from 116,774 in 2003 to 271,863 in 2013) in mining and manufacturing, respectively.

The numbers of firms, persons engaged, and employees remain overwhelmingly large in the south in both manufacturing and mining, compared to numbers for the north. However, comparisons of the growth rates show an interesting divergence from the national trend as manufacturing dominates growth in the north, whereas the south remains the mining hub. The north’s share of manufacturing firms grew from 19 percent (4,623 out of 23,797) in 2003 to

[8] “Persons engaged” includes the total number of persons who work in or for the firm. This category includes operatives, other engaged employees, working proprietors, active business partners plus learners (including unpaid apprentices), and unpaid family workers (GSS 2006).

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.[9] On the other hand, 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 at an overwhelming 98 percent in both years.

In 2007, Ghana discovered oil in the Jubilee field (the oil fields in the Deep Water Tano and West Cape Three Points blocks). 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. The country began drilling in two additional oil fields, Tweneboa, Enyenra Ntomme and Sankofa Gye Nyame, in 2016 and 2017, respectively. The country's volume of cumulative oil production increased steadily, from 1.2 million barrels in 2010 to 508.4 million barrels in 2021 (PIAC 2021) (figure A4). Other mining activities (mainly gold mining) in 2003 were limited to only a handful of districts in the Ashanti region in the south (figure 2, panel b). By 2013, mining activities related to oil and gas were spread across many districts in the south due to the proximity to offshore oil and gas mines (figure 2, panel c). Mining industries grew alongside a steady growth in downstream oil-marketing industries and upstream services activities (Skaten 2018; OEF 2019); the growth of these upstream and downstream activities potentially explains the 314 percent growth in firms in services in the south between 2005 and 2014 (figure A3).

The growing importance of the mining sector in Ghana's economy can also be observed from rapid changes in the country's export basket (figure A5). In 2006, gold accounted for a mere 4.3 percent of export earnings. This changed dramatically within the next 12 years, with mining products constituting almost 65 percent of exports earnings by 2018, of which gold accounted for 40 percent and crude petroleum 25 percent.

[9] Data are not available for nonindustrial sectors from the 2003 census. 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).

We next investigate the key manufacturing sectors at a disaggregated level. We distinguish between heavy manufacturing and light manufacturing.[10] Given the importance of food and clothing, in selected analyses, we also examine them separately.

Table A1 compares the district-level growth of firms and growth in the number of employees ("growth of employees") between 2003 and 2013 in manufacturing as well as in four subcategories of manufacturing, namely heavy manufacturing, light manufacturing, clothing, and food.[11] The rate of growth of firms and employees in the clothing industry is significantly higher in the north than in the south. Figure 2 (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.

4. Spatial Differences in Intersectoral Linkages

To estimate spatial differences in intersectoral linkages, we construct five-sector national I-O tables based on the 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. Appendix B discusses the approach used to construct the national I-O table. We then apply nonsurvey-based methods (Miller and Blair 2009; Flegg and Tohmo 2011; Kowalewski 2013) to construct I-O tables for the north and the south of Ghana for 2004 and 2013 from the national I-O tables. Appendix C discusses the approach used to construct the regional I-O tables.

We compute upstreamness and downstreamness (Miller and Blair 2009; Antras et al. 2012; Antras and Chor 2013; Miller and Temurshoev 2017) at the sector level for 2004 and 2013 using the national and regional I-O tables. The upstreamness index measures the average distance from final output users, whereas the downstreamness index measures the average distance from primary input suppliers (Antras et al. 2012; Miller and Temurshoev

[10] 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.

[11] Since independence in 1960, Ghana's district boundaries have changed multiple times. The 2003 enterprise census follows a classification of 138 districts, and the 2013 enterprise census follows a classification of 216 districts.

2017). Appendix C discusses the derivation of these indices and the procedure for calculating them.

Figure 3 reports the main results on upstreamness and downstreamness across sectors. Mining is the only sector that gained both in terms of upstreamness and downstreamness between 2004 and 2013. The growing importance of mining in the supply chain is observed in the south as well as in the north. However, the level of downstreamness in mining in 2013 is higher in the south (1.28) than in the north (1.15). We also observe regional diversity in the relative positions of other sectors in the supply chain. The upstreamness of agriculture declined by 18 percent (from 1.66 to 1.36) in the south compared to 4 percent (from 1.28 to 1.23) in the north, whereas the downstreamness of WRT services declined by 25 percent (from 1.79 to 1.34) in the south compared to 10 percent (from 1.50 to 1.35) in the north. Appendix C provides further details on the contributions of purchasing sectors to the upstreamness index and the contributions of selling sectors to the downstreamness index. Despite a drop in the upstreamness of "other industry," the contribution of mining to this sector has increased by almost 10 percentage points in both the north and the south between 2004 and 2013.

Our I-O tables are constructed using the supply and use tables from various sources. As such, the validity of any economic interpretations based on the results generated from these I-O tables relies on their consistency and comparability over time. As a sensitivity check, we use the I-O table for Ghana from 1968, available from the United Nations Input-Output Tables for Developing Countries (UN 1985). Figure A6 compares the upstreamness and downstreamness indices at the national level using our newly constructed I-O tables for Ghana in 2004 and 2013 and the I-O table in 1968.

We observe two trends emerging from the long-term evolution of intersectoral networks in Ghana. First, "other industry" maintained a dominant position in the supply chain in 1968 and 2004 by having the largest share of intermediate output in gross output. However, in 2013, the dominance of "other industry" in the supply chain is achieved through its share of intermediate input in gross input and stronger intermediate input supply links with industries that have large downstreamness. Second, 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 directly contribute to the second trend, it could also be associated with a shift in the role of "other industry" in the supply chain between 2004 and 2013 toward becoming a more downstream sector and having a stronger intersectoral linkage with mining.

To provide suggestive evidence on the evolution of the key sectors, we compare upstreamness (forward linkage) and downstreamness (backward linkage) based on a four-way classification of forward and backward linkage effects proposed by Chenery and Watanabe (1958).[12] A sector is classified as "independent of other sectors" if both forward and backward linkage effects are weak; "dependent on other sectors" if both forward and backward linkages are strong; "dependent on supply" if the forward linkage effect is weak but the backward linkage effect is strong; and, finally, "dependent on demand" if the forward linkage effect is strong but the backward linkage effect is weak. We consider the forward linkage effect for a sector to be weak (strong) if its size is smaller (larger) than the average forward linkage effect across all sectors. Similarly, the backward linkage effect for a sector is seen as strong (weak) if its size is larger (smaller) than the average backward linkage effect across all sectors. Table A2 reports the evolution of the key sectors between 2004 and 2013. At the national level, except for mining and "other services," intersectoral linkages became weaker for other sectors. Mining's role as a growing upstream industry is mainly driven by the south.

5. Intersectoral Linkages, Sectoral TFPs, and Outputs

In section 4, we showed that Ghana's mining productivity shock is correlated with the diverging pattern of intersectoral linkages between the north and the south. Here, we first examine the relationship between intersectoral linkages and sectoral productivity growth (measured in terms of sectoral output TFP growth). We then investigate the relationship between the mining productivity shock and sectoral output through intersectoral linkages, on the basis of a multisector and multistage production function that allows for substitution parameters to vary across intermediate inputs. Applying the Morishima Elasticity of Substitution (MES), Paul and Raju (2022) derive a condition for the change in the output ratio between two sectors resulting from the change in the ratio of productivity gain for the same two sectors based on (1) the elasticity of substitution between value-added TFP and output TFP and (2) the elasticity of substitution between value-added and output TFP.

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 such, we cannot estimate changes in the MES over time. Instead, we conduct a thought experiment based on the sectoral output TFP ratios, value-added TFP ratios, and value-added ratios and provide some tentative evidence

[12] A comparison of the size of output and input multipliers helps identify the key sectors in an economy (Miller and Blair 2009).

on the direction of the change in sectoral outputs. Appendix D discusses the theoretical foundation underpinning the relationship between Domar weights, value-added TFPs, gross output TFPs, and the MES.

Domar Weights

Figure 4 shows changes in Domar weights, which is the ratio of sectoral output to GDP, between 2004 and 2013. At the national level, production activities primarily shifted from agriculture and “other services” to mining and “other industry.” The Domar weight increased the most for mining (16 percentage points), followed by WRT services (10 percentage points). The Domar weights for agriculture and for “other services” fell by 28 and 17 percentage points, respectively. The role of final and intermediate sales behind the changes in the Domar weights differs markedly by sector. Almost three-fourths of the increase in the Domar weight for mining is due to intermediate sales, whereas almost half of the increase in the Domar weight for WRT services is due to intermediate sales. In agriculture, almost fourth-fifths of the decrease in the Domar weight is due to final sales.

The pattern of changes in the Domar weight across sectors in the south mirrors the pattern at the national level. 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).

The implications of changes in the Domar weight for intersectoral linkages are three-fold. First, except for “other services,” final sales dominate the changes in the Domar weight for all sectors irrespective of the direction of change. Second, “other industry” continues to be the most important sector in the production network of the north—it had the largest gain in both final and intermediate sales. Third and most importantly, mining plays a dominant role in the production network, especially in the south. These findings reinforce the evidence on the diverging pattern of intersectoral linkages discussed in section 4.

Sectoral Output TFP Growth, Upstreamness, and Downstreamness

Sectors with longer production chains experience larger growth in productivity (McNerney et al. 2022). However, the correlation between intersectoral linkages and sectoral productivity can be conditioned by the income level of a country. Fadinger et al. (2022) show that highly interlinked sectors are more productive than less interlinked sectors, but that such evidence is more prominent for low- and middle-income countries than high-income countries. As the south of Ghana is richer than the north of the country (Paul and Raju 2021), we examine whether the south demonstrates a weaker relationship between sectoral linkages and sectoral productivity compared to the north following the observed cross-country patterns by Fadinger et al. (2022).

We estimate sectoral TFP using the I-O tables (Miller and Blair 2009). This technique is based on Jorgenson et al. (1987), a standard reference in the literature for the estimation of TFPs. To measure the change in intersectoral linkages over time, we compute the log difference between 2004 and 2013 in sectoral output upstreamness and input downstreamness. Table 2 compares sectoral TFPs, and growth in upstreamness and downstreamness, between the north and the south. The TFP for mining, "other industry," and WRT services is higher in the south than in the north. However, we find a much stronger correlation between TFP and upstreamness across sectors in the north (0.76) than in the south (0.39). Also, the correlation between TFP and downstreamness across sectors is stronger in the north (–0.69) than in the south (–0.44). The north clearly shows a much stronger relationship between intersectoral linkages and productivity growth across sectors compared to the south, corroborating, at the subnational level, the results by Fadinger et al. (2022).

Sectoral Value-Added Ratios

Table A3 reports the value-added ratios between mining and other sectors in 2004 and 2013. At the national level, value-added in mining is lower than value-added in other sectors in 2004. After the large-scale production of oil and gas commenced in 2010, these ratios change dramatically. In 2013, the value-added in mining becomes greater than the value-added in WRT services, and almost equals the value-added in agriculture. While the value-added of mining vis-à-vis other sectors increases both in the north and in the south, the absolute change in the ratios is much larger in the south.

Sectoral Output TFP and Value-Added TFP Ratios

Given that we only have TFP values for one period (2004 to 2013), we cannot estimate the MES elasticities based on TFP. As a result, we cannot directly test the extent to which the reallocation of resources across sectors is conditioned by TFP. As a second-best alternative, we compare changes in value-added ratios between 2004 and 2013, and output TFP ratios and value-added TFP ratios of mining to other sectors, in the north and in the south.

We calculate value-added TFPs from output TFPs based on equation D8 (see appendix D). Table A3 also reports output TFP and value-added TFP ratios between mining and other sectors. Both in the north and the south, mining's output TFP is the second lowest (after "other industry"), suggesting that the patterns based on value-added TFP ratios are qualitatively similar. Comparing output TFP and value-added TFP ratios, at the national level and in the south, the ratios for mining with respect to agriculture and "other services" are smaller when measured using output TFPs than using value-added TFPs. By excluding intermediate inputs, value-added TFP obviates an important source of economic growth at the sector level (Jorgenson and Stiroh 2001). Thus, one of the sources of difference between output TFP and value-added TFP is the growth of intermediate inputs over time. As a result, value-added TFP may overstate the extent of the change in technology compared to output TFP. The difference between value-added TFP and output TFP can vary across sectors. In the context of Ghana, this difference is much larger in agriculture and WRT services between the north and the south. This explains why productivity in mining relative to other sectors differs between output TFP and value-added TFP.

Lastly, we estimate the effect of an increase in relative mining productivity on the ratio of output in mining to output in other sectors at the national level. As figure A7 shows, mining output is complementary to output in agriculture, "other industry," WRT services, and "other services" as productivity growth in mining between two periods, 1968–2004 and 2004–13, leads to a fall in the ratio of output in mining to output in all these sectors.

Final Remarks on Intersectoral Linkages and Structural Transformation

Since high-productivity growth sectors release resources to low-productivity growth sectors, assuming a positive productivity shock only in mining, a larger TFP gap between mining and any other sector corresponds to a larger reallocation of resources between mining and that sector. The TFP ratio between mining and agriculture is much larger in the south (12.088) than in the north (–9.594). Correspondingly, we find a larger increase in the value-added ratio between mining and agriculture in the south (from 0.322 to 2.177) than in the north (0.002 to 0.179). The south experienced a much stronger productivity shock in mining than the north. Also, the TFP ratio between mining and "other industry" is larger in the south (0.532) than in the north (0.204), which is accompanied by a larger increase in the value-added ratio between mining and "other industry" in the south (0.430 to 0.730) than in the north (0.024 to 0.250). The TFP ratio between mining and WRT services in the south (–1.785) is much smaller than that in the north (21.434). This corresponds to a much larger increase in the value-added ratio between mining and WRT services in the north (0.019 to 0.612) than in the south (from 1.011

to 1.337). However, the change in the value-added ratio between mining and "other services" is higher in the south (0.173 to 0.845) than in the north (0.006 to 0.430).

To recapitulate, we find much stronger support for the link between differences in intersectoral linkages and reallocation of resources between sectors in the south than in the north. Several factors could explain this result, including a weak productivity shock in mining and limited intermediate sales by other sectors in the north. Differences in sectoral productivity growth based on TFP may not fully explain the allocation of resources between sectors if final sales grow at a much faster rate than intermediate sales (Oulton 2016), which, in turn, also limits the role of intersectoral linkages.

6. Intersectoral Linkages and Sectoral and Firm Performance

In the previous sections, we discussed evidence on the role of the mining output shock in shaping regional differences in intersectoral linkages (section 4) and on the stronger effect that intersectoral linkages have on structural transformation in the south compared to the north (section 5). Here, we aim to understand the mechanisms that link production networks and structural transformation at a more granular level. We use the NIC 2003 and IBES 2014 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 performance 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 compared to the north. The aggregate employment effect at the region level, however, is stronger for light manufacturing compared to 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 the 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:

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

$NewFirm^{s}_{d,t}$ 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 IBES 2014 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. 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 4 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 IBES 2014 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:

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

Equation (4) estimates the gap in the 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 NIC 2003 and IBES 2014 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 gap 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.

The 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. Evidence at a disaggregated level 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.

7. Conclusion

Following the start of large-scale production of offshore oil and gas in Ghana in 2010, we find that the output shock of mining was larger in the south than in the north of the country. This led to a diverging pattern of regional intersectoral linkages. Based on our new regional I-O tables, between 2003 and 2013, the increase in value-added and output shares of mining in the south was more than double that in the north. In terms of channels for growth, we find evidence for a stronger production network and larger TFP. Estimates based on enterprise census data support these channels at the district level and provide further insights on these channels. Sectors that mainly depend on mining inputs (for example, heavy manufacturing) registered a higher elasticity of employment with respect to changes in mining employment across districts than other sectors, especially in the south. The mining employment shock appears to have induced the entry of new firms and increased average firm-level employment in heavy manufacturing. Overall, the evidence based on the regional I-O tables and enterprise census data supports the occurrence of a concentrated mining shock in the south. This concentrated shock, in turn, drove the process of structural transformation to differ between the north and the south of Ghana.

Understanding regional differences in intersectoral linkages and patterns of structural transformation can generate policy-relevant insights on how to further promote aggregate productivity growth in multiple ways. 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 south. Industrial policies aimed at fostering a stronger linkage between mining and other sectors can help not only to secure greater economic gains from mining but also to redress the lack of access to modern energy services in other sectors, particularly in manufacturing as highlighted by Aryeetey and Ackah (2018). Growing upstreamness in mining has the potential to generate employment, investment, and income along the production value chain.

Second, the Voltaian basin in the north is likely to become Ghana's first onshore oil and gas field in the next few years as geological preconditions for oil and gas deposits have been found in the region (Skaten 2018). Is the north prepared to achieve a similar level of growth in output and productivity as experienced in the south of the country? The answer to this question depends on how efficiently industrial policies allocate resources to strengthen intersectoral linkages that transform mining into a leading upstream sector in the north.

Third, divergent patterns of structural transformation across regions promote regional specialization (for example, clothing industry in the north, heavy manufacturing in the south), which could enhance aggregate productivity growth with the introduction of stronger interregional trade linkages (Caliendo et al. 2018). After the COVID-19 pandemic, followed by the oil price shock, Ghana's upstream mining activities started recovering in the first half of 2021. In 2021, the projected petroleum revenues earmarked for financing development projects amounted to US$885.7 million, with 54 percent of the total set to go toward infrastructure development (PIAC 2021). The prospects of place-based development (Busso et al. 2013; Kline and Moretti 2014) have already been highlighted in the context of Ghana (Aragon and Rud 2013; Fafchamps et al. 2017), and the resources generated from petroleum revenues can be directed through place-based policies to achieve the abovementioned goals.

The role of production networks is also important for investigating productivity shocks in sectors other than mining. After decades of deindustrialization, industry is back at the center stage of the policy debate in Sub-Saharan Africa, following an increase in the manufacturing sector's share of total employment from 7.2 percent in 2010 to 8.4 percent in 2018 (Kruse et al. 2021). However, a steady growth of informal small manufacturing firms and the production of low-quality goods to satisfy rising demand by domestic consumers remain a threat to realizing a positive productivity shock in manufacturing (Diao et al. 2021;

Kruse et al. 2021). If informal activities produce a negative productivity shock by crowding out investment through lack of property rights in manufacturing, then it not only constrains the productivity growth from structural transformation (Paul and Raju 2021) but also propagates the negative productivity shock to the aggregate level.

Lastly, our study argues for a broader research agenda to understand the role of intersectoral linkages and productivity shocks in mining as the drivers of structural transformation in Sub-Saharan Africa. Similar studies on other emerging oil and gas producers including Kenya, Mozambique, Tanzania, and Uganda could provide further insights into the debate on the sustainability of the ongoing process of industrialization in Sub-Saharan Africa (McMillan and Zeufack 2022) and how mining shocks and intersectoral linkages help bolster industrial growth by moving sectors up the value chain.

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

		2003 (1)	2013 (2)	Change (Percent) (3)
a. Number of firms				
National	Mining	125	294	135
	Manufacturing	23,797	101,789	328
North	Mining	22	33	50
	Manufacturing	4,623	31,281	577
South	Mining	103	261	153
	Manufacturing	19,174	70,508	268
b. Persons engaged				
National	Mining	15,254	48,977	221
	Manufacturing	221,953	570,327	157
North	Mining	319	762	139
	Manufacturing	34,030	153,732	352
South	Mining	14,935	48,215	223
	Manufacturing	187,923	416,595	122
c. Employees				
National	Mining	14,869	40,120	170
	Manufacturing	116,774	271,863	133
North	Mining	247	645	161
	Manufacturing	10,386	44,507	329
South	Mining	14,622	39,475	170
	Manufacturing	106,388	227,356	114

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

Table 2: Sectoral TFP, Upstreamness, and Downstreamness

	National (1)	North (2)	South (3)
a. Output-based TFP (2004–2013)			
Agriculture	0.006	0.012	–0.009
Mining	–0.059	–0.115	–0.111
Other industry	–0.340	–0.563	–0.208
WRT services	0.061	–0.005	0.062
Other services	0.222	0.246	0.181
b. Log difference in output upstreamness (2013–2004)			
Agriculture	–0.199	–0.035	–0.197
Mining	0.134	0.135	0.126
Other industry	–0.280	–0.247	–0.254
WRT services	–0.029	–0.002	–0.048
Other services	0.062	0.056	0.029
c. Log difference in input downstreamness (2013–2004)			
Agriculture	0.046	0.049	0.057
Mining	0.155	0.136	0.151
Other industry	–0.006	0.001	–0.016
WRT services	–0.275	–0.102	–0.291
Other services	–0.221	–0.169	–0.223

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

Note: TFP = total factor productivity. 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 3: 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 of 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 4: 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)
$NewMFirm_{r(d' \neq d),t-1}$	0.374***	0.226**	0.072	0.251***	0.279***
	(0.082)	(0.090)	(0.069)	(0.086)	(0.075)
$NewMFirm_{r(d' \neq d),t}$	0.346***	0.121*	0.089	0.119	0.227***
	(0.097)	(0.068)	(0.065)	(0.090)	(0.076)
$NewMFirm_{d,t+1}$	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)
$NewMFirm_{r(d' \neq d),t+1}$	–0.026	–0.059	0.032	0.282***	0.219***
	(0.077)	(0.051)	(0.072)	(0.081)	(0.080)
$NewMFirm_{r(d' \neq d),t+2}$	0.082	0.064	0.027	0.024	0.175***
	(0.081)	(0.059)	(0.053)	(0.074)	(0.065)
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)
$NewMFirm_{r(d' \neq d),t-1}$	0.098***	0.028	0.018	0.087***	0.065**
	(0.026)	(0.025)	(0.019)	(0.029)	(0.028)
$NewMFirm_{r(d' \neq d),t}$	0.103***	0.036	0.015	0.062*	0.054**
	(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)
$NewMFirm_{r(d' \neq d),t+1}$	-0.003	-0.002	0.034**	0.068**	0.041
	(0.029)	(0.019)	(0.017)	(0.030)	(0.035)
$NewMFirm_{r(d' \neq d),t+2}$	0.059*	0.016	0.045**	0.126***	0.097***
	(0.034)	(0.025)	(0.019)	(0.029)	(0.027)
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

Table 4: Firm Creation, North and South

	$NewFirm^{s}_{d,t}$				
	Light manufacturing (1)	Heavy manufacturing (2)	Other industry (3)	WRT services (4)	Other services (5)
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.

Notes: This table presents estimates of 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 the 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 5: 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 of 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 6: Changes in Firm-Level Employment, 2003–2013

a. Light manufacturing

	$\log ManEmp_{i,t}$				
	Light (1)	Food (2)	Clothing (3)	Paper (4)	Other (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

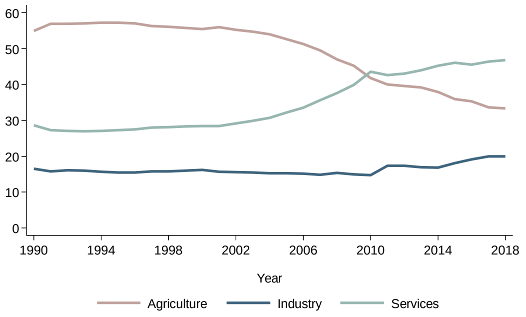
Source: Authors' estimates based on data from the 2003 National Industrial Census and the 2014 integrated business Establishment Survey.

Note: This table reports estimates of 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.

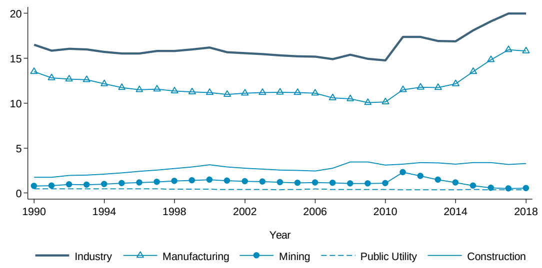
Figure 1: Trends in Sectoral Employment Shares and Value-Added Shares, 1990–2018

Sectoral employment shares

a. Broad sectors

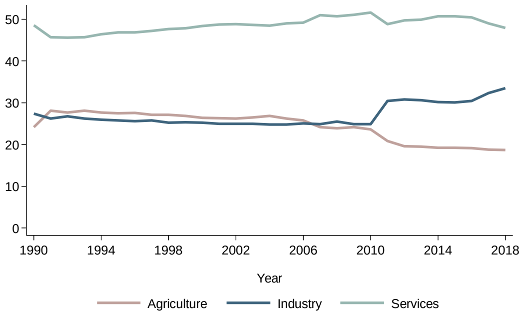


b. Subsectors within industry

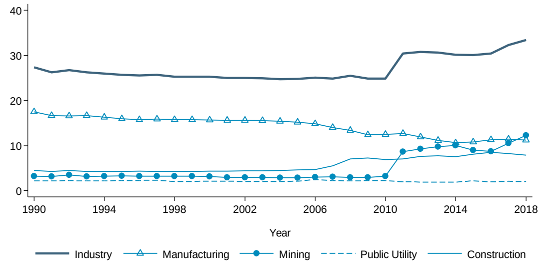


Sectoral value-added shares

c. Broad sectors



d. Subsectors within industry



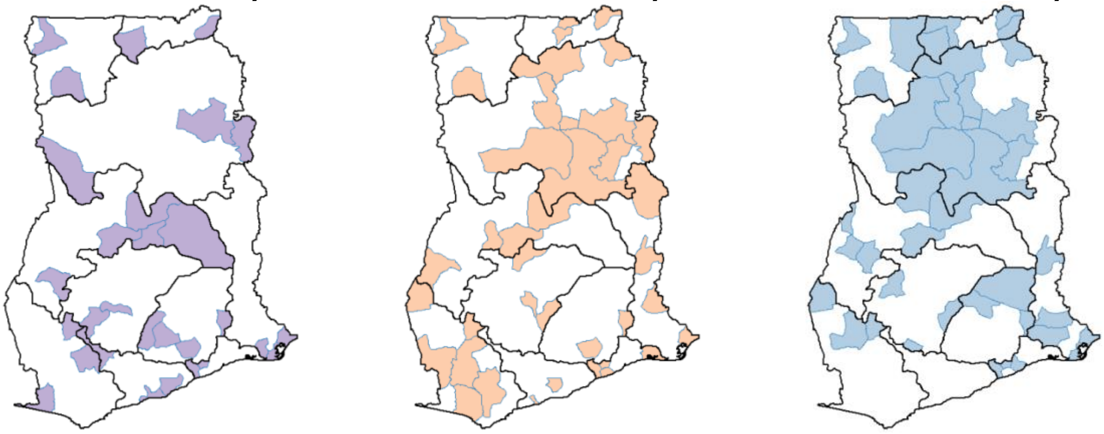
Source: Authors' estimates based on statistics from the Economic Transformation Database.

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 2: Spatial Growth of Sectoral Employment, 2003–2013

a. The north and the south | **b. Districts with mining employment, 2003** | **c. Districts with mining employment, 2013**

d. Employment growth in heavy manufacturing (top one-third of districts) | **e. Employment growth in light manufacturing (top one-third of districts)** | **f. Employment growth in clothing industry (top one-third of districts)**

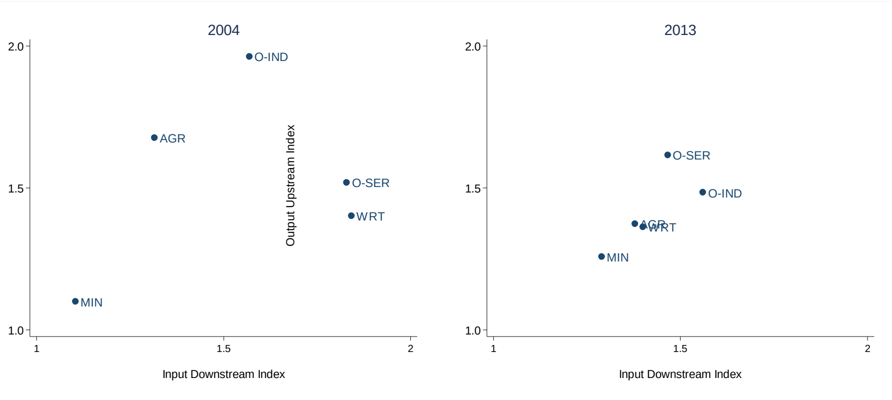


Source: Authors' estimates based on data from the 2003 National Industrial Census and the 2014 integrated business Establishment Survey.

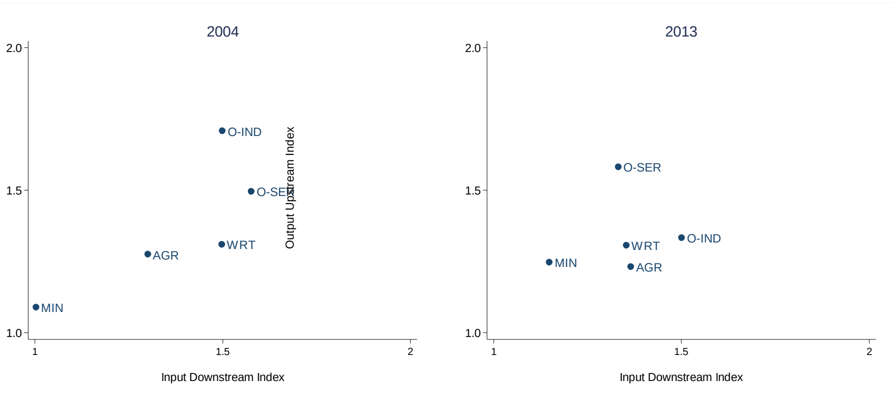
Note: In panel a, light green regions refer to the north and dark green regions refer to the south of Ghana. Panels b and c show the prevalence of mining activities at the district level. A district is shaded in grey if it has mining employment greater than zero. Panel d highlights districts that are in the top 33rd percentile in terms of growth in employment in heavy manufacturing sectors between 2003 and 2013. Panel e highlights districts that are in the top 33rd percentile 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 × (log [*X* in 2013] – log [*X* in 2003]).

Figure 3: Output Upstreamness and Input Downstreamness

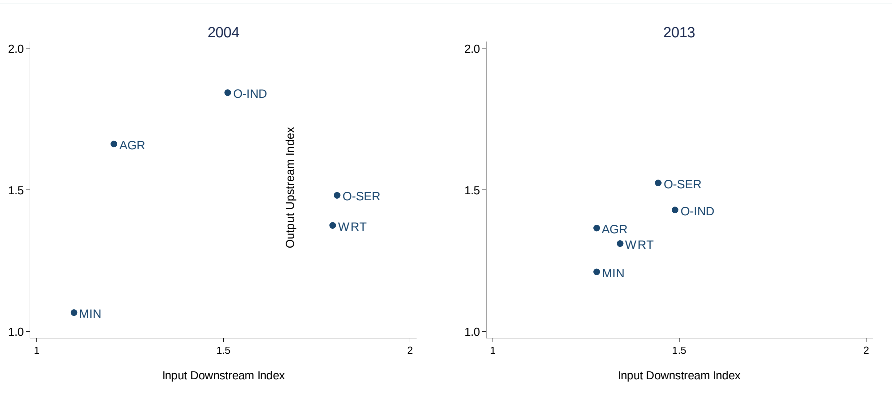
a. National



b. North



c. South



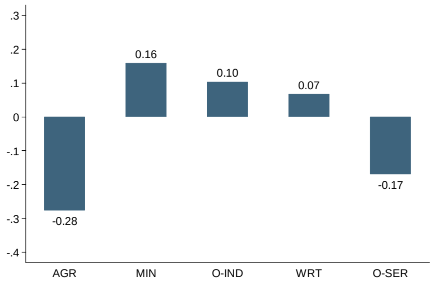
Source: Authors' elaboration based on 2004 and 2013 supply and use tables (GSS 2006, 2021).

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 output upstreamness and input downstreamness.

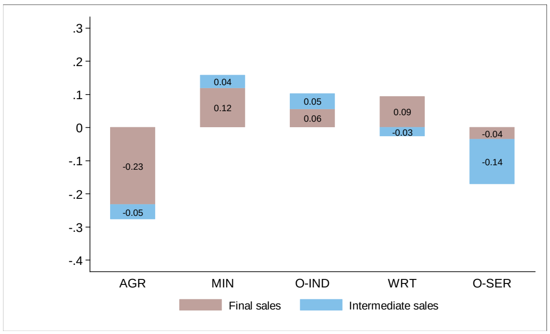
Figure 4: Changes in Domar Weights, 2004–2013

National

a. Total change

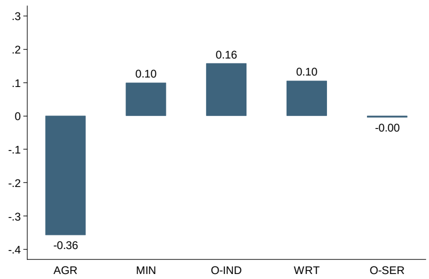


b. Change by sales categories

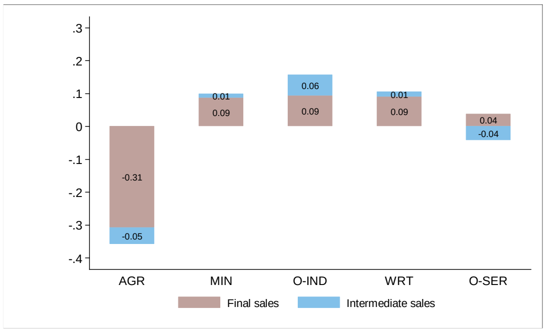


North

c. Total change

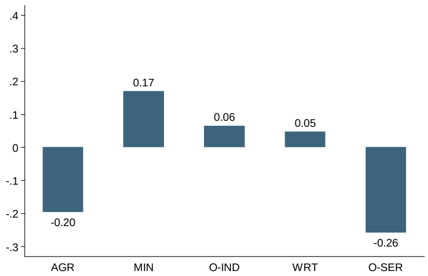


d. Change by sales categories

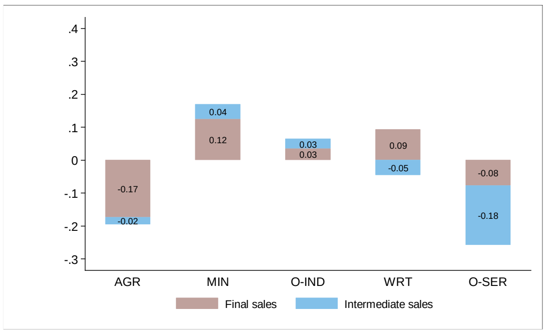


South

e. Total change



f. Change by sales categories



Source: Authors' elaboration based on 2004 and 2013 supply and use tables (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. $D_i = \frac{y_i{}^O}{GDP} = \frac{y_i{}^O\,(from\,final\,sales) + y_i{}^O\,(from\,intermediate\,sales)}{GDP}$, where D_i= Domar weight in sector *i* and $y_i{}^O$ = gross output in sector *i*.

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 = total 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, wearing apparel, and leather-related products. Growth in *X* = 100×(log [*X* in 2013] – log [*X* in 2003]). Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A2: Classification of Forward and Backward Linkage Effects

	National	
	2004	2013
Agriculture	Dependent on demand	Independent
Mining	Dependent	Dependent
Other industry	Independent	Independent
WRT services	Dependent on supply	Independent
Other services	Dependent on supply	Dependent
	North	
	2004	2013
Agriculture	Independent	Dependent on supply
Mining	Dependent	Dependent on demand
Other industry	Independent	Independent
WRT services	Dependent on supply	Dependent on supply
Other services	Dependent	Dependent on demand
	South	
	2004	2013
Agriculture	Dependent on demand	Independent
Mining	Dependent	Dependent
Other industry	Independent	Independent
WRT services	Dependent on supply	Independent
Other services	Dependent on supply	Dependent

Source: Authors' elaboration based on 2004 and 2013 supply and use tables (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. FLE = forward linkage effect, BLE = backward linkage effect. We determine a FLE (BLE) is weak / strong if its value is smaller / greater than the sectoral average of FLE (BLE). A sector is independent if the FLE and the BLE are weak; dependent if the FLE and the BLE are strong; dependent on supply if the FLE is weak and the BLE is strong; and dependent on demand if the FLE is strong and the BLE is weak.

Table A3: TFP and Value-Added Ratios Between Sectors

	National (1)	North (2)	South (3)
a. Value-added ratio, 2004			
Mining to agriculture	0.130	0.002	0.322
Mining to “other industry”	0.431	0.024	0.430
Mining to WRT services	0.814	0.019	1.011
Mining to “other services”	0.143	0.006	0.173
b. Value-added ratio, 2013			
Mining to agriculture	0.963	0.179	2.177
Mining to “other industry”	0.594	0.250	0.730
Mining to WRT services	1.203	0.612	1.337
Mining to “other services”	0.766	0.430	0.845
c. Output TFP ratio			
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
d. Value-added TFP ratio			
Mining to agriculture	–8.268	–3.269	15.815
Mining to “other industry”	0.165	0.127	0.566
Mining to WRT services	–0.774	11.545	–1.631
Mining to “other services”	–0.219	–0.257	–0.569

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

Note: TFP = total factor productivity. 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 A4: Firm Creation, National

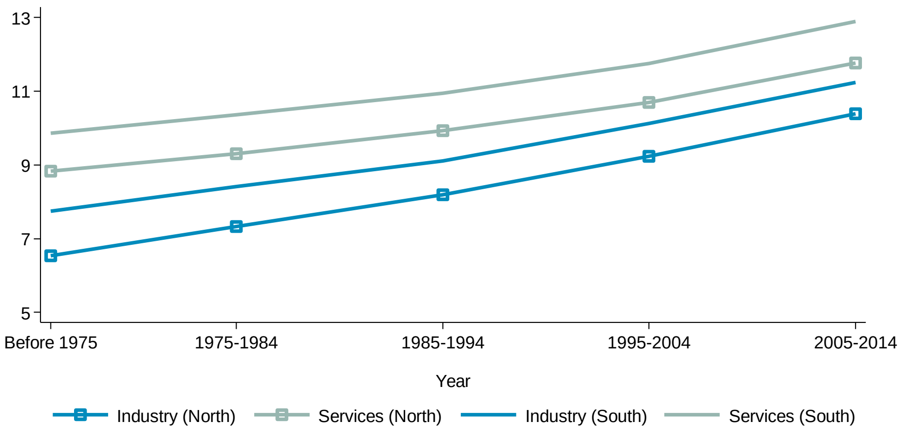
	$NewFirm^{s}_{d,t}$				
	Light manufacturing (1)	Heavy manufacturing (2)	Other industry (3)	WRT services (4)	Other services (5)
$NewMFirm_{d,t-1}$	0.043	0.131***	0.228***	0.124**	0.136*
	(0.060)	(0.045)	(0.056)	(0.061)	(0.078)
$NewMFirm_{d,t}$	0.044	0.145***	0.021	0.100	0.041
	(0.098)	(0.048)	(0.048)	(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.

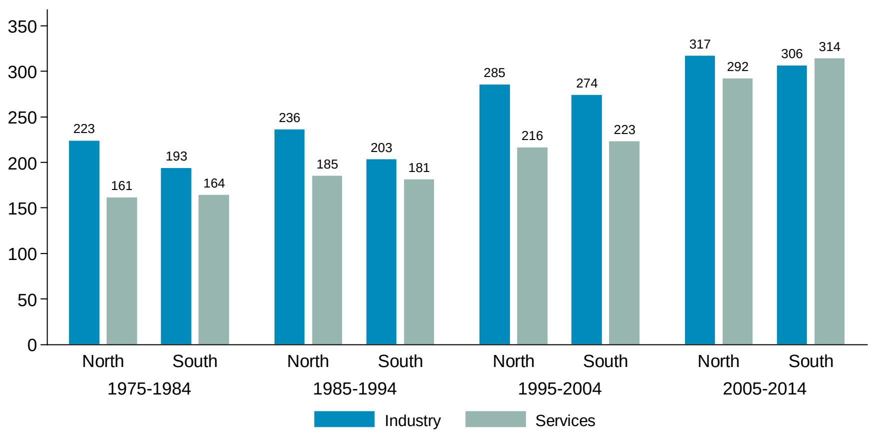
Note: This table presents variants of the regression specification in equation (2). The dependent variable is an indicator variable indicating entry of at least one new firm in year *t* and district *d* in respective sectors. Regression outcomes are based on a district-year panel comprising 119 districts and 24 years (1990–2013) based on the location and the year of entry of a 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.

Figure A1: Firms in Industry and Services, 1975–2014, North and South

a. Number of firms



b. Growth in number of firms

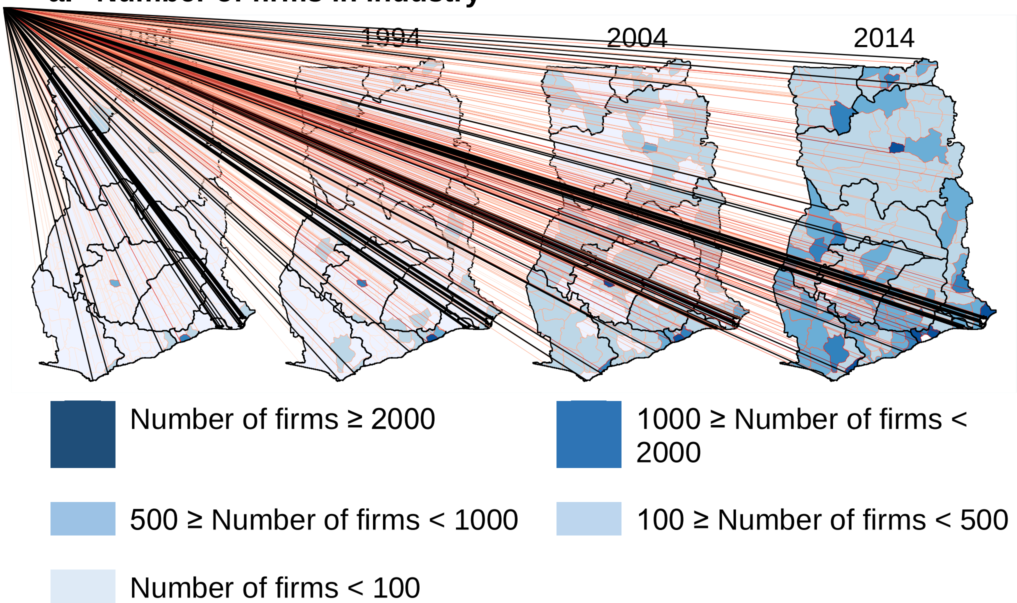


Source: Authors' estimates based on statistics obtained from GSS (2016).

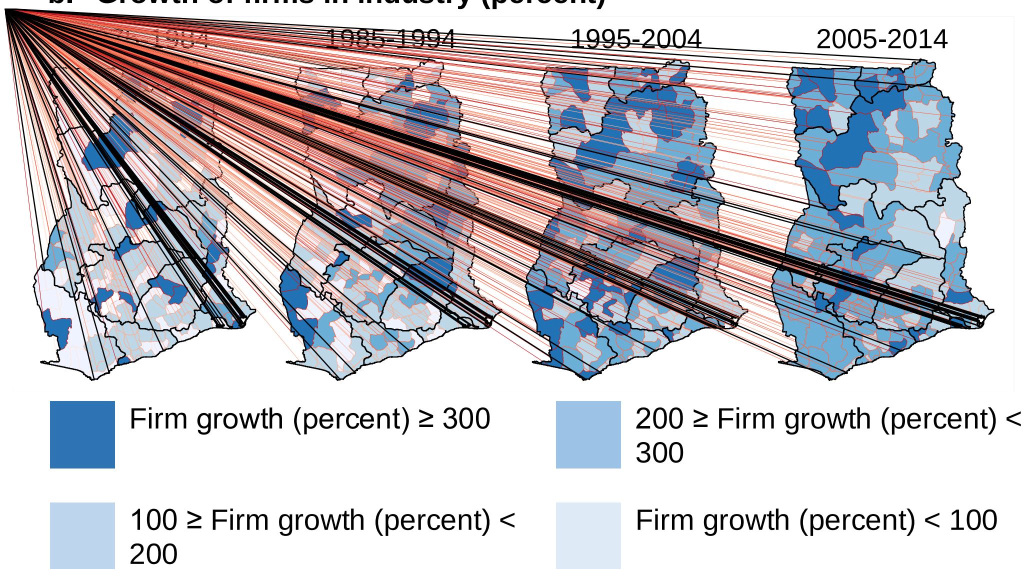
Note: Industry = mining, manufacturing, public utilities, and construction. Services = wholesale and retail trade, transportation and storage, financial and real estate activities, government services, and private services. District-level time series of firms in industry and services are constructed from the tables in GSS (2016) on year of firm establishment by district. Ghana has 137 districts in total, of which 67 are in the north and 70 are in the south. Growth in the number of firms is measured at the district level. Average figures of the district-level growth of firms in the north and the south are plotted for each time interval.

Figure A2: Spatial Growth of Firms in Industry, 1975–2014

a. Number of firms in industry



b. Growth of firms in industry (percent)

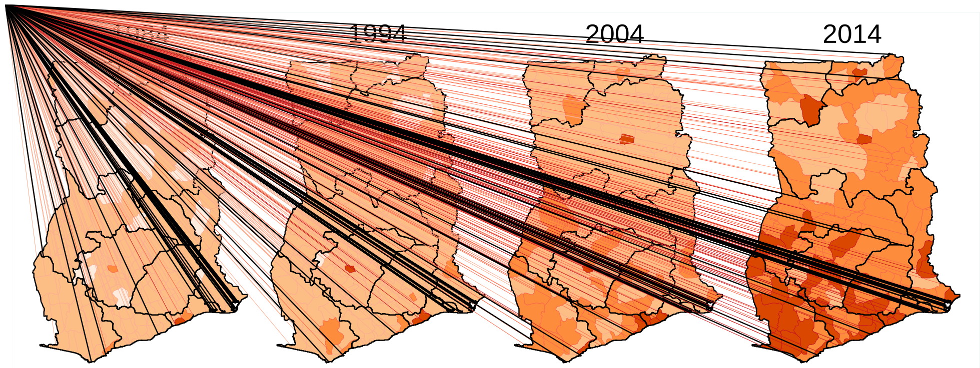


Source: Authors' estimates based on statistics from GSS (2016).

Note: District-level time series of firms in industry are constructed from the tables in GSS (2016) on the year of firm establishment by district.

Figure A3: Spatial Growth of Firms in Services, 1975–2014

a. Number of firms in services



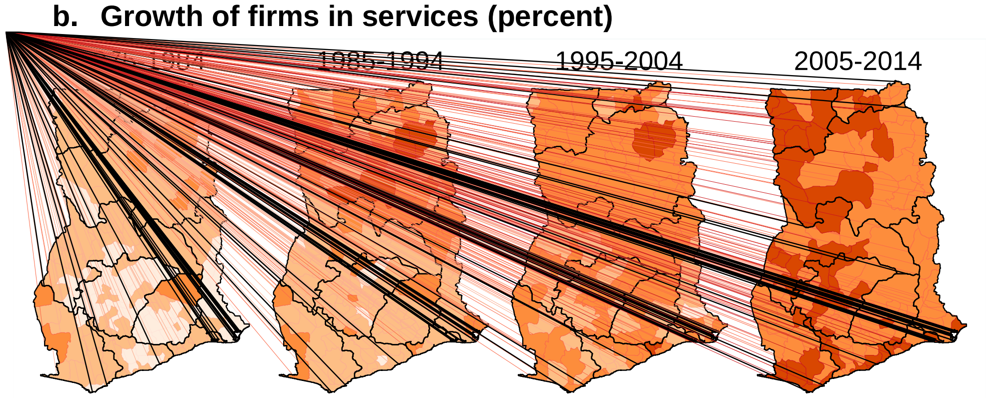
Number of firms ≥ 3000

1000 ≥ Number of firms < 3000

100 ≥ Number of firms < 1000

Number of firms < 100

b. Growth of firms in services (percent)



Firm growth (percent) ≥ 200

100 ≥ Firm growth (percent) < 200

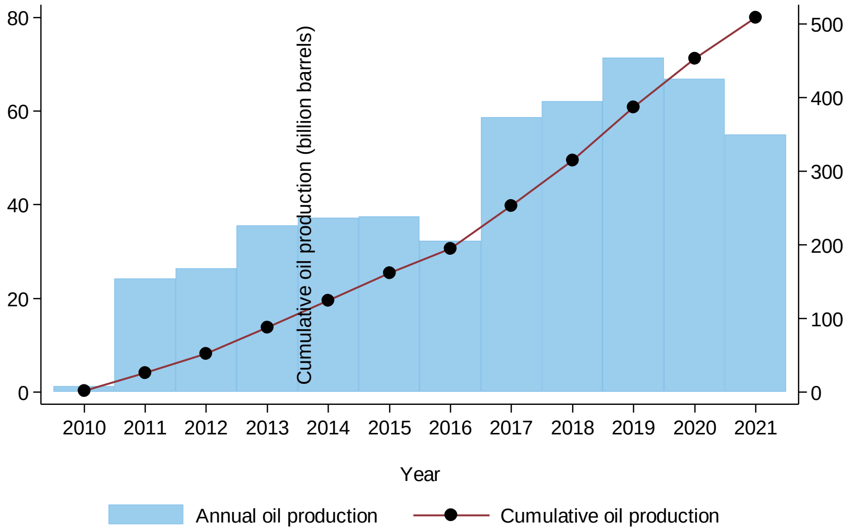
50 ≥ Firm growth (percent) < 100

Firm growth (percent) < 50

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

Note: District-level time series of firms in services are constructed from the tables in GSS (2016) on the year of firm establishment by district.

Figure A4: Annual and Cumulative Oil Production in Ghana, 2010–2021

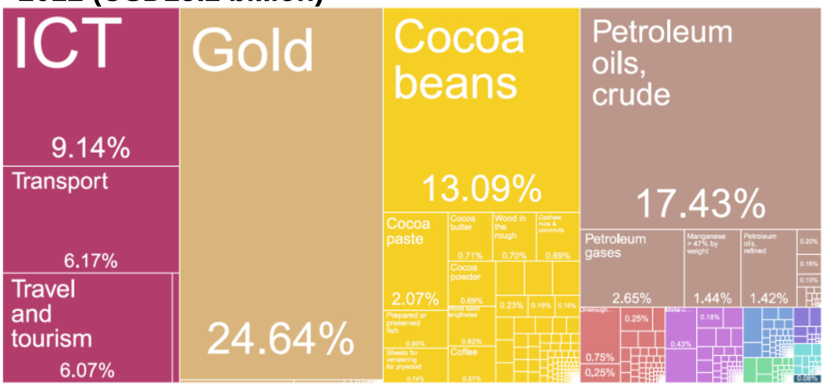


Source: Authors' estimates based on information obtained from PIAC (2021).

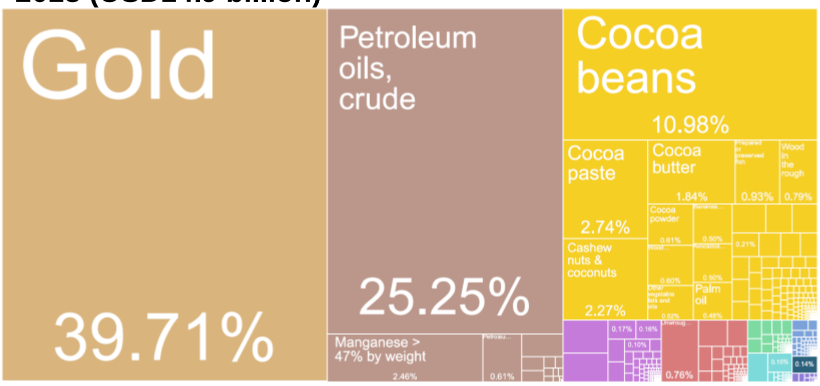
Figure A5: Growing Importance of Minerals in Ghana's Export Basket, 2006–2018

a. 2006 (USD4.1 billion)

b. 2012 (USD15.1 billion)

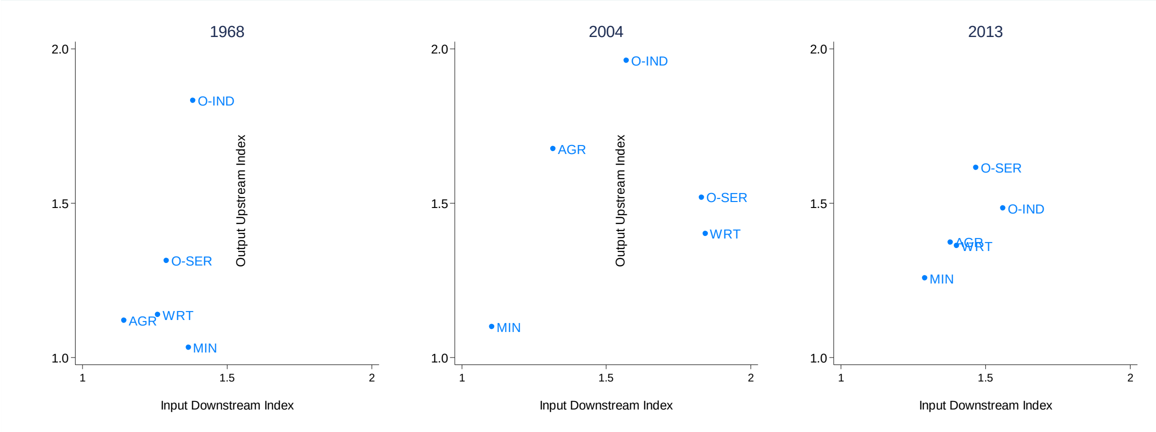


c. 2018 (USD14.9 billion)



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

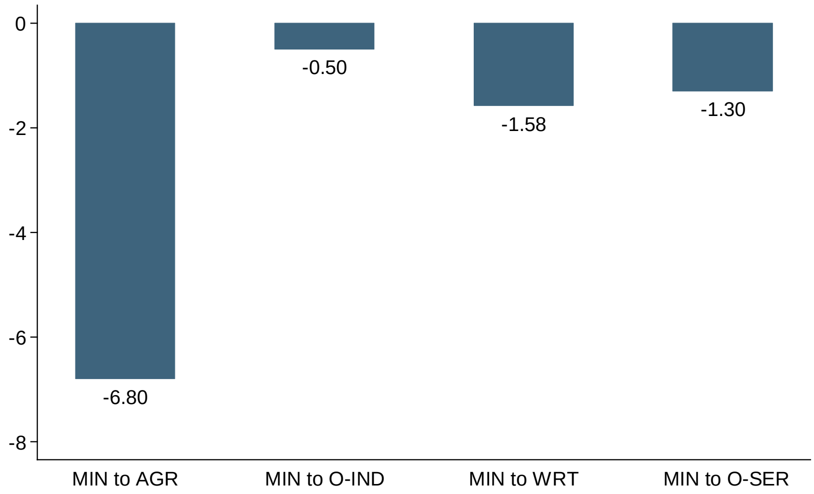
Figure A6: Output Upstreamness and Input Downstreamness, 1968, 2004, and 2013



Source: Authors' elaboration based on 2004 and 2013 supply and use tables (GSS 2006, 2021), and the 1968 I-O table for Ghana from the the United Nations Input-Output Tables for Developing Countries, available at https://digitallibrary.un.org/record/106839?ln=zh_CN.

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 output upstreamness and input downstreamness.

Figure A7: Change in the Sectoral Output Ratios from the Mining Productivity Shock, 1968–2004 and 2004–2013



Source: Authors' elaboration based on 2004 and 2013 supply and use tables (GSS 2006, 2021), and the 1968 I-O table for Ghana from the the United Nations Input-Output Tables for Developing Countries, available at https://digitallibrary.un.org/record/106839?ln=zh_CN**.**

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. We first compute output total factor productivity (TFP) growth and value-added TFP growth between 1968 and 2004 and between 2004 and 2013, and then utilize these statistics to calculate the Morishima elasticity of substitution (MES) following equation (D16) in appendix D.

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 enterprises, 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).[13]

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).

Valuation 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:

[13] 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.[14]

Let us define $\emptyset_1 = V * inv[diag(s)]$, where $diag(s)$ = diagonal matrix of product output. $\emptyset_1$ calculates 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.

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:

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[14] 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.

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).

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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 $(C_1, C_2, .., C_N)$:

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

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

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:

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

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

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

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

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

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 is 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).[15] 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 cedis was devalued. The current cedis is 10,000 times the old cedis (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.[16]

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[15] See https://statsghana.gov.gh/nationalaccount_macros.php?Stats=MTY4OTA1MDkwNC4wOTY=/webstats/2s1p460rn5 (accessed May 30, 2022).

[16] 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:

$$\boldsymbol{x} = A\boldsymbol{x} + \boldsymbol{f}, \tag{C5}$$

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 coauthors (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

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

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}:

$${A_{ij}}^R = \begin{cases} A_{ij} & if\ FLQ_{ij} \geq 1 \\ FLQ_{ij} \cdot A_{ij} & if\ FLQ_{ij} < 1 \end{cases} \quad \text{(C7)}$$

Table C2 presents the Leontief inverse matrices for all-Ghana (national), the north, and the south in 2004 and 2013.

Upstreamness and Downstreamness

To measure upstreamness, 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:

$$X_i = \sum_j^5 A_{ij} X_j + F_i. \quad \text{(C8)}$$

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:

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

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:

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

By construction, $U_{1i} \geq 1$. A larger value of U_{1i} indicates a higher level of upstreamness. For sector i, a measure of upstreamness close to one suggests that all output of sector i goes to final consumption use. U_i can be treated as the average distance from final output use, and it equals the value of total backward linkage effects (Miller and Blair 2009). At the sector level, if sector i uses inputs from sector j, then upstreamness measures the extent to which an expansion of the demand for output in sector j induces more activities in sector i.

The downstreamness measures the average distance from primary inputs suppliers (Miller and Temurshoev 2017). An expression for downstreamness (equation C11) looks similar to equation (C10), except for sectoral final consumption (F_i) is replaced by sectoral value-added (V_i).

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

A sector with large U_i has a large share of intermediate output in gross output and has strong intermediate output supply links with industries that have large upstreamness. On the other hand, a sector with large D_i has a large share 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.

Figure C1 shows sectoral upstreamness in 2004 and 2013. At the national level, the size of the upstreamness decreased in three sectors: by18 percent (from 1.68 to 1.37) in agriculture, by 25 percent (from 1.96 to 1.48) in "other industry," and by 3 percent (from 1.40 to 1.36) in wholesale and retail trade services. On the other hand, mining had the largest increase in upstreamness by almost 15 percent (from 1.10 to 1.26), followed by a 7-percent increase (from 1.52 to 1.62) in "other services." The patterns in the changes in sectoral upstreamness for the north and the south are comparable to those at the national level, except for agriculture. In agriculture, the fall in upstreamness between 2004 and 2013 is predominantly driven by trends in the south of the country. Upstreamness in mining has grown in both the north and the south, and despite a drop in the upstreamness of "other industry," the contribution of mining to this sector increased by almost 10 percentage points in both the north and the south between 2004 and 2013. These patterns indicate the growing importance of the mining sector in the south.

Figure C2 shows sectoral input downstreamness in 2004 and 2013. At the national level, the mining sector accounted for the largest increase—15 percent (from 1.10 to 1.29)—followed by agriculture, with a 5-percent increase (from 1.30 to 1.37). The growth rate of the downstreamness for mining is higher in the south (15 percent) than in the north (12 percent). On the other hand, input demand for WRT services and "other services" dropped by almost 24 percent (from 1.84 to 1.40) and 20 percent (from 1.83 to 1.47) at the national level, respectively. Regional variation in the growth rate of downstreamness also points to mining's stronger role as a downstream industry in the south than in the north.

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Table C1: 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	32513	41195
	MIN	0.000	0.000	0.066	0.000	0.000	0.066	4472	4790
	O-IND	0.031	0.036	0.201	0.025	0.070	0.362	14141	22174
	WRT	0.272	0.010	0.194	0.092	0.000	0.567	5433	12562
	O-SER	0.070	0.011	0.017	0.129	0.252	0.479	20915	40135

b. 2013 (in million 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	30944	41959
	MIN	0.000	0.053	0.138	0.001	0.004	0.195	21913	27227
	O-IND	0.039	0.026	0.099	0.145	0.080	0.388	45247	73906
	WRT	0.010	0.090	0.001	0.003	0.180	0.284	38534	39654
	O-SER	0.072	0.019	0.042	0.073	0.119	0.325	38703	57364

Source: Authors' elaboration based on 2004 and 2013 supply and use tables (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 C2: 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

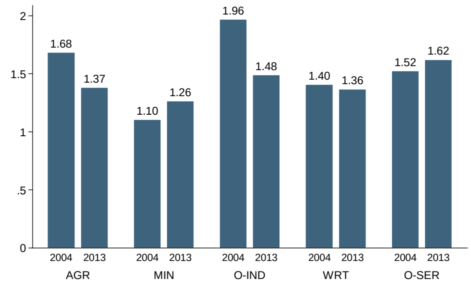
Source: Authors' elaboration based on 2004 and 2013 supply and use tables (GSS 2006, 2021).

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.

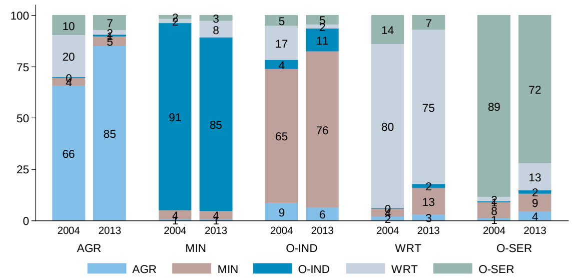
Figure C1: Upstreamness

National

a. Upstreamness

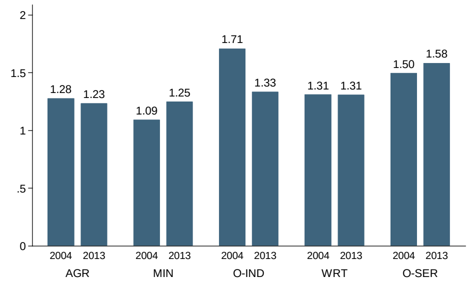


b. Contribution by selling sectors

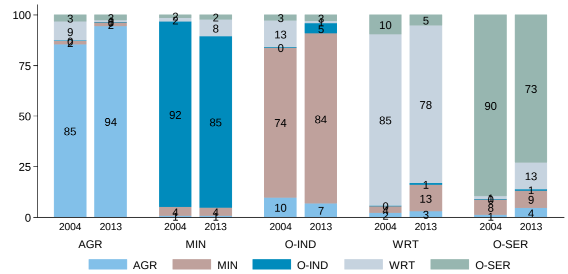


North

c. Upstreamness

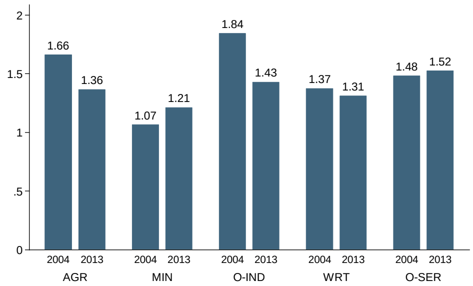


d. Contribution by selling sectors

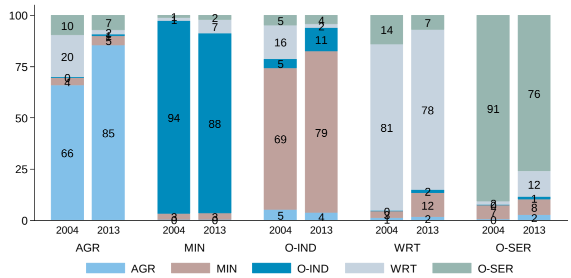


South

e. Upstreamness



f. Contribution by selling sectors



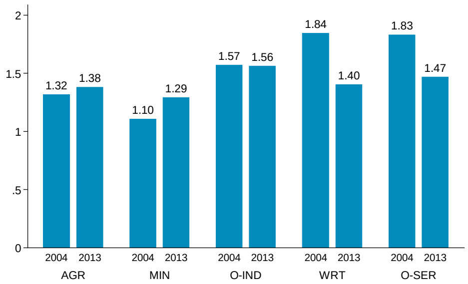
Source: Authors' elaboration based on 2004 and 2013 supply and use tables (GSS 2006, 2021).

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.

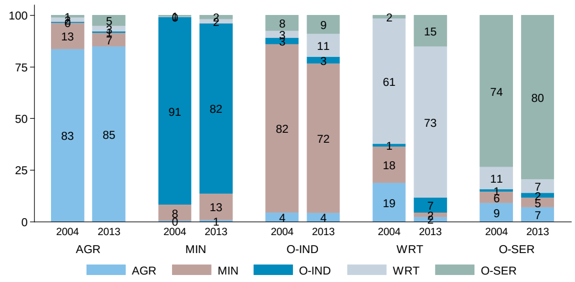
Figure C2: Downstreamness

National

a. Downstreamness

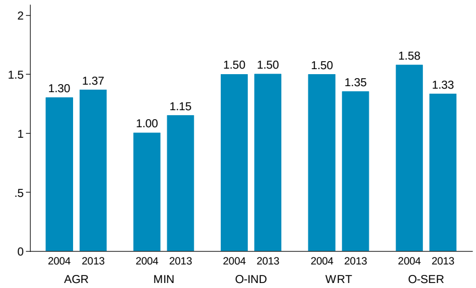


b. Contribution by purchasing sectors

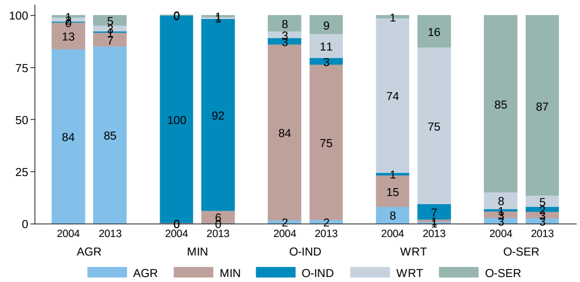


North

c. Downstreamness

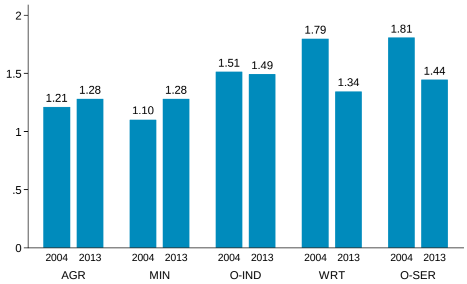


d. Contribution by purchasing sectors

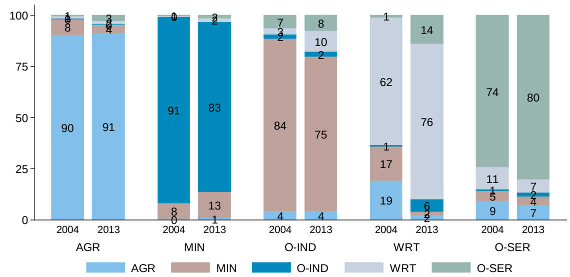


South

e. Downstreamness



f. Contribution by purchasing sectors



Source: Authors' elaboration based on 2004 and 2013 supply and use tables (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.

Appendix D

Effect of Spatial Differences in Intersectoral Linkages on Sectoral Output and Productivity

General Equilibrium Model

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 $(C_1, C_2, .., C_N)$:

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

$$\text{Subject to } \sum_i^N P_i C_i = w\bar{l} + \sum_i^N \pi_i, \tag{D1}$$

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 (D1) 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:

$$y_i = A_i F_i(L_i, x_{i1}, x_{i2}.., x_{iN}), \tag{D2}$$

where A_i is a Hick-neutral technology, L_i is labor used for 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 producers of good i can be written as

$$\pi_i = P_i y_i - w_i l_i - \sum_j^N P_j x_{ij}, \tag{D3}$$

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 good (sector) i can be written as

$$\varphi_i = \frac{\sum_j^N x_{ji}}{y_i}. \tag{D4}$$

We distinguish between the gross sectoral output and value-added production function. The value-added total factor productivity (TFP) is derived from output TFP based on an additional condition that real gross output per unit of real intermediate input is determined entirely by input prices and can never be reduced by technological progress (Baumol and Wolff 1984; Oulton 2016). A value-added production function exists only under this condition. We rewrite equation (D2) by adding a suffix "*O*" and "*V*" for output (in short for gross output) and value-added, respectively:

$$y_i{}^O = A_i{}^O F_i(L_i, x_{i1}, x_{i2}.., x_{iN}),$$
$$y_i{}^V = A_i{}^V F_i(L_i). \quad \text{(D5)}$$

We assume marginal cost pricing based on a competitive market, and that a given input receives the same price across all sectors. Then, using the standard definition of TFP, output TFP becomes

$$A_i{}^O = \hat{y}_i{}^O - \alpha_L{}^O \hat{L}_i - \sum_{j=1}^{N} \alpha_{ij}{}^O \hat{x}_{ij}, \quad \text{(D6)}$$

where $\wedge$ is the growth rate of a variable over time, $\alpha_s{}^O$ is the elasticity of any input s with respect to output, which becomes the share of output in sector i under a competitive market. Likewise, value-added TFP can be written as

$$A_i{}^V = \hat{y}_i{}^V - \alpha_L{}^V \hat{L}_i, \quad \text{(D7)}$$

where $\alpha_L{}^V$ is the elasticity of labor with respect to value-added, which becomes the share of gross value-added in sector i as input markets are competitive. From equations (D6) and (D7), we derive the following relationship between value-added TFP and output TFP:

$$y_i{}^O = \frac{A_i{}^V}{A_i{}^O} y_i{}^V \text{[17]}. \quad \text{(D8)}$$

Equation (D8) holds only if value-added is measured by double deflation, one for input prices and one for output prices. Single deflation works only when output and input prices change at the same rate, which is unlikely. (See Steindel and Stiroh 2001 and Oulton and O'Mahony 1994 for further discussions on this topic.) Based on equation (D8), we can rewrite the Domar weight (D_i) for sector i as

$$D_i = \frac{y_i{}^O}{GDP} = \frac{A_i{}^V}{A_i{}^O} \frac{y_i{}^V}{GDP}. \quad \text{(D9)}$$

Taking the log of both sides of equation (D9), the log of the ratio of the Domar weight between sectors i and j becomes a function of three terms, as follows:

$$\text{Log} \frac{D_i}{D_j} = \log \frac{y_i{}^V}{y_j{}^V} + \log \frac{A_i{}^V}{A_j{}^V} - \log \frac{A_i{}^O}{A_j{}^O}. \quad \text{(D10)}$$

The first term shows the log of the value-added ratio between sectors i and j, the second term shows the log of the value-added TFP ratio between sectors i and j, and the third term shows the log of the output TFP ratio between sectors i and j. Differentiating both sides of equation (D10) with respect to $log \frac{A_i{}^O}{A_j{}^O}$, we obtain

[17] See Gabaix (2011) and Oulton (2016) for a proof of this result.

$$\frac{d\log\frac{D_i}{D_j}}{d\log\frac{A_i{}^O}{A_j{}^O}} = \frac{d\log\frac{y_i{}^V}{y_j{}^V}}{d\log\frac{A_i{}^O}{A_j{}^O}} + \frac{d\log\frac{A_i{}^V}{A_j{}^V}}{d\log\frac{A_i{}^O}{A_j{}^O}} - 1. \tag{D11}$$

As equation (D11) shows, the elasticity of substitution between the Domar weight and output TFP across sectors i and j can be measured using the elasticity of substitution between output TFP and value-added TFP across sectors i and j, and the elasticity of substitution between output TFP and value-added across sectors i and j.

Elasticity Parameters

Production networks are typically modelled as a two-stage, multi-input constant elasticity of substitution (CES) production function, under the assumption of a constant elasticity of substitution across intermediate use of sectoral outputs (Atalay 2017; Baqaee and Farhi 2019; Carvalho et al. 2021). It is generally assumed that the factor inputs are used in the first stage, and the intermediate inputs as output from other sectors are used in the second stage. In this type of general equilibrium models, nonunitary elasticities of substitution parameterize intersectoral linkages through (1) the degree of substitution between the intermediate use of sectoral outputs and (2) the degree of substitution between value-added and the intermediate use of sectoral outputs.

However, equation (D11) suggests a varying degree of substitutability across intermediate input pairs and it is not feasible to model this in a single-stage CES production model. Therefore, we consider a nested CES technology that allows for a multistage production process incorporating interstage and intrastage substitution between inputs. The production of goods and services often involves multiple stages, each of which uses a set of inputs that includes outputs from previous stages of production (we call this a composite intermediate input). For example, the production of semiconductors goes through several steps. These steps comprise cleaning of silicon wafers, film deposition, resist coating, exposure, development of pattern on the layer, etching, activation and, finally, assembly.

Each of these steps is a different process consisting of composite intermediate inputs that are produced in one of the previous stages of production and raw intermediate inputs that are used for the first time in the production. The nesting or clustering of a production network can be undertaken in alternative ways. For example, a cascading CES production technology with binary compounding assumes a compound intermediate input (produced in the previous nest) and a raw input in each nest (Nakano and Nishimura 2018). We adopt a relatively flexible multistage model, in which n inputs are partitioned into K nests. We rewrite the production function for sector i (equation (D2)) with $n+1$ inputs including labor, and n raw intermediate inputs.

In our multistage sectoral production process, n raw inputs are transformed into K composite inputs across different stages of production. Omitting the subscript for sector i, the sectoral production function becomes

$$y = \ AF(x_1,\ x_2 .., \ x_{n+1}), \tag{D12}$$

where $y(\geq 0)$ is output, $x_i(\geq 0)$ are inputs, and A is total factor productivity (TFP). Each nest X_k, $k = 1,\ 2,\ \ldots, K$ consists of a combination of inputs $x_1,\ x_2 \ldots,\ x_{n+1}$ following two conditions: (1) $X_k \cap X_r = \phi$ for all $k \neq r$ and (2) $X_1 \cup X_2 \ldots \cup X_K = \{x_1,\ x_2 \ldots,\ x_n\}$. In other words, all inputs are exhaustively used, and no input can be used in multiple nests. This assumption may appear rather restrictive as labor can be used in each stage of the production process. Since our main goal is to understand the relationship between TFP and the intermediate use of sectoral outputs, the assumption that labor is used only in the final stage of the production process or in one of the nests is less concerning to us.

Denote the input vector as x, the input price vector as p, the unit cost function for the final output as $c(p)$, and the unit cost function for the nest k as $c_k(p_k)$. Each nest k follows a CES production technology denoted as $\Psi^k\left(x^{[k]}\right)$, and uses a subvector of inputs $x^{[k]}$ through which a compound intermediate good X_k is produced, such that $x = \left(x^{[1]},\ x^{[2]} \ldots ., x^{[K]}\right)$ and $p = \left(p^{[1]},\ p^{[2]} \ldots ., p^{[K]}\right)$. We assume each input market is competitive. The partitioning of the whole production process into K subprocesses or nests is made explicit by

$$y = \ AF\left(\Psi^1\left(x^{[1]}\right),\ \Psi^2\left(x^{[2]}\right) \ldots ., \Psi^K\left(x^{[K]}\right)\right). \tag{D13}$$

In a multistage production process, to capture the essence of both intrastage and interstage substitutions as part of the substitution elasticity parameter between any two inputs, we apply a measure of input substitutability introduced by Morishima (1967), which, later, Blackorby and Russell (1989) termed as the Morishima elasticity of substitution (MES). In the presence of a CES technology, some properties of the MES change because CES imposes a more stringent condition on the variability of the substitution parameter within a nest (Blackorby and Russell 1989). According to Blackorby and Russell, the MES is a natural multi-input generalization of the Hicksian two-input elasticity of substitution. The MES is essentially a two-factor, one-price elasticity of substitution (TOES), which measures the percentage change in the ratio between two inputs resulting from a one-percent change in the price of one input (Chambers 1988).

Under the current formulation, we can write the MES between inputs i and j based on a cost minimization problem (Blackorby and Russell 1989; Anderson and Moroney 1993), as follows:

$$MES_{ij} = \begin{cases} {\eta_{ji}}^{[k]} - {\eta_{ii}}^{[k]}, \;\; i, j \in X_k \\ {\theta_i}^{[k]} MES_{kr} - {\eta_{ii}}^{[k]}, \;\; i \in X_k, \;\; j \in X_r, \; k \neq r \end{cases}, \tag{D14}$$

where ${\eta_{ji}}^{[k]}$ is the cross-price elasticity of conditional demand within nest k, ${\eta_{ii}}^{[k]}$ is the own-price elasticity of conditional demand within nest k, ${\theta_i}^{[k]}$ is the cost share of input i in nest k, and MES_{kr} is the Morishima interstage elasticity of substitution between nests k and r. The nesting of CES processes generates symmetric intranest MES (i.e., $MES_{ij} = MES_{ji}$) but asymmetric internest MES (i.e., $MES_{ks} = MES_{sk}$). Internest MES are symmetric and constant only when intranest input cost shares are equal, and substitution parameters across nests are equal (Blackorby and Russell 1989; Anderson and Moroney 1993).

The MES shows changes in the cost-minimizing optimal input ratio resulting from a percentage change in the price ratio induced by a change in p_i, holding p_j constant. The MES holds prices of other factor inputs constant and adjusts the measure of the elasticity of substitution accordingly. As originally suggested by Pigou (1934), one way to address this issue is to hold output and other input factors, except for one of the two in the ratio, constant. Inputs x_i and x_j are Morishima complements if $MES_{ij} < 1$, and inputs x_i and x_j are Morishima substitutes if $MES_{ij} > 1$.

In a nested production technology, the MES is a sufficient statistic to evaluate the comparative static results of the log of relative input cost shares with respect to the log ratio of technology parameters, which is reciprocal to the change in the ratio of input prices. Denoting the input cost share of nest k as θ_k, we obtain

$$\begin{aligned} (i) \quad & \frac{\partial \log\left(\frac{\theta_k}{\theta_r}\right)}{\partial \log\left(\frac{A_k}{A_r}\right)} = MES_{kr} - 1, \\ (ii) \quad & \frac{\partial \log\left(\frac{{\theta_i}^{[k]}}{{\theta_j}^{[k]}}\right)}{\partial \log\left(\frac{A_i}{A_j}\right)} = MES_{ij} - 1, \\ (iii) \quad & \frac{\partial \log\left(\frac{{\theta_i}^{[k]}}{{\theta_j}^{[r]}}\right)}{\partial \log\left(\frac{A_i}{A_j}\right)} = {\theta_i}^{[k]} MES_{kr} - {\eta_{ii}}^{[k]} - 1, \end{aligned} \tag{D15}$$

where $\frac{A_k}{A_r}$ is the TFP ratio between nest k and nest r, and $\frac{A_i}{A_j}$ is the TFP ratio between inputs i and j. If $n = k$, that is, each nest contains only one input, then (iii) in equation (D15) becomes identical to (i) in equation (D15). If intermediate inputs x_i and x_j are Morishima complements (substitutes), then technological progress in sector i compared to sector j leads to an increase (decrease) in the ratio of sectoral output in sector i compared to sector j.

In an aggregate production function that uses sectoral output as an intermediate input, the input cost share becomes equivalent to the Domar weight. Then, comparing equations (E11) and (E15), and rearranging terms, we obtain a new expression for the MES as follows:

$$MES_{ji} = \frac{d\log\frac{y_j{}^V}{y_i{}^V}}{d\log\frac{A_j{}^O}{A_i{}^O}} + \frac{d\log\frac{A_j{}^V}{A_i{}^V}}{d\log\frac{A_j{}^O}{A_i{}^O}}. \tag{D16}$$

If the sum of the elasticity of substitution between output TFP and value-added TFP across sector i and j and the elasticity of substitution between output TFP and value-added across sector i and j are less (more) than one, then technological progress in sector i relative to sector j leads to an increase (decrease) in the ratio of sectoral output in sector i relative to sector j. As Paul and Raju (2022) show, the nonlinear effect of sectoral productivity shock on aggregate productivity can be expressed using MES_{ji}, which is analogous to the conditions for the propagation of sectoral productivity shocks to the comovement of sectoral outputs through intersectoral linkages derived in Baqaee and Farhi (2019) and Carvalho et al. (2021).

Illustrative Example

Consider a three-sector, two-stage model in which output (y) in each sector is produced with inputs from mining (M), “other industry” (I), and services (S), where M and S are used in nest N_1 and only I is used in nest N_2, as follows:

$$y = \left[\delta_{N_1}\left[\mu_M M^{\frac{\rho-1}{\rho}} + \mu_S S^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}\frac{\sigma-1}{\sigma}} + \delta_{N_2} I^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} = N_1(M,S) + N_2(I), \tag{D17}$$

where δ and 1- δ are input cost shares between N_1 and N_2, respectively; μ and 1- μ are input cost shares between M and S, respectively; ρ is the constant elasticity of substitution between M and S; and σ is the constant elasticity of substitution between N_1 and N_2. Varying substitution parameters across inputs are obtained in different ways using the MES, as follows:

$$\begin{aligned} MES_{MS} = MES_{SM}(= \rho) &= \eta_{SM} - \eta_{MM}, \quad M,S \in N_1, \\ MES_{MI}(\neq \sigma) &= \theta_M MES_{N_1N_2} - \eta_{MM}, \quad M \in N_1;\ I \in N_2, \\ MES_{IM}(\neq \sigma) &= \theta_I MES_{N_1N_2} - \eta_{II}, \quad M \in N_1;\ I \in N_2. \end{aligned} \tag{D18}$$

We also obtain the following comparative statics results for the relative input cost shares:

$$\frac{\partial \log\left(\frac{\mu_M}{\mu_S}\right)}{\partial \log\left(\frac{A_M}{A_S}\right)} = MES_{MS} - 1,$$

$$\frac{\partial \log\left(\frac{\mu_M}{\delta_I}\right)}{\partial \log\left(\frac{A_M}{A_I}\right)} = \mu_M MES_{N_1 N_2} - \eta_{MM} - 1. \qquad \text{(D19)}$$

Assuming that the MES parameters can be estimated for the north and the south of Ghana, the following remarks are in order:

(1) If $\rho^{North} = \rho^{South} < 1$, then it implies that labor will move from high-productivity mining to low-productivity services (since both ρ^{North} and ρ^{South} are Morishima complements) following Baumol's cost disease argument.

(2) Suppose ${MES_{N_1N_2}}^{North} < {MES_{N_1N_2}}^{South}$. Then ${MES_{MI}}^{North} < {MES_{MI}}^{South}$ if θ_M and η_{MM} do not vary between the north and the south. This implies that mining and "other industry" are more substitutable in the south than in the north. We then have the following three subcases:

(a) ${MES_{MI}}^{North} < {MES_{MI}}^{South} < 1$ implies that labor will move from high-productivity mining to low-productivity "other industry" in both regions, but at a higher rate in the north than in the south (since both ${MES_{MI}}^{North}$ and ${MES_{MI}}^{South}$ are Morishima complements).

(b) ${MES_{MI}}^{North} < 1 < {MES_{MI}}^{South}$ implies that labor will move from high-productivity mining to low-productivity "other industry" in the north but labor will move from low-productivity "other industry" to high-productivity mining in the south (since ${MES_{MI}}^{North}$ is a Morishima complement and ${MES_{MI}}^{South}$ is a Morishima substitute).

(c) $1 < {MES_{MI}}^{North} < {MES_{MI}}^{South}$ implies that labor will move from low-productivity "other industry" to high-productivity mining in both regions, but at a higher rate in the south than in the north (since both ${MES_{MI}}^{North}$ and ${MES_{MI}}^{South}$ are Morishima substitutes).

Given the finding that the employment share in mining decreases in the south, case (2)(c) is less likely to occur. Either case (1), (2)(a), or (2)(b), or a combination of them can produce an increase in the employment share in "other industry" in the north and a decrease in the employment share in mining in the south.

Further insight on the link between sectoral productivity shocks and intersectoral linkages can be drawn from the literature on the aggregate effects of sectoral productivity shocks through input-output networks. See Carvalho and Tahbaz-Salehi (2019) for an extensive survey of the literature on this topic. The propagation of sectoral productivity shocks to the comovement of sectoral outputs and the aggregate productivity level is conditioned by the pattern of intersectoral linkages exogenously given in the model (Carvalho et al. 2021). If sectoral productivity shocks are region-specific, then intersectoral linkages can vary across regions due to regional specialization of sectoral activities (for example, mining in the south of Ghana). In this sense, intersectoral linkages become endogenous to sectoral productivity shocks. By comparing the pattern of intersectoral linkages before and after the mining productivity shock and between the south and the north of Ghana, we can estimate the correlation between sectoral productivity shocks and changes in the pattern of intersectoral linkages.

At the same time, complementarities in the consumption of sectoral output can drive resources away from high- to low-productivity growth sectors, known as Baumol's cost disease effect (Baumol 1967). See Herrendorf et al. (2014) for an extensive survey of the literature on the drivers of structural transformation. Both the degree of complementarities in sectoral consumption and the productivity gaps across sectors are instrumental in the reallocation of resources across sectors. Combining the literature on the drivers of structural transformation with aggregate effects of sectoral shocks in the context of Ghana, if the consumption of sectoral output is complementary, then differences in intersectoral linkages between the north and the south can explain the diverging trends in sectoral employment and value-added shares between the two regions. Thus, the industry share of employment can increase in the north and the industry share of value-added can increase in the south.

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