Global Value Chains, Industrial Upgrading, and Local Labor Markets *

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Abstract

Moving from the production of low-processed commodities to downstream basic manufacturing activities within a value chain is a popular policy strategy in emerging resource-rich economies. However, the welfare and productivity gains from this *"route to industrialization"*, and its distributional impacts in local labor markets are not unambiguous. This study exploits variation in the upgrading from low-processed mine copper to smelting and refined copper exports in Chile, the world's largest copper producer, with two main objectives: (1) identifying the role of resource endowments and export competition in inducing industrial upgrading in local labor markets; and (2) estimating the local welfare and productivity gains from this process of industrial upgrading. The results suggest that: (1) competition in global value chains plays a major role in shaping the development of downstream industries in the smelting and refinement of minerals; (2) the local welfare and productivity gains from industrial upgrading in local labor markets are small; and (3) due to comparative advantages given by resource endowments, the potential gains from industrial policy are largely concentrated in the primary segment of mineral extraction.

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" ... the mineral resources provides the mineral economies with additional foreign exchange, taxes and an extra route to industrialization. That additional route is a via resource-based industrialization which is the downstream processing of the ore into metal and finished products".

Richard Auty, *Sustaining Development in Mineral Economies (1993)*

1 Introduction

Global value chain (GVC) participation has significantly increased over the last three decades. Compared to previous waves of globalization, this increased participation implied larger gains from trade as both specialization and division of labor increased (World Bank, 2019). However, the distributional consequences of GVC expansion are a growing concern for academics and policymakers (Antràs, 2020). There is increased attention on fostering the GVC participation of developing countries that produce low-processed commodities and are involved in the primary production stages of GVCs. In particular, the focus is on moving from the production of low-processed commodities to basic manufacturing exports, where the major boost for growth is expected to occur (World Bank, 2019). Within this strategy of development, policymakers tend to consider, and usually favor, policies that integrate downstream manufacturing activities into higher segments of the value chain. The aim is to add more value to low-process exports and foster industrialization.

However, the effectiveness of these policies in the developing world may be undermined by the intensification of the unintended consequences of GVC expansion. These include the higher entry costs and competition effects associated with producing goods in increasingly functional and geographically fragmented global production networks (Antràs and de Gortari, 2020). Furthermore, *learning-by-doing* and productivity spillovers from the agglomeration of firms and workers may decline due to the reallocation of activities with higher potential to induce increasing returns to scale. These features may be particularly troublesome for resource-rich emerging economies. These issues create disincentives for industrial upgrading and push policymakers to promote participation in the lower stages of the GVC in extractive industries (Korinek, 2020). However, while these strategies may be able to capture important value-added gains, it can come at the cost of increasing economic dependence on primary activities. This can potentially hinder long-term economic development strategies.

In order to inform this dilemma, this paper studies how the aggregate growth of higher downstream activities relative to lower segments of a value chain in local labor markets, impacts local economic development.[1] And provides evidence on how local comparative advantages and export competition in GVCs influence this process of industrial upgrading. Specifically, this study examines the growth of the copper industry over the last few decades in Chile, the world's largest copper producer. I exploit spatial and temporal variation in the upgrading from low-processed mineral commodities (primary production stage of mineral extraction) to more refined mineral exports (intermediate manufacturing process of smelting and refinement). I have two main objectives central to the current policy debate.[2] First, this study examines how industrial upgrading in local labor markets is affected by export competition and local comparative advantages in these GVC segments. Second, I identify the welfare and productivity gains for the local economy from this process of industrial upgrading in local labor markets. These two objectives can be informative about the potential effect of industrial policies targeting different segments of a value chain on economic development.

For these purposes, in the empirical analysis, I focus on three main aspects. First, by relying on exogenous spatial and temporal variation inducing the process of industrial upgrading from mine to refined copper in local labor markets, I identify the plausible causal role of resource endowments and export competition in inducing industrial upgrading. This exercise provides a measure of the extent to which industrial upgrading in local labor markets responds differently to local and global features of trade in value chains. On the one hand, the local component is captured by exogenous variation in resource endowment and is informative about the role of comparative advantages. On the other hand, the global shock is the result of international competition in the different segments of the value chain involved in the process of industrial upgrading. Owing to the exogenous nature of these shocks, the results of these regressions also characterize the first stage of the identification strategy of the local economic impacts of industrial upgrading.

Second, I explore the average and heterogeneous impacts of industrial upgrading on the changes in several variables that are informative about the economic performance of local labor markets. Initially, I focus on the effects of industrial upgrading on relative social welfare. This is proxied by the changes in the local population and real wages.[3] I then explore the impacts of industrial upgrading on local employment, and nominal wages as a proxy for labor

[1] This is an aggregate "traditional" view of industrial upgrading. See Verhoogen (2021) for a detailed discussion on industrial upgrading at the firm level.

[2] During industrial upgrading, internalizing a GVC activity that creates higher value-added products is classified in the literature as chain upgrading. Within the copper industry, this means moving from low processed mineral commodities to smelting and refined mineral exports. Other forms of industrial upgrading involve process, products, or functions (Verhoogen, 2021).

[3] As is standard in spatial equilibrium models with idiosyncratic restrictions on the mobility of workers (Moretti, 2010; Allcott and Keniston, 2018).

productivity. Considering the heterogeneous impacts of these effects in the manufacturing and non-manufacturing sectors. Finally, I provide evidence of how industrial upgrading in local labor markets affects the competitiveness of firms participating in the lower and higher segments of the copper value chain. Specifically, I explore the effects of industrial upgrading on workers and firms' agglomeration in local labor markets, and their productivity spillovers to manufacturing firms. These estimates distinguish between directly and indirectly copper-related subsectors, and are compared against the effects of industrial upgrading on the size and profitability of services suppliers in the lower segment of the value chain. This comparison is motivated by the importance given by resource-rich economies to industrial policies that foster the formation of a cluster of local services supplier firms around the extractive sector (Atienza et al., 2021).

However, the expansion of production in different segments of a value chain is likely correlated, sharing similar trends and impacts. This may difficult the empirical identification of these effects in the local economy. To address this, I exploit features in the copper industry that are plausibly exogenous to local economic conditions and firm strategies, and helps in identifying and disentangling these heterogeneous causal effects of industrial upgrading in local labor markets. First, the value chain structure of the copper industry is simple, which makes it feasible to precisely track down activities and study the geographical organization of the different production stages. Furthermore, it can be generalized to other mineral commodities. Second, it has a strong exogenous component involving the location decisions and production of firms due to the locational specificity of mine deposits and global demand-driven price shocks.[4] Finally, the expected effects of the variation in industrial upgrading in the copper industry on the local economy are presumably sizeable. This may be because the important role of the sector in the strategy of development of the case study.

Besides the novelty in the empirical analysis and the important policy implications of this work, critical for many emerging economies where primary activities play an important role (Addison and Roe, 2018), from a theoretical perspective, this study also contributes to the growing literature on the relationship between GVCs and local labor markets (Antràs and Chor, 2021). More generally, multiple scholars had explored the mechanisms and channels through which export expansion impacts workers and firms in local labor markets. This study relates closely to some of these works exploring the heterogeneity of these impacts among value chains (Shen and Silva, 2018). This study is also related with the literature on place-based and industrial policies (Kline and Moretti, 2014; Bartelme et al., 2019), how local labor markets adjust to large trade shocks (Autor et al., 2013a,b, 2015, 2016; Dix-Carneiro, 2014;

[4] More precisely, the price commodity shock induced by the expansion of the manufacturing sector in China.

Artuç et al., 2010), the effects of trade shocks on firms (Amiti and Davis, 2012), and the spatial diffusion of global productivity shocks among local labor markets (Hornbeck and Moretti, 2019) and firms (Huneeus, 2018; Carvalho and Tahbaz-Salehi, 2019).

Specifically, I provide a better understanding on how local economies respond when some segments within the same sector in a value chain lose comparative advantages while others gain.[5] I provide a theoretical discussion on the mechanisms that explain the incentives to promote industrial upgrading in local labor markets, as well as how this is affected by export competition and the expected economic effects of these types of industrial policies in local labor markets. These implications are largely challenged by the fact that the location-specific nature of each activity within a value chain may imply that the impacts of industrial upgrading have large spatial variations among local labor markets. Moreover, these effects can indirectly extend to several other local labor markets through general equilibrium effects depending on the extent of the mobility of factors of production (Moretti, 2010).

The remainder of this study is organized as follows. Section 2 describes the empirical case. Section 3 details the methodology used. Section 4 describes the data, Section 5 presents the results and mechanisms, and Section 6 presents the conclusions of this study.

2 Background

This section describes the meaning of industrial upgrading in the copper value chain as well as the economic incentives to promote it. It discusses the relevant between- and within-country geography of the copper value chain for the case study. Furthermore, the specific role of China in reallocating part of these activities is discussed, both as a main driver of changes in GVCs in the past few decades as well as a source of exogenous variation. Finally, I comment on industrial policies targeting the mining sector that have been promoted in Chile.

2.1 Industrial Upgrading in the Copper Value Chain

Manufacturing and mining industries are the industries most engaged in trade in GVCs (Antràs and Chor, 2021). Copper is the most traded metal and is an input in multiple production processes. Furthermore, the demand for copper has continued to increase, especially with the recent surge in demand due to the energy transition. While several activities in the copper value chain are common to most mineral commodities, the copper industry is much more fragmented than other similar industries such as steel or aluminum. The copper value

[5] For a detailed description of the state of the literature, see Redding (2020).

chain is generally organized in a sequential form (also known as "snake-form", Baldwin and Venables, 2013), composed of three main stages of production illustrated in Fig. A.1: 1) a geographically embedded primary production stage where the ore is extracted; 2) a more mobile second stage of basic processing in which the metal is purified; and 3) a final manufacturing process in which copper-based final products, such as wire rods or cables, are produced. Importantly, the sector is capital-intensive and most of the labor is required during the first phase. Even if the product in the second stage is classified as an intermediate input, a significant value is added in this stage.

The first stage in the copper value chain comprises the activities of prospecting (concept and pre-discovery), exploration (discovery, feasibility, and development), and exploitation of mines. Depending on the geological and financial uncertainties inherent to the process, exploration activities can take decades before even the machinery is installed for development.[6] From this stage, hard minerals are extracted in the form of metal ore. In the second stage, denoted as basic industrial production, the ore is transformed and refined in two main phases: (1) treatment, and (2) smelting and refinement. Each of these activities adds substantial value to the commodity by improving the purity of the mineral, which is 25-35% for mined copper, to 99.99% for the cathode after the refinement process. The cathode premium relative to copper concentrate is estimated to be approximately 50–150 USD per ton of copper (Langner, 2011).[7] After this basic processing, the commodity can be exported as mined copper (copper concentrate) or refined copper (copper cathodes).

After the treatment, the mineral is delivered in the form of a concentrate. Owing to the high transportation costs and vast amounts of waste materials, this basic transformation is done in close proximity to the mine. Meanwhile, smelting and refinement transform the mineral into anodes and cathodes, respectively. This more advanced stage of mineral processing can occur near mines, or cities and distribution ports. In many cases, mining companies develop their own infrastructure to transport minerals at different stages of production.[8] Essentially, the minerals from any of these second stage activities can be exported. The development of these activities depends on a series of factors, such as labor and transport costs, environmental regulations (Pérez et al., 2021; Sturla-Zerene et al., 2020; Sturla, 2020), and institutional conditions (Leiva, 2020). Due to the large sunk costs involved in primary production and

[6] During the early activities of prospecting and exploration, there are funding risks associated to financial speculators, and technical and discovery risks. Meanwhile, more institutional and strategic investment is made during the phase of development and exploitation.

[7] Yet, most of the value-added gains of the copper value chain are concentrated in the extractive places, which tend to gain a large share of the gains of even advance manufacturing copper processing.

[8] Sometimes, several mines share infrastructure spanning multiple countries, such as some mines in the Argentinian Andes exporting products through ports in the north of Chile.

the long-term nature of mining projects, mining companies usually have low risk aversion to determine these investments.

Other types of minerals, usually classified as by-products of hard minerals, such as rare-earth metals, are extracted using the same process from the ore and concentrate; they are separated in the refinement stage and exported as a different commodity. Some by-products include molybdenum and gold from the ore, and refinement by-products like sulfuric acid, iron silicate stone or slag, and arsenic. The profits from by-products can be very large and, in some cases, cover the entire operational costs of a mine. For example, molybdenum is the second major mineral export by Chile. This increases the incentives to locate and develop the smelting and refinement process in the same country in which mines are located. Moreover, the price of some of these rare metals has been increasing in recent decades and is projected to continue increasing given their low substitutability, and intensive use in the energy and computing sectors. This has increased the potential future profitability of value-addition from these by-products. However, on the negative side, the environmental cost of smelting and refinement versus copper extraction tends to be larger and more visible for local communities.[9]

2.2 Comparative Advantages in the Copper Value Chain

As processing is more complex and closer to final demand, production in the copper value chain is more geographically fragmented. Primary production activities (Fig. A.1) are undertaken in resource rich economies where mines are located. However, other activities from the basic and advanced manufacturing stages are less tied up to a specific location. For instance, major copper producers such as Chile, Peru, and Australia do not specialize in activities in the basic processing stage that add substantial value to the product and are more labor intensive. Furthermore, policymakers in resource-rich economies are undertaking substantial efforts to develop the mineral production supply chain further, as they have larger comparative advantages in it, instead of developing smelting and refinement processing. This is partly explained by the fact that investments required for developing this more advanced industry are large and gains are not straightforward. The uncertainty about benefits may be due to the competition effects in international markets induced by the China shock, environmental regulations, and mineral price volatility.[10] Further, although the prices of mine and refined copper tend to

[9]Notably, the production of these by-products differs among mines. This is because different mines have different qualities of minerals extracted per unit of waste material. This is an important factor driving the profitability of each mine. I use this to inform our empirical identification strategy.

[10]The massive reallocation of world manufacturing industries to China has affected the organization of production of many sectors. The copper industry is illustrative of this. As Appendix Fig. A.5 shows, in the past few decades, China became the main consumer of copper with over 40% of global demand as well as the major refiner, despite having limited extraction sites.

vary in the same direction, refined copper exports can be more profitable than mine copper exports. This implies that important markups can be exploited from this activity.[11]

As shown in Figure A.2, Chile has been the major exporter of mine copper for many decades. The country went from supplying approximately 40% to nearly 60% of the global copper demand in over a decade between 1990 and 2002. Moreover, during the first part of the 1990s, Chile also became a major producer of refined copper, reaching almost 40% of the global market for this commodity. However, its position in global markets in both segments of the value chain decreased substantially after 2002 with the super-cycle in commodity prices. One of the main factors explaining this loss in market concentration is China's entry into the market, After which Chile's participation in the production of refined copper fell to less than 20% by 2015. Although the production of refined copper in absolute terms has not changed significantly since 2002, the production of mine copper has continued to increase during this super-cycle. This substantial variation in the production of both segments of the copper industry in Chile and its position in the global markets is a major concern for policymakers. Moreover, it may have substantially affected local labor markets which are associated with these segments.

Several additional activities and local spillovers are associated with both segments of the copper value chain. For example, mining companies usually develop their own infrastructure for the production and transportation of minerals, Such as electric grids, water provisions, roads, railroads, and ports. Meanwhile, the state plays a more important role in smelting and refinement, with mining companies reluctant to invest in these areas. Furthermore, services are being increasingly outsourced, especially knowledge-intensive services (Atienza et al., 2021). These services include geological, engineering, design, construction, energy, and water management; environmental studies; communication and transport; and leasing, maintenance, and repair of equipment. Recently, with the growth in automation and remote work, the demand for data and software management and design has increased as a proportion of activities in some mines is being done from remote locations. This may further reduce incentives for the formation of local productive linkages even in services provided in the low value-added segments of the value chain.

I characterize the spatial attributes of industrial upgrading in local labor markets and how this responds to resource endowments –a proxy for natural local comparative advantages–

[11] The premium for smelting and refinement is estimated to be approximately 50–150 USD/ton of copper over concentrate, depending on the operation costs of smelter and refinement plants. These are substantial gains, considering that the copper content of refined copper cathodes is 99.99% while that of copper concentrate is 20–25%. Moreover, primary production may have substantial losses when the "law of the mineral", or quality, is lower than expected.

and export competition in these segments of the copper value chain. Fig. A.3 describes the spatial distribution of this variable among cities with different exposures to mining activity. I observe a negative correlation between these variables: cities that were more exposed to extractive activities do not necessarily tend to develop industrial processing. However, the distribution has great dispersion for low values of exposure to mining activity. This correlation is consistent with the idea that places largely specialized in the production of the primary segment of extractive activities fail to move up in the value chain and industrialize through the development of downstream manufacturing processing of these minerals, and grow through related activities that supply the lower segment. Indeed, the current policy approach suggests this (Korinek, 2020).[12]

2.3 Industrial Policy in the Copper Industry

Multiple industrial policies are applied to the copper industry and tend to follow two paths. First, given the recent growth in trade in services and global production networks, strengthening the services suppliers of mining companies in the first stage of the value chain has become increasingly popular among policymakers. Second, there is the more traditional approach to industrial policies, such as in Chile. Motivated by the size of the market in the first stage of the copper value chain, attempts have been made to develop the second stage of the smelting and refinement industries. This had resulted in a remarkable growth in refined copper production between 1992 and 2002. However, few policies have aimed at developing copper scrap recycling and manufacturing copper-based products from the third stage of the copper value chain, such as wires, cables, and semis. These activities are usually performed near advanced manufacturing production centers.

The literature also follow the same direction as current policies, highlighting that services may be one development pathway for countries specializing in natural resources (Korinek, 2020). Services play an important role in the supply chain of mineral commodities. Policymakers attempt to develop a comparative advantage in the services supply of mining companies by fostering the productivity of these services suppliers (Morris et al., 2012; Farooki and Kaplisky, 2014; Figueiredo and Piana, 2016; Katz and Pietrobelli, 2018; Pietrobelli et al., 2018). Example policies include those from Chile, Peru, Argentina, Brazil, and Australia. However, the long-term effects of relying on services suppliers for diversification and long-term local economic

[12]The high dispersion for low values of exposure to mining activity may be because smelting and refinement activities are more mobile than extractive industries. Therefore, firms can profit from locating smelting and refinement plants in places that have lower wages and are well connected to ports. Places where extractive activities may not have these conditions that firms are looking for. Moreover, the government had incentivized locating smelting and refinement activities in places with high unemployment to foster local economic activity.

growth are questionable (Atienza et al., 2021; Atienza and Modrego, 2019).[13] Furthermore, industrial activity with more value-added is likely to be formed by developing downstream stages in the value chain; that is, by exploiting forward linkages rather than backward linkages.

Chile is one of the main importers of mining services. Latin America concentrates a third of the value-added in mining services, with the major exporting countries being the USA and China (Korinek, 2020). Retail and repairs are the most important mining services subsectors. Not all service operations require on-site actions and innovation tends to be more concentrated in services related to mining equipment, which is a specialized skilled-intensive activity. Moreover, access to mines does not play a very important role in most higher productive and knowledge-intensive activities within mining services. As large- and medium-sized mines operate 24x7, they usually require a substantial amount of inputs and services with a fast delivery time. These conditions, together with the specificity of the tasks and the small size of many services suppliers, make it difficult for local companies to compete in global markets (Korinek, 2020).

3 GVCs and Industrial Upgrading in Local Labor Markets

To guide the empirical analysis, this section describes the main theoretical mechanisms behind the latest attempts to formalize an economic theory of local labor market participation in GVCs. Within this context, I discuss the economic rationale for industrial upgrading in local labor markets as well as the incentives to implement industrial policies.

3.1 Industrial Upgrading and GVCs

Industrial upgrading in local labor markets is shaped by the participation of these segments in GVCs (Yang, 2018). Although GVC participation is associated with positive effects on aggregate social welfare and firm productivity (World Bank, 2019), the gains from industrial upgrading in local labor markets do not necessarily vary monotonically with these gains from GVC participation. This is partly due to the multiplicity of the underlying mechanisms. On the one hand, production in one segment may decline due to export competition; subsequently, capital and labor may be displaced from one segment to another. Then, operating

[13] Many mining companies tend to outshore more profitable activities to foreign firms and take advantage of their market power in domestic contracts. One of these forms of bargaining power by downstream companies are contracts in which payments can be delayed up to 90 days. These usually have substantial negative effects on the survival of small- and medium-sized enterprises, who typically have limited financial and other resources (Atienza and Modrego, 2019).

and specializing in lower segments of the value chain may be preferable due to comparative advantages (Giuliani et al., 2005). This may be due to resource endowments and/or because technology in higher stages relies on more mobile factors of production. The reallocation of higher stages of the value chain to more competitive locations will reduce industrial activity, and consequently, decrease productivity spillovers and *learning-by-doing* (Soto-Díaz, 2022).

On the other hand, export competition in GVCs can also induce firms to become more productive, and thus, expand, thereby demanding more local labor and inputs, through *learning-by-exporting* (Garcia-Marin and Voigtlander, 2019; Verhoogen, 2021). While this may induce local economic growth, it can also cause a crowding-out effect on other segments of the value chain. Moreover, if both stages in the value chain compete for the same local labor and capital, this crowding-out effect can cause a decline in some stages of the value chain. The extent to which this may harm the local economy depends on the capital-intensive nature of each value chain segment as well as on its complementarities (Venables, 2004).

These arguments suggest that complementarities in production between different stages of a value chain play a crucial role. Specifically, these complementarities imply that a reduction (increase) in the marginal cost in lower segments may imply a decrease (increase) in the marginal costs in higher value-added segments and, therefore, higher (lower) economies of scale in downstream activities within the value chain.[14] To understand the mechanisms of the role of local comparative advantages and global trade shocks in inducing industrial upgrading in local labor markets, let us first focus on the marginal cost of a value chain, as formalized in Yang (2018). Abstracting from the economic environment of this Ricardian trade model of GVCs and local labor markets, I denote two stages within a value chain: a primary stage ℓ_1 and a secondary downstream stage ℓ_2. Then, the marginal cost of a value chain $c(\ell_1, \ell_2)$ can be represented by the following:

$$c(\ell_1, \ell_2) = \underbrace{\tau_{\ell_2}\left(\frac{w_{\ell_2}}{z_c^2(\omega)}\right)^{\alpha}}_{\text{second stage}} \underbrace{\left(\frac{\tau_{\ell_1\ell_2}w_{\ell_1}}{z_c^1(\omega)}\right)^{1-\alpha}}_{\text{first stage}}$$

where w denotes the wage in each segment, τ the trade cost of each stage, and z the productivity of each step. Assuming a Cobb-Douglas production function, implies complementarities between the first and second stages. Furthermore, the productivity term z of the value chain

[14] This is how recent economic trade theories have modeled firms' decisions within GVCs (Antràs and de Gortari, 2020; Yang, 2018) by assuming that the idiosyncratic productivity components among the different stages of a value chain are interdependent.

follows a Type II extreme value distribution with

$$\Pr\left((z_c^1)^{1-\alpha}(z_c^2)^{\alpha} \leq z\right) = \exp\{-z^{-\theta}(T_{\ell_1}^1)^{1-\alpha}(T_{\ell_2}^2)^{\alpha}\}.$$

As an extension of Eaton and Kortum (2002), this characterization of productivity in each segment allows to clarify the role of comparative advantages in each segment location given by T. This is weighted by a productivity shifter specific to the value chain. For example, for natural resources, a large resource endowment in a specific location would imply a high $T_{\ell_1^1}$. This will not only reduce the marginal cost of the first stage but also the overall marginal cost of the value chain. The role of these comparative advantages is governed by the trade elasticity θ and the relative importance of these comparative advantages between both segments is given by α. Meanwhile, if location 2 is endowed with a large pool of workers, the second stage will likely have lower wages, and therefore, lower marginal costs. While this would not affect the first stage, it would affect the overall marginal cost of the value chain.

Furthermore, trade costs play a key role in these marginal costs. As denoted by the term τ, this relevance is both theoretical and empirical. In this context, given the high comparative advantages in the primary export sector and that trade costs tend to decrease with further downstream activities within the value chain, Antràs and de Gortari (2020) predicts that the specialization on a specific activity in the value chain, and thus, industrial upgrading, will have low sensitivity to trade costs, and therefore, export competition. These results, originally presented at the country level, have been extended to local labor markets as well (Yang, 2018).[15] In particular, for the copper industry, the trade cost of these intermediate goods at different points within the value chain is a major variable that affects the location decisions of smelting and refinement companies. Furthermore, with tariffs and barriers, trade costs will induce successful production reallocation unless significant value added is lost during transportation.

3.2 The Incentives to Promote Industrial Upgrading

Based on these considerations, one can hypothesize that when one of the value chain segments is subject to substantial competition in international markets, industrial policies can have very little impact on industrial upgrading. This may be because the incentives to promote such a policy–greater subsidy for a specific value chain segment compared to another–

[15] Yang (2018) expanded Antràs and de Gortari (2020) framework to include sub-national patterns of fragmentation of production and participation in GVCs to understand the role of trade costs in shaping GVCs. The author finds that, in the case of Chinese highway infrastructure investments, cities with more access to foreign markets have greater participation in GVCs, which leads to important welfare gains.

rely on the existence of heterogeneous welfare gains from industrial policy in each of these segments (Bartelme et al., 2019). More precisely, in a Pigouvian framework, the incentives for industrial policy in line with industrial upgrading are due to the existence of higher economies of scale in higher value-added segments of the value chain. This implies that there is space for an industrial policy that favors higher over lower stages in a value chain, and therefore, an economic rationale for the promotion of industrial upgrading for the policy-maker.

To identify the existence of such heterogeneous economies of scale within a value chain, and consequently, the presence of different externalities in each segment, I may need to compare the marginal costs of production in these two segments, as well as the productivity spillovers, or externalities, that these two segments generate. The difference between the marginal costs of each value chain segment and its externalities in the local economy is the size of the subsidy; that is, the space for industrial policy. Figure A.4 illustrates this with an example of the difference in space for industrial policy within the two segments of the value chain. The welfare gains from industrial upgrading from this perspective are equal to the gains from the economies of scale in each segment of the value chain. This differs from the overall welfare of the industry; that is, despite the welfare gains from industrial upgrading, these gains may not exceed the overall gains from the industry. Intuitively, given limited resources, industrial upgrading may induce more welfare gains than an industrial policy that targets each segment differently.[16]

Industrial policies can take several forms. Some may seek to reduce trade costs by reducing or increasing trade barriers, which directly affects the exposure of each local labor market to export shocks. The existence of external economies of scale provides space for the implementation of industrial policies. Specifically, these external economies of scale imply that the social cost of production is lower than the private marginal cost. Then, the size of the subsidy of the industrial policy equals the difference between the two. Equivalently, the welfare gains of this industrial policy are equal to the area between the social marginal cost and demand curves.[17] These external economies of scale may be due to productivity spillovers from industrial agglomeration or learning-by-doing. However, productivity would be lost from learning-by-doing if the associated activities are spatially relocated (Soto-Díaz, 2022). More-

[16] An important point here is to consider the extent to which these activities are not only performed within the boundaries of a country, but within the boundaries of a firm. Given that these different activities within the a value chain are subject to economies of scale (Williamson, 1965).

[17] This simple framework is expanded and tested empirically in Bartelme et al. (2019). As these authors explain and Kucheryavyy et al. (2021) demonstrate, these economies of scale that provide space for industrial policy can arise from trade models with perfect competition with direct external economies, or can be derived from product differentiation and love for variety from monopolistic competition models with free entry (Krugman, 1991).

over, if the relocated activities are more knowledge-intensive or have more value added, and therefore, have greater potential to induce economies of scale, this may reduce the gap between the private and social marginal costs. Consequently, industrial policy will have less space and its expected welfare gains would be limited.

In this model, trade cost plays an important role because in many types of industrial policies, countries can impose tariffs on the more upgraded mineral commodities to create incentives to develop those activities in their own countries. In addition, they may have the requisite scale to perform those activities. This Marshallian view of industrial policy, taken from Bartelme et al. (2019), helps illustrate the space for industrial policy. However, few studies have goods and services that are part of the same value chain, and therefore, have economies of scale that are beyond a product and within a value chain. In summary, the above discussion shows that within a sector, two segments can have heterogeneous implications for industrial policy, given their scale and comparative advantages.

3.3 Local Labor Market Exposure to GVCs

Given the previously described macro factors that influence industrial upgrading, we need a framework that allows us to more precisely understand how these mechanisms are propagated among local labor markets, and their expected welfare and productivity effects. A natural departure point, which is in line with previous theoretical insights, is Autor et al. (2013a) and subsequent works that have explored the impacts of international trade shocks on local labor markets.[18] One of the key contributions of Autor et al. (2013a) is a measure derived from a standard gravity model of international trade that can easily be matched with the data. I use this measure based on Feng et al. (2019), who use it to analyze the impacts of export competition in local labor markets, and then adapt it to capture industrial upgrading in local labor markets. Specifically, the exposure of a local labor market c to a trade shock in activity j is given by

$$EPW_{jc} = \frac{L_{jc}}{L_c}\frac{X_j}{L_j} \tag{1}$$

where the first part of the equation is the local labor share $\frac{L_{jct}}{L_{ct}}$ and the second part is the value-added per worker in that exporting activity $\frac{X_{jt}}{L_{jt}}$. This equation has been widely used in the literature on the China shock in the US and has been applied to many different contexts. Given that this term reflects a specific industry j, a natural departure point is to take the ratio of the two industries to measure the relative impact of trade shocks in local labor markets.

[18] This literature is carefully reviewed in Redding (2020).

Moreover, I can use the ratio by considering two segments within a value chain to measure industrial upgrading. Note that this measure is a relative approximation of the exposure of local labor markets to trade shocks. However, as previously mentioned, the complementarities between both segments of the value chain should be explicitly incorporated within these frameworks to better characterize their impacts on local labor markets.

There are multiple mechanisms induced by industrial upgrading in local labor markets, such as the general equilibrium effects of the resource sector (Allcott and Keniston, 2018; Soto-Díaz, 2022). Within a spatial equilibrium setting and abstracting from local Dutch-Disease, the effects of industrial upgrading on social welfare and productivity would depend on the extent to which the activities in each segment are considered disamenities by local workers and firms.[19] This affects their preference for a specific location with this activity. Specifically, for the mining and refinement/smelting of copper, the evidence supports this hypothesis, as shown by Sturla (2020), Rivera (2020), and Soto-Díaz (2022) for the case study. However, the magnitude of these effects is unclear. Abstracting from both the amenity effect and the local Dutch Disease effects from Allcott and Keniston (2018), industrial upgrading should induce positive social welfare and productivity gains.

4 Data

Different data sources are combined to triangulate and provide reliable evidence of the different mechanisms and effects. For the copper industry's production in Chile, I compile data on the production at each extraction site for almost two decades. In addition, I use the composition of exports within the mining sector to observe aggregate changes from copper exploitation (exports of mined copper) to basic industrial production (exports of refined copper). Local sectoral employment indicators at the city level are constructed using population and employment censuses for 1992 and 2002. To measure subnational economic performance at the city level (local labor markets), I combine household surveys from the Chilean National Household Survey (CASEN) between 1990 and 2017 for information related to worker. For firm-related information, I use the manufacturing censuses (ENIA) between 1995 and 2007, and combined data from the Chilean Mining Services Suppliers (SICEP) and the Internal Revenue Services (SII) between 2007 and 2013.[20]

[19] Allcott and Keniston (2018) shows that a resource boom may induce losses in social welfare if there is a crowding-out of firms in the tradable sector. Soto-Díaz (2022) goes further; the author finds evidence on these negative impacts of the resource sector on the productivity of manufacturing firms in Chile and that these negative effects are more likely to be induced by multinationals firms in the resource sector.

[20] A detailed description of the cleaning and merging of these different data sources is provided in the Online Appendix.

5 Empirical Evidence

5.1 Baseline Reduced-Form Specification

5.1.1 Measuring Industrial Upgrading in Local Labor Markets

Chile has two main exports in the copper value chain: (1) low-processed copper or mine copper, exported as copper concentrate, and (2) smelting and refined copper, exported in the form of cathodes. To measure the local labor market exposure to each segment, an analogous shift-share strategy proposed by Feng et al. (2019) adapted from Autor et al. (2013a) is used. Two shift-share variables are computed, each measuring the local exposure to the production expansion in each of the two different segments (mine and refined copper) of the copper value chain. The shift component is the change in exports of each output relative to the number of workers in that segment. The share component is a measure of relative local employment in that specific segment of the value chain. Specifically, the exposure to a shock in a value chain $j \in \{\text{mine copper}, \text{refined copper}\}$ in city c in year t is measured as follows:

$$\Delta EPW_{jct} = \frac{L_{jct}}{L_{ct}} \frac{\Delta X_{jt}}{L_{jt}} \tag{2}$$

where $\Delta X_{jt}/L_{jt}$ is the change in exports per worker in Chile in value chain segment j between years t and $t-1$, and L_{jct}/L_{ct} is the share of employment in value chain segment j in city c in year t relative to the total labor in that city. The shift component captures the change in exports, whose economic impacts in local labor markets are assumed to be transmitted through the share component of relative labor in that city and specific value chain segment. However, to specifically capture the effects of industrial upgrading in local labor markets, that is, the effect of a change in local labor market exposure to the high versus low value-added segments of the value chain, an upgrading variable is constructed using the ratio between ΔEPW_{jct} for $j = \{\text{refined copper}\}$ in relation to $j = \{\text{mine copper}\}$,

$$Upgrading_{ct} = \Delta EPW_{j=refined,ct} / \Delta EPW_{j=mine,ct}. \tag{3}$$

The $Upgrading_{ct}$ variable in Equation 3, denotes the idea of industrial upgrading in local labor markets within the copper value chain; that is, a local substitution of exports from the low value-added segment of mine copper towards the higher value-added segment of refined copper. Intuitively, a local economy that is shifting its export composition towards the higher value-added segment of copper production should induce a direct positive effect on local economic outcomes. The effects of industrial upgrading on the different outcome variables in local labor markets are not a priori certain. The effect of this variable on the local economy is affected by the relative changes in exports within these two segments as well as by the relative gains from local specialization in those different activities, with different investment returns and comparative advantages. The final effect also depends on the extent to which these changes in the production composition of the mining sector in the local economy are labor saving and intensive in the demand for local intermediate inputs; that is, if industrial upgrading creates more productive linkages with the local economy. The estimates of how industrial upgrading responds to local resource endowments and export competition, as well as the different relative effects of industrial upgrading on local economic outcomes, are tested with the following specifications.

5.1.2 Industrial Upgrading, Resource Endowments, and Export Competition

To study the channels of resource endowments and export competition in the copper value chain, first, I use a measure of exposure to mining activity to study the role of resource endowments. Specifically, the mining exposure variable is a measure of activity in the mining sector taken from Soto-Díaz (2022), and is computed as follows:

$$MiningExposure_{ct} = \sum_{k} Q_{kt} \left(d_{kc}\right)^{-1}, \tag{4}$$

where Q_{kt} is the production of minerals in an extraction site k and year t, and d_{kc} is the distance to mining site k and city c. This variable is regressed against industrial upgrading to estimate the role of local comparative advantages created by resource endowment in the first stage of the value chain. Then, to evaluate the role of export competition in industrial upgrading, this variable of exposure to mining activity is interacted with a relative measure of world production in the two different segments involved in industrial upgrading, namely mine and refined copper. This measure is defined as follows:

$$ExportCompetition_{ct} = MiningExposure_{ct} \left(\frac{\Delta X^{ROW}_{j=refined,t}}{\Delta X^{ROW}_{j=mine,t}} \right) \tag{5}$$

Consequently, the role of export competition in industrial upgrading is estimated with the following specification:

$$\log Upgrading_{ct} = \beta \log ExportCompetition_{ct-1} + \mathbf{X'}_{ft-1}\gamma + \delta_f + \epsilon_{ct}. \tag{6}$$

5.1.3 Industrial Upgrading, Employment, Wages, and Firms' Agglomeration

The upgrading variable in Equation 3, that measures changes in the composition of mineral exports due to the developing of activities with more value added is regressed against several indicators of economic performance in local labor markets. Specifically, the baseline empirical specification takes the following form:

$$\Delta \log Y_{ct} = \beta \log Upgrading_{ct-1} + \mathbf{X'}_{ct-1}\gamma + \delta_t + \epsilon_{ct}, \tag{7}$$

where Y_{ct} = are the different economic outcomes in city c and year t: (1) social welfare proxies for population and real wages, (2) employment and nominal wages as proxies of labor productivity, and (3) the number, sales, and aggregate revenue of firms. δ_t are year fixed effects and $\mathbf{X'}_{ct-1}$ is a vector of controls in the initial period at the city level, which includes the share of high-skill workers (college-educated) and the share of migrant population, among others.

Coefficient β, which captures the effect of industrial upgrading on different local economic outcomes, has a similar interpretation to a difference-in-difference specification. This is because in Equation 7, the upgrading variable, previously defined in Equation 3, is in logarithms, and therefore, equivalent to taking the percentual difference between ΔEPW_{jct} for $j = \{\text{refined copper}\}$ with respect to $j = \{\text{mine copper}\}$. Consequently, the β coefficient reflects the percentage effect on the changes in local economic outcomes Y_{ct} with a relative change in the refined copper component of the value chain in the mine-copper component.

The effects of industrial upgrading are estimated for the overall level of outcomes, and distinguishing between manufacturing and non-manufacturing sectors. Taking advantage of data from the SII, the effects on employment and number of firms are also estimated for each segment in the value chain in question, distinguishing between processed minerals directly related to copper and others indirectly related to processed outputs. Furthermore, specific data from the SICEP are used to test the effects of industrial upgrading on the size and profitability of these service companies in local labor markets.[21]

5.2 Identification Strategy

The two different segments involved in the copper value chain in Chile are correlated. Hence, the main empirical challenge for identification is to find sources of variation that are exogenous to local economic conditions and firms' strategic behavior, and allow the plausible causal identification of both mine and refined copper production impacts on the different economic

[21] This data has been first used in Atienza et al. (2021) and Atienza and Modrego (2019).

outcomes. Endogeneity between local and firm economic outcomes, and the exposure variable can arise from several sources. First, there may be omitted variables that are correlated with upgrading and local economic outcomes, such as unobserved industrial policies, firm strategies (to the extent that these firms are large enough), or unobserved local economic conditions that explain both firm-location decisions and local economic outcomes. Second, related to the idea that these firms are large, there may be simultaneity by reverse causality between both variables, such as firms locating in specific regions after consider local economic conditions that also explain future economic performance.

The identification of a causal effect associated with industrial upgrading may be difficult to the extent that the upgrading variable is driven by any change induced by these endogenous factors which affect the relative dominance of the country in the international market, as well as local specialization. However, with respect to international factors, this measure would be more exogenous and then the coefficient identified would be consistent. The differentiated growth pattern in refined copper production led by China, shown in Fig. A.5, is an indicator of these plausible exogenous variation in the higher value-added segment. To mitigate potential concerns, an instrumental variable strategy is followed. In the first stage, the upgrading variable is regressed against local geological factors explaining changes in mining extraction, as follows:

$$\log Upgrading_{ct} = \alpha \log MineralConcentration_{ct-1} + \delta_t + \mu_{ct}. \tag{8}$$

Mineral concentration is more related to the first segment of the value chain and reducing the costs of copper processing also affects the second stage. The mineral concentration is a predictor of the profitability of mines, given that the purification process in the smelting and refinement segment is easier as the mineral concentration increases, implying lower costs and higher profitability. Note that any potential change in tariffs that also affects industrial upgrading is captured by year fixed-effects. In summary, the identification of the impact of the expansion of the low value-added segment relies on the fact that production in this segment is driven by exogenous geological factors influencing mining extraction and profitability, while production in the refinement sector is exogenously affected by export competition. Further, both are subject to differentiated exogenous variations in the prices of mine and refined copper.

6 Results

6.1 Global and Local Shocks to Industrial Upgrading

As discussed previously, both comparative advantages and trade costs determine the different patterns of integration or offshoring of activities within a value chain in local labor markets, which in turn can emerge from the cost-minimizing location decisions of firms. The copper refinement activities have more international competition as they are more labor intensive and have lower entry costs than the primary stage of the value chain, in which the resource-rich country has more comparative advantages. These features of the copper industry motivate testing the role of competition in GVCs and the local comparative advantages imparted by resource endowments in shaping industrial upgrading in local labor markets.

Columns (1) to (4) of Table A.1 show a negative relationship between resource endowment and industrial upgrading in local labor markets. This result is robust to controlling for local economic conditions and plausible causal factors, as shown by the estimates using the exogenous variation induced by the concentration of minerals in mining extraction sites. Meanwhile, columns (7) to (9) suggest that higher relative international competition in these segments of the value chain induces lower industrial upgrading in local markets. This elasticity is particularly high at approximately -1.5, and robust to the inclusion of year fixed effects and local controls. This result is consistent with the increasing competition in international markets induced by the China shock, as shown in Fig. A.5. Furthermore, the elasticity is much higher than the elasticities reported from the interaction of resource endowment and mineral prices in columns (4) to (6).

These results suggest that the local conditions induced by resource endowment, which favor the development of extractive activities in the primary stage of the value chain, play an important role in determining the extent of industrial upgrading in local labor markets. Specifically, places with more resource endowments are highly specialized in the production of low-processed commodities and are less likely to develop the further industrial stages of smelting and refinement in the value chain of copper. This may be due to the labor-intensive nature of refinement processing compared to the primary stage of mineral extraction, which is capital-intensive, and tied to specific places pre-determined by geological conditions.

Simultaneously, export competition in international markets in these segments plays an important role in determining the extent of industrial upgrading in local labor markets. Places with higher relative export competition are more specialized in these activities and do not tend to develop industrial upgrading. These effects coincide with the idea that at least in the medium and short term, industrial policies may be more likely to succeed if they are implemented in activities with strong comparative advantages. Otherwise, creating highly profitable conditions in other higher value-added sectors may be difficult, even if these sectors are related to the key primary sector.

The small impacts on the population are consistent with evidence in Autor et al. (2013a) and Autor et al. (2020). This is in line with the argument of Amior and Manning (2018) that the existence of large employment effects and small population adjustments is explained by the fact that population responses lag employment effects; this induces differences in employment-population ratios across local labor markets. Labor force participation can be an adjustment mechanism that may explain these differences in responses between employment and population.

6.2 Who benefits from industrial upgrading in local labor markets?

To understand the relative importance of industrial upgrading in the aggregate location incentives of workers and firms, I explore the effects of industrial upgrading on proxy indicators of social welfare in local labor markets. In a standard Rosen-Roback spatial equilibrium setting with idiosyncratic restrictions on mobility, such as the general framework of Moretti (2010), changes in the local population and real wages in local labor markets are measures of relative local welfare. This is because in equilibrium, spatial differences in population and real wages are informative of the spatial differences in the location incentives of workers and firms. Following these assumptions, Table A.2 describes the impacts of industrial upgrading on changes in the local population and real wages. As in Autor et al. (2013a), the population is restricted to individuals in their working age (between 15 and 65 years old), given that this group is more informative of mobility patterns induced by firms' location decisions. Meanwhile, real wages are measured as nominal wages adjusted for housing rents.[22] Interestingly, the effects of industrial upgrading in the population and real wages in local labor markets are generally positive but small and lose significance in the IV estimations.

These limited economic impacts of industrial upgrading in population and real wages suggest that the effects of industrial upgrading in local labor markets, if they exist, may be heterogeneous, concentrated in specific sectors, and/or directly affect these outcomes through multiple channels. To explore these arguments in more detail, Table A.3 shows the effects of industrial upgrading on aggregate local employment and nominal wages, as well as restricting the sample to manufacturing and non-manufacturing workers. Here, nominal wages are used

[22]Given data constraints, I have no information on general local prices apart from housing rents.

as a proxy of labor productivity to identify whether there are productivity gains for workers from agglomeration externalities or learning-by-doing induced by industrial upgrading in local labor markets. Spatial differences in nominal wages across local labor markets are consistent with the existence of a spatial equilibrium *à la Roback-Rosen*, in which spatial differences in productivity/amenities materialize as differences in nominal wages. However, the extent to which these differences persist in real wages depends on the extent of restrictions on the mobility of factors of production. These are apparently not very important in this case, given the limited impacts of industrial upgrading in real wages described in Table A.2.

The impact of industrial upgrading on employment and nominal wages in local labor markets is likely to be heterogeneous, depending on the level of tradability and relatedness with mining activity. This may also be influenced by the capital- versus labor-intensive nature of the first and second stages of the copper value chain involved in industrial upgrading (Venables, 2004). In addition to the potential productive linkages with the local economy, these sectors can generate (Soto-Díaz, 2022) intermediate goods and services, as well as skill-intensive labor requirements. Given that the higher stage activities of smelting and refinement in the copper value chain are more labor-intensive than the primary stage of mineral extraction, a higher crowding out or resource movement of labor towards these industrial activities is more likely. This implies that industrial upgrading has a negative effect on less related and more tradable sectoral employment. Lower employment induced by industrial upgrading can also imply lower nominal wages in those sectors owing to the loss of learning-by-doing and localization economies, while a positive effect should be expected in the local employment and wages of related sectors.

The evidence reported in Table A.3 is consistent with the heterogeneous impacts suggested by the theory. The positive impacts of industrial upgrading are concentrated in the manufacturing sector, as expected by the nature of the activities. This is likely because in the manufacturing sector, factors of production tend to be more geographically mobile, inducing efficient reallocation in space as required. Table A.3 shows that, overall, the employment and nominal wage effects of industrial upgrading in local labor markets are negative but small. However, the impacts in the manufacturing sector are positive and more important in magnitude, but negative in non-manufacturing activities. These heterogeneous impacts of industrial upgrading among manufacturing and non-manufacturing activities suggest that an industrial policy that aims to develop higher value/level industrial activities within the copper value chain may have overall negative effects on employment and nominal wages; simultaneously, they may also induce more manufacturing activity. This can be a source of long-term local economic development if these manufacturing industries are more skill- and knowledge-intensive than the non-tradable sectors, which tend to be more volatile. However, this is not usually the case with smelting and refinement activities.

6.3 Does industrial upgrading induce more industrial activity?

Although the positive effects of industrial upgrading in local labor markets seem to be highly concentrated in the manufacturing sector, as Table A.3 suggests, the gains may still be highly heterogeneous within this sector. This is because there is a wide variety of manufacturing activities directly and indirectly related. To further explore the idea that industrial upgrading can induce more industrial activity, I leverage the detailed description of activities within the tax data from the SII. Table A.4 explores the effects of industrial upgrading on changes in employment and number of firms. Specifically, it distinguishes between activities directly and indirectly related to copper in both the primary segment of mineral extraction and the secondary segment of smelting and refinement of minerals. Each panel in Table A.4 considers only sectors at the CIIU-4 digit level, which are classified as primarily extractive (Panel a) and smelting and refinement (Panel b).[23]

The effects of industrial upgrading on labor are notoriously concentrated in primary production: that is, direct extractive mining activities. These effects are negative and consistent in both employment and firms' agglomeration in local labor markets and robust across OLS and IV estimators. This implies that industrial upgrading is associated with negative changes in the agglomeration of firms and workers in the lower stages of mining extraction. These negative effects in the low-value-added segments of the copper value chain can be explained by the movement of resources from the lower stage towards the smelting and refinement segment. Thus, although these activities belonging to the same value chain and are directly related, they may compete for the same local labor and capital. The effects on the higher segment of the copper value chain of smelting and refinement are positive in the majority of the estimations; however, they are also less precise with lower significance.

These results suggest that there may be a substitution effect between the activities involved in industrial upgrading in the copper value chain. That is, industrial upgrading may cause a reallocation of resources from the lower stage of mineral extraction to the higher stage of smelting and refinement of copper. This substitution effect, likely induced by the competition for local resources between both segments, may harm the local economy in the short- and long-term. In many resource-rich economies, the country typically has clear comparative advantages in the lower stage of the value chain due to resource endowments and geological

[23] See Appendix for more detail on the activities classified as directly and indirectly related with each stage of the copper value chain.

conditions; however, it has more export competition as well as no clear comparative advantages in the secondary stage of smelting and refinement. This is shown in Table A.1: the growing participation of China in the refined mineral market (see Figure A.2), and the labor-intensive and more geographically mobile nature of those activities.

Thus far, I see that while the positive effects of industrial upgrading are highly concentrated in some specific activities within the manufacturing sector, they have important negative effects that deviate from resources from other sectors. These arguments are in line with the idea that an industrial policy may have larger positive impacts in the short- and long-term, if it focuses on strengthening the sector with higher comparative advantages. Given this context, a feasible strategy for resource-based development in resource-rich countries is to support services suppliers of extractive activities. These supply-chain-oriented policies tend to reduce the cost of local inputs for mining firms, and foster knowledge spillovers and innovation (Pietrobelli et al., 2018). Promoting the internationalization of these supplier firms is another policy objective in order to leverage the *learning-by-exporting* of those goods and services. Many policymakers do consider these policies in Chile to be successful (Korinek, 2020), despite the lack of clear evidence on their economic impacts.

I also explore this aspect using the data from the services supplier firms of the mining sector (SICEP). Table A.5 explores the effects of industrial upgrading on the size and profitability of services supplier firms in the mining sector on local labor markets. Interestingly, the effects on the average employment and sales of services supplier firms in local labor markets are positive across all estimations. The elasticities from the IV estimator are approximately 0.04 for the change in employment and approximately 0.02 for the change in sales. Notably, when the average revenue changes, the OLS and IV estimators differ in sign. The negative elasticity in the OLS is corrected to 0.02 when the variation that comes from exogenous resource endowments is used in the IV for identification. This corrected value is consistent with the effects on employment and sales. However, the lack of precision in the estimators does not allow us to derive strong conclusions regarding the impact of industrial upgrading on the profitability of service providers of mining companies.

Among these service suppliers, firms that do not necessarily provide the same services to mining companies in the first and secondary stages in the copper value chain. For instance, the effects of industrial upgrading on the growth in size and profitability of mining services suppliers in local labor markets are positive, albeit small in magnitude. This is likely because of the heterogeneous nature of the different services provided by these firms, and the substitutability among the two segments. As Atienza et al. (2021) show, knowledge-intensive service suppliers are highly concentrated in big cities, while supplier firms in resource-rich regions tend to be smaller, less productive, and perform more labor-intensive activities.

Finally, one of the most common arguments given by policymakers to promote industrial upgrading in the copper industry is that activities in higher stages of the value chain would induce a higher concentration of manufacturing firms, and consequently, more productivity spillovers due to learning-by-doing and agglomeration economies. The previous section shows that the effects on the concentration of firms are very limited and overall negative, given the crowding-out of workers and firms from the primary sector and non-manufacturing workers. This suggests that the effects on manufacturing firms' productivity may follow a similar pattern. Exploring these effects yielded non-significant results; furthermore, the level of aggregation at the firm-region in the first stage does not provide a strong source of variation for identification (see Appendix A, Table A.8).

7 Conclusion

In resource-rich economies in the developing world, governments typically have attempted to develop a cluster around a resource-oriented sector to foster other industries. Through this, their aim is to strengthen the country's position in the global economy. Relevant policies include fostering industrialization by integrating higher value-added segments of the value chain from downstream manufacturing activities around the extractive sector within the country. However, in recent decades, the growth of trade in services and increasing participation of local firms in global production networks has popularized policies that foster activities in primary segments in these value chains where countries have comparative advantages; the typical policy tool is strengthening the local suppliers in these segments. To further clarify on this issue of policies targeting different segments within the same value chain, this study explores economic impacts of industrial upgrading in local labor markets: how the growth of higher downstream segments in a value chain relative to the lower one in local labor markets affect economic development. I focus on the copper industry in Chile, which is the world's largest copper producer.

The empirical evidence suggests overall negative or negligible effects from industrial upgrading in local labor markets. The negative impacts are highly concentrated in non-manufacturing sectors and manufacturing, but not in related sub-sectors. However, this is highly influenced by the fact that the primary low value-added sector has strong comparative advantages. This limitation of our modeling efforts can be overcome by using a theoretical model that allows one to distinguish the effects of industrial upgrading in local labor markets when the primary sector does not have such a strong role in the overall economy. Paradoxically, however, it is common for industrial policies to promote industrial upgrading in local labor markets in mineral economies based on the idea that these economies have clear comparative advantages in the extraction of minerals that can be potentially transmitted to higher stages within the value chain. However, this study shows that this is not likely the case, and rather, the opposite happens: Deviations in resources weaken the comparative advantages of the primary exporter sector, without substantial gains from developing the higher value-added activities in higher stages in the copper value chain.

As activities in the mineral commodity value chain closer to the final demand are more labor intensive, even if the country does not have a large global market share in the manufacturing of those products, it may still be attractive. This is due to the higher employment offered by the higher value-added segments in higher stages. However, this study goes beyond that argument and presents evidence that supports the hypothesis of a commodity trap in local labor markets highly specialized in extractive activities. Specifically, investments in industrial upgrading in local labor markets crowd out the lower-stage activities within the mineral commodity value chain. This reduces their competitiveness and leads to the reallocation of resources toward upper-stage activities that do not have clear comparative advantages in international markets. Regrettably, this also encourages policies that focus on the primary production stage, which may have negative long-term economic effects as highlighted by the literature on the resource curse. Consequently, local labor markets that are highly specialized in extractive activities find it difficult to develop higher value-added industries, even if they are related to the resource sector.

The volatility of mineral commodity prices is another argument for industrial policies that promote local economic development by moving out from extractive activities by developing further stages within the value chain. Yet, our results suggest that developing further value chain stages may not reduce the impacts of a negative shock from mineral prices. This is because the output of these activities are intermediate inputs that have not been manufactured into final goods. Consequently, their production is similarly sensitive to mineral prices. The only difference may be observed for activities in the third stage of the copper value chain, such as the production of copper cables and wired rods. However, these industries have greater export competition. Furthermore, they have very limited production in Chile, and more generally, in mineral developing economies.

Together, this evidence supports the argument for establishing high royalties in the extractive sector to invest these resource windfalls in other key sectors with high comparative advantages. However, this may come at the expense of long-term local economic development in resource-rich regions. In this complex scenario, policies that support the supply chain of extractive activities provide an effective approach to the problem of resource-driven local economic development. This is partly because the strong source of local economic development comes from sectors with larger comparative advantages. These services supplier policies can become an important source of local economic development if firms that supply mining companies can also become competitive exporters in international markets. Then, the focus should be on developing skills- and knowledge-intensive activities, promoting research and innovation, and productivity spillovers through learning-by-exporting. However, these efforts should be part of a larger national strategy of development, rather than local efforts, given the lack of agglomeration externalities in cities near extractive locations.

Another interesting area can be scrutinizing our results in light of the literature on relatedness, diversification, and local economic development. This literature has grown in recent decades, arguing for the importance of economic diversification through related activities for long-term local economic development. However, these results suggest that the growth in related activities, in general, may not necessarily induce higher local growth and development. Rather, it is the growth in specific related activities that strengthen local comparative advantages. That is, activities that do not tend to compete for the same local resources but induce lower input costs in sectors with large comparative advantages. Otherwise, an industrial policy that fosters local growth through sectors that compete for the same local resources of the key sector and simultaneously face substantial competition in international markets may fail at promoting local economic growth and development not only in the short term but also in the long term. This is because developing comparative advantages in new sectors has substantial sunk costs; furthermore, there are opportunity costs of policies that merely focus on developing the key sector.

Finally, even if there are limited gains from industrial upgrading in local labor markets, the potential long-term losses of continuing to specialize in low value-added activities in extractive industries is a strong incentive for policy makers to incur the cost of these policies, with the aim of inducing a more sustainable path of local economic development. The long-term nature of the returns of these investments is exemplified in historical cases such as the iron industrial policy and the automobile industry in Japan. Nevertheless, knowing the extent of local welfare and productivity losses from export competition is important for understanding the extent to which these policies may yield returns in the long term. As this study shows, this is unlikely to be the case for industrial upgrading in local labor markets from low-processed mine copper to smelting and refined copper, owing to both local and global conditions. Moreover, these activities cannot generate productive linkages that mitigate excessive specialization in low value-added segments.

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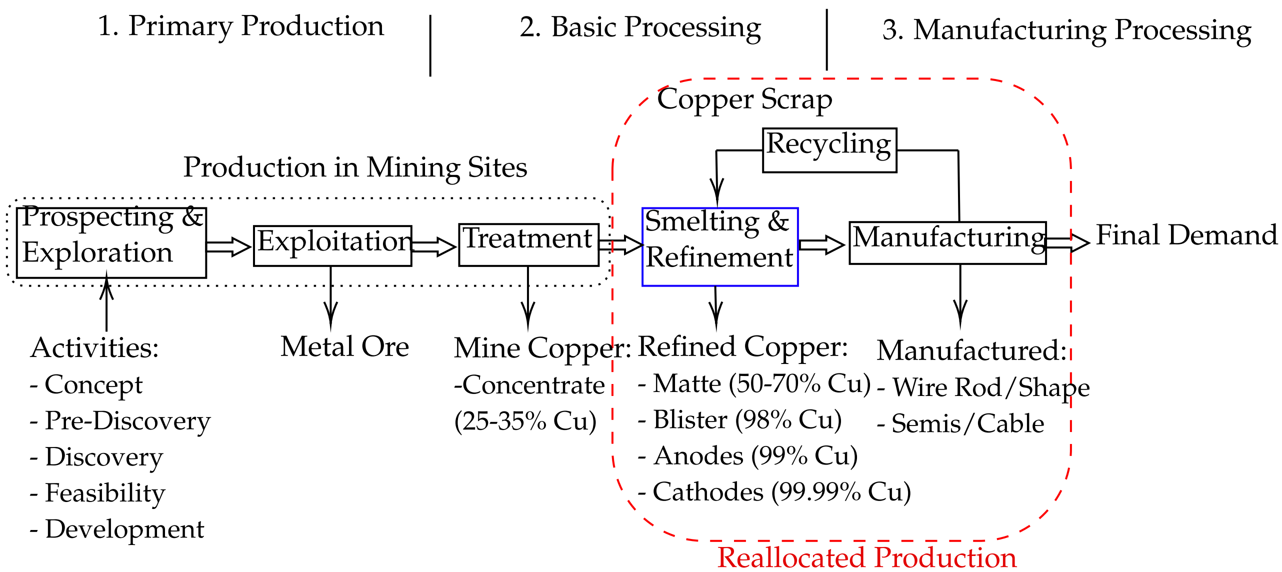
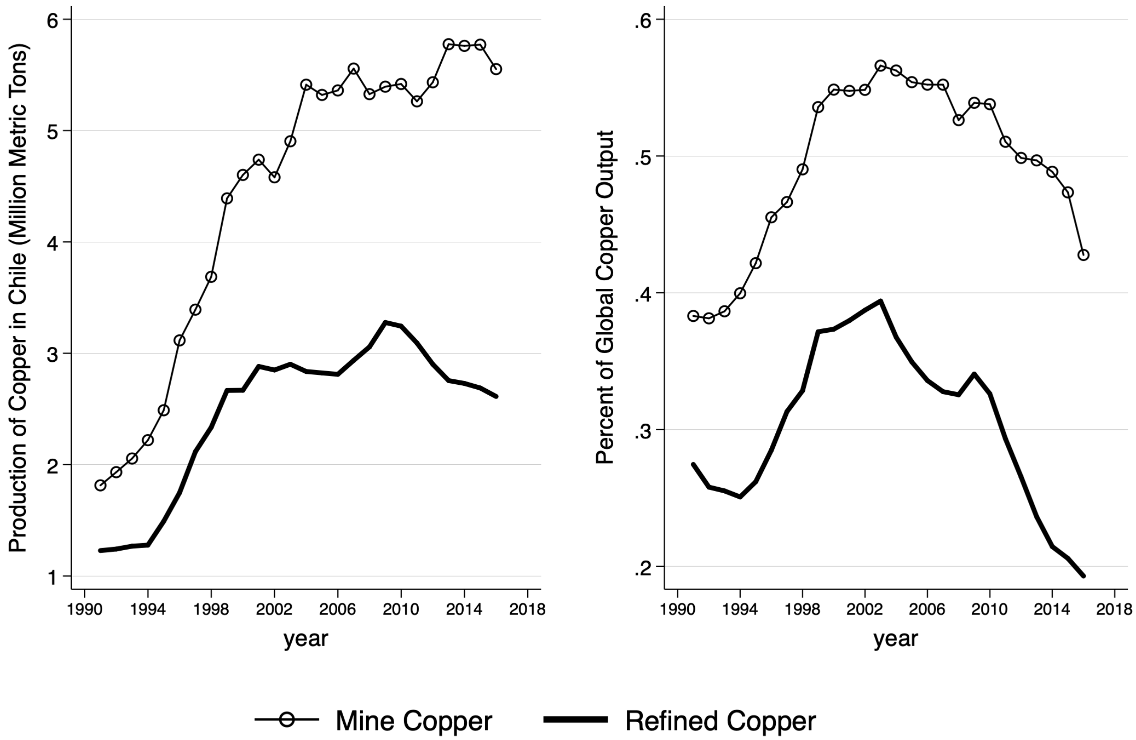
A Appendix



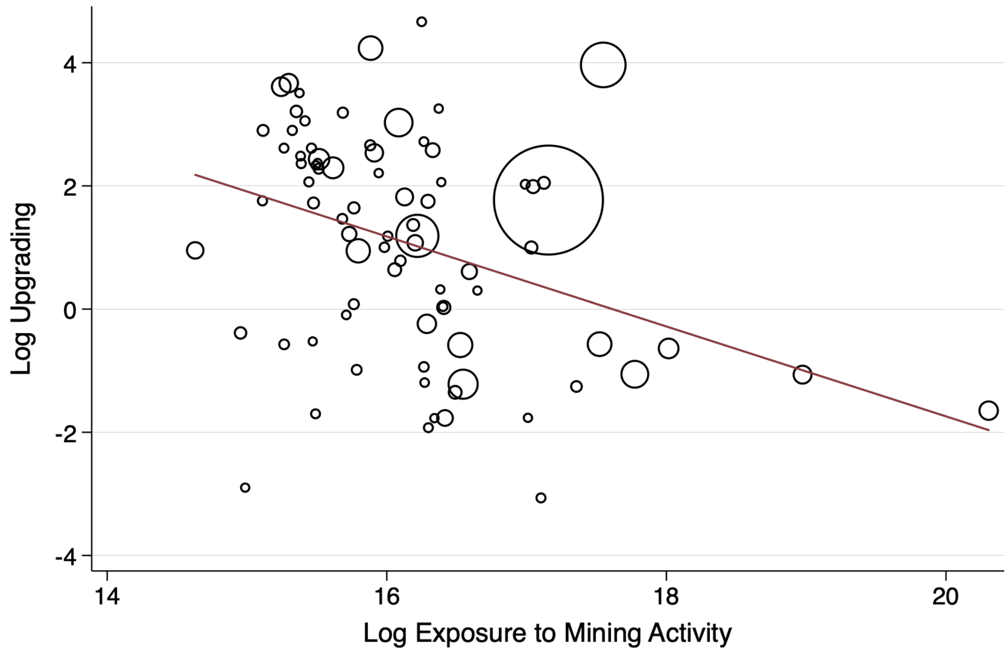
Notes: The figure illustrates a simplified description of the copper industry value chain. Treatment is usually developed in close proximity to mining sites or ports. The copper content of each product in the stages of Treatment, and Smelting & Refinement is displayed in parentheses. As an example, 1 ton of copper concentrate can give nearly 250-350kg of copper cathodes. Some of the material that is not classified as copper in these two stages can be processed as sub-products, such as Molybdenum, and Silver and Gold in less proportion. Other sub-products are obtained from the basic processing, such as Sulfuric Acid, Iron Silicate Slag, or Anod Slime. The production that has been reallocated to foreign countries is highlighted in red (specially China). However, most of this reallocation has been in the Smelting & Refinement stage. Registered copper cathodes are the units transacted in the London Metal Exchange. Currently, 17% of copper cathodes in the world market are from scrap processing, while 19% are from SX/EW and 64% from smelting & refinement.

Figure A.1: Value Chain of the Copper Industry



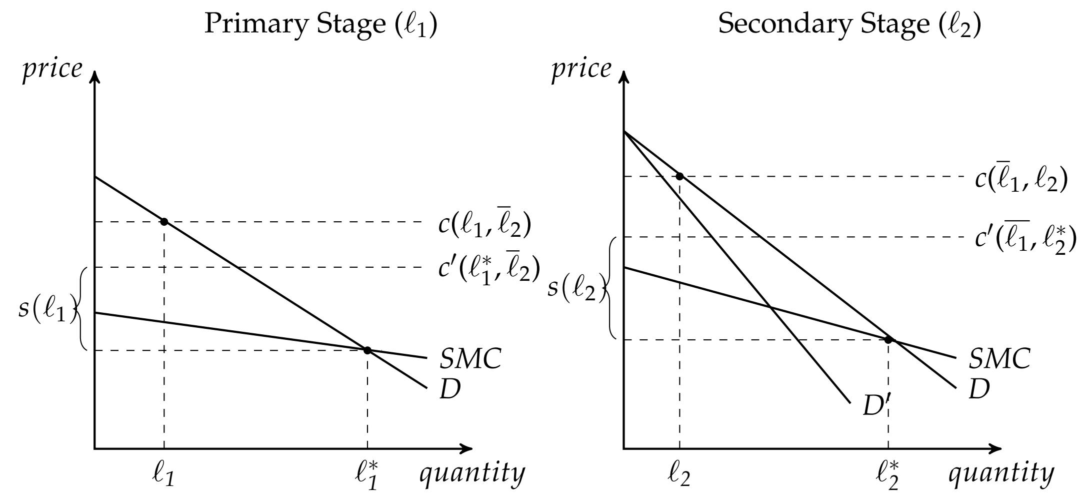
Notes: The figure shows the evolution in the production of mine and refined copper in Chile (left panel), as well as the evolution of this production share in the world market (right panel) between 1990 and 2015. The rise and decline in global market concentration in both segments of the value chain follows the same trend of increasing demand of copper commodities from China since the 1990s and then the import substitution of these commodities by China following the 2000s.

Figure A.2: Production of Copper in Chile



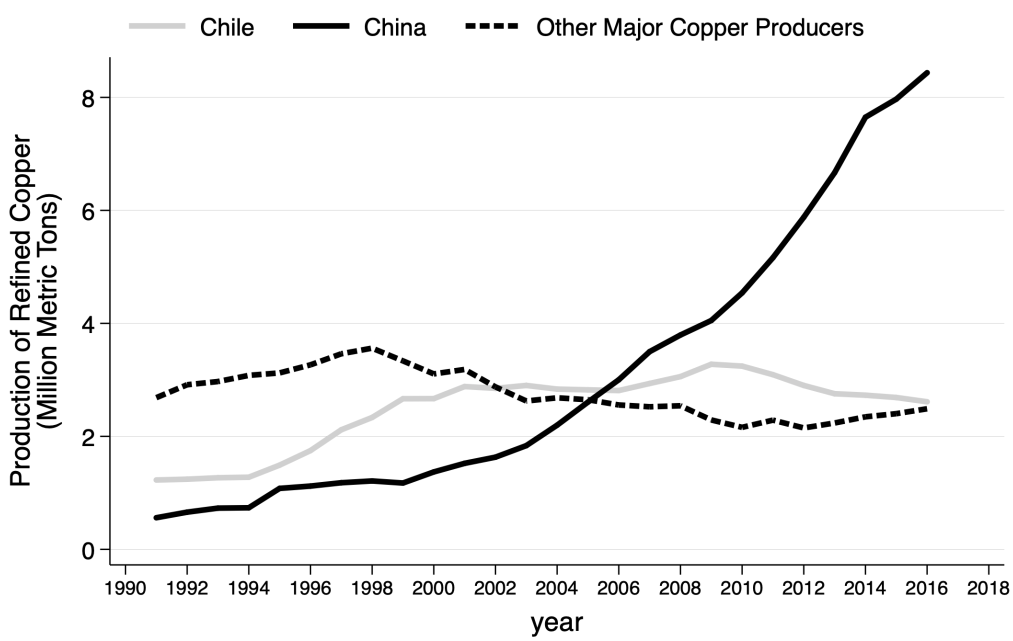
Notes: The figure illustrates the relationship between industrial upgrading and a measure of the exposure to extractive activities in the mining sector. Markers represent cities with over 25,000 inhabitants and are weighted according to population size. The exposure to a shock in a value chain $j \in \{\text{mine copper}, \text{refined copper}\}$ in a city c in year t is measured as $\Delta EPW_{jct} = \frac{L_{jct}}{L_{ct}} \frac{\Delta X_{jt}}{L_{jt}}$, where $\Delta X_{jt}/L_{jt}$ is the change in exports per worker in Chile in a value chain segment j between year t and $t-1$, and L_{jct}/L_{ct} is the share of employment in a value chain segment j in a city c in year t compared to the total labor in that city. The upgrading variable is constructed using the ratio between ΔEPW_{jct} for $j = \{\text{refined copper}\}$ in relation to $j = \{\text{mine copper}\}$, i.e., $Upgrading_{ct} = \Delta EPW_{j=refined,ct}/\Delta EPW_{j=mine,ct}$

Figure A.3: Resource Endowment and Industrial Upgrading



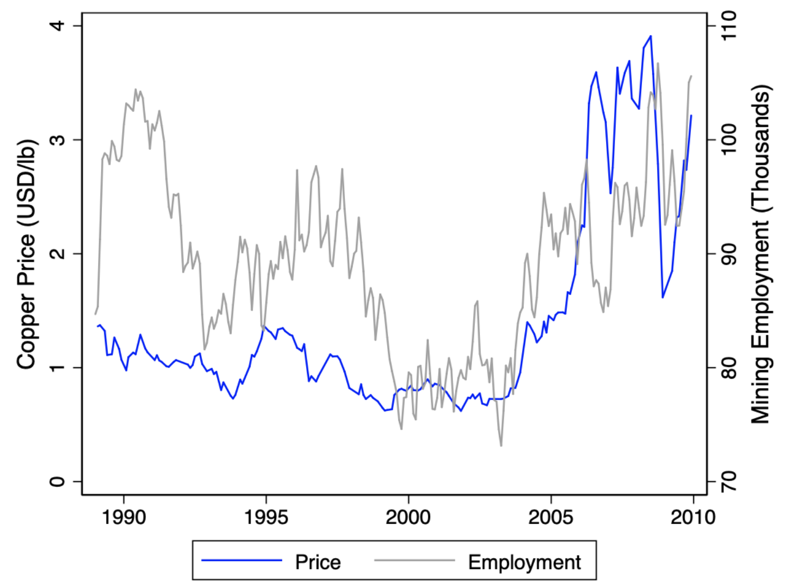
Notes: The figure compares the heterogeneous welfare gains from industrial policy among two segments of a value chain. If the area of the triangle of the secondary stage ℓ_2 is less than that of the primary stage ℓ_1, there are no incentives to implement industrial upgrading. This because investments in the primary stage ℓ_1 would lead to higher welfare gains. Moreover, subsidizing the primary stage ℓ_1 would also decrease marginal costs in the secondary stage ℓ_2, which may also foster the overall industry. *Source:* Adapted from Bartelme et al. (2019).

Figure A.4: The Incentives for Industrial Policies and Value Chains

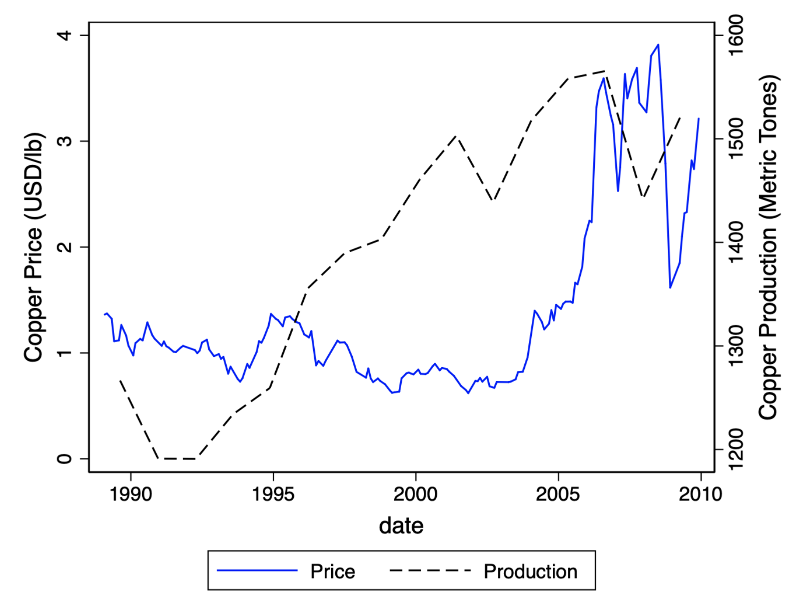


Notes: Other major producers include Australia, Peru, U.S., among other.

Figure A.5: World Production of Refined Copper



(a) Mineral Prices and Employment



(b) Mineral Prices and Mining Production

The figure describes the evolution of mineral prices, employment, and production.

Figure A.6: Copper Prices, Mining Employment, and Copper Production

Table A.1: Resource Endowment, Mineral Prices, Export Competition, and Industrial Upgrading in Local Labor Markets

	Log Industrial Upgrading								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Log Resource Endowment	-1.206***	-1.207***	-1.243***						
	(0.186)	(0.187)	(0.188)						
*(Log Mineral Prices)				-0.014***	-0.014***	-0.014***			
				(0.002)	(0.002)	(0.002)			
*(Log Export Competition)							-1.435***	-1.436***	-1.479***
							(0.221)	(0.222)	(0.223)
Constant	1.005***	1.005***	0.651**	1.015***	1.015***	0.693**	1.005***	1.005***	0.651**
	(0.166)	(0.167)	(0.300)	(0.181)	(0.181)	(0.300)	(0.166)	(0.167)	(0.300)
Year FE		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓
Adjusted R^2	0.366	0.360	0.367	0.325	0.319	0.324	0.366	0.360	0.367
F-statistic	42.175	41.769	25.404	39.404	39.097	22.365	42.175	41.769	25.404
Observations	374	374	374	374	374	374	374	374	374

Notes: Standard errors (in parentheses) are clustered at the regional level. City-level controls in the initial year include the share of high-skilled workers and the Krugman index of specialization. The variation in resource endowment that interacts with export competition is used for identification in the following estimation, when exploring the effects of industrial upgrading on local economic outcomes.

Table A.2: Industrial Upgrading and Overall Impacts in Local Labor Markets

	Change in Log Population (working age, between 15 and 65 years)				Change in Log Real Wages (nominal wages adjusted by housing rents)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	2SLS	OLS	OLS	OLS	2SLS
Log Upgrading	0.000	0.000	0.000	-0.009**	0.007***	0.005***	0.005***	0.003
	(0.001)	(0.001)	(0.001)	(0.004)	(0.002)	(0.001)	(0.002)	(0.004)
Year FE		✓	✓	✓		✓	✓	✓
Controls			✓	✓			✓	✓
Adjusted R^2	-0.003	0.044	0.046		-0.001	0.873	0.872	
Observations	360	360	360	360	377	377	377	377
First-Stage:								
K-P F-stat				34.893				46.599
P-val endog. test				0.012				0.375
Log Resource Endowment *(Log Export Competition)				-1.501***				-1.455***
				(0.254)				(0.213)

Notes: Standard errors (in parentheses) are clustered at the regional level. The wage residuals are the local average of the residuals of individual-wage equation regressed in the first step (results reported in the Appendix). City-level controls in the initial year include the share of high-skill workers and the Krugman index of specialization. The instrument used is the concentration of heavy metals in soil in mining operations within a 500km radius from each city interacted with the export competition variable. The data came from six waves of the household characterization survey (CASEN) between 2000 and 2013.

Table A.3: Industrial Upgrading and Employment and Wages in Local Labor Markets

	Change in Log Employment								
	Overall			Manufacturing			Non-Manufacturing		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS
Log Upgrading	-0.001	-0.001	-0.003**	0.015***	0.013**	0.022**	-0.003*	-0.003*	-0.006***
	(0.001)	(0.001)	(0.001)	(0.005)	(0.005)	(0.009)	(0.001)	(0.001)	(0.001)
Year FE & Controls		✓	✓		✓	✓		✓	✓
Adjusted R^2	-0.003	0.193		0.001	0.197		-0.000	0.068	
Observations	374	374	374	374	374	374	374	374	374
First-Stage:									
K-P F-stat			43.799			43.799			43.799
P-val endog. test			0.215			0.486			0.280
Log Resource Endowment			-1.479***			-1.479***			-1.479***
*(Log Export Competition)			(0.223)			(0.223)			(0.223)
	Change in Log (Nominal) Wages								
	Overall			Manufacturing			Non-Manufacturing		
	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS
Log Upgrading	-0.001	-0.001	-0.003	0.009*	0.010*	0.011	-0.003*	-0.002	-0.005
	(0.001)	(0.001)	(0.004)	(0.005)	(0.005)	(0.007)	(0.001)	(0.002)	(0.004)
Year FE & Controls		✓	✓		✓	✓		✓	✓
Adjusted R^2	-0.003	0.641		0.000	0.295		-0.002	0.703	
Observations	377	377	377	377	377	377	377	377	377
First-Stage:									
K-P F-stat			46.599			46.599			46.599
P-val endog. test			0.535			0.804			0.456
Log Resource Endowment			-1.455***			-1.455***			-1.455***
*(Log Export Competition)			(0.213)			(0.213)			(0.213)

Notes: Standard errors (in parentheses) are clustered at the regional level. The wage residuals are the local average of the residuals of individual-wage equation regressed in the first step (results reported in the Appendix). City-level controls in the initial year include the share of high-skill workers and the Krugman index of specialization. The instrument used is the concentration of heavy metals in soil in mining operations within a 500km radius from each city interacted with the export competition variable. The data came from six waves of the household characterization survey (CASEN) between 2000 and 2013.

Table A.4: Industrial Upgrading and Agglomeration of Workers and Firms along the Value Chain in Local Labor Markets

Panel a): first stage of primary production												
	Change in Log Employment						Change in Log Number of Firms					
	Direct Related Activities			Indirect Related Activities			Direct Related Activities			Indirect Related Activities		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS
Log Upgrading	-0.064***	-0.066***	-0.135***	-0.087***	-0.082***	-0.074*	-0.064***	-0.063***	-0.107***	-0.050***	-0.047***	-0.070***
	(0.018)	(0.020)	(0.037)	(0.018)	(0.013)	(0.039)	(0.013)	(0.015)	(0.027)	(0.010)	(0.008)	(0.021)
Year FEs & Controls		✓	✓		✓	✓		✓	✓		✓	✓
Adjusted R^2	0.013	0.070		0.013	0.185		0.036	0.209		0.020	0.325	
Observations	686	668	668	686	668	668	686	668	668	686	668	668
Panel b): second stage of basic processing												
	Change in Log Employment						Change in Log Number of Firms					
	Direct Related Activities			Indirect Related Activities			Direct Related Activities			Indirect Related Activities		
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS
Log Upgrading	0.016	0.016*	0.029	-0.005	0.004	-0.045	0.003	0.005	0.008	-0.002	0.003	0.006
	(0.010)	(0.008)	(0.021)	(0.022)	(0.013)	(0.034)	(0.006)	(0.004)	(0.010)	(0.010)	(0.006)	(0.014)
Year FEs & Controls		✓	✓		✓	✓		✓	✓		✓	✓
Adjusted R^2	0.000	0.042		-0.001	0.297		-0.001	0.134		-0.001	0.508	
Observations	686	668	668	686	668	668	686	668	668	686	668	668

Notes: Standard errors (in parentheses) are clustered at the regional level. Each panel considers only sectors at the CIIU-4 digit, which are classified as primary extractives (Panel A) and refinement (Panel B). The details of the classification of these activities are reported in Appendix B. City-level controls in the initial year include the Herfindahl index of industry concentration, the local population, wages, and rents. First-stage results: K-P F-stat 51.225; log mineral concentration = -1.673*** (0.234).

Table A.5: Industrial Upgrading and the Size and Profitability of Services Suppliers

	Change in Log Employment			Change in Log Sales			Change in Log Revenue		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	2SLS	OLS	OLS	2SLS	OLS	OLS	2SLS
Log Upgrading	0.024	0.045*	0.037	0.004	0.007	0.018	-0.013	-0.019	0.018
	(0.018)	(0.026)	(0.023)	(0.008)	(0.013)	(0.014)	(0.009)	(0.016)	(0.029)
Year FE & Controls		✓	✓		✓	✓		✓	✓
Adjusted R^2	0.000	-0.016		-0.003	0.035		-0.000	0.023	
Observations	241	233	233	244	236	236	207	199	199
First-Stage:									
K-P F-stat			75.494			74.783			39.348
P-val endog. test			0.776			0.318			0.280
Log Mineral Concentration			-1.555***			-1.562***			-1.324***
			(0.179)			(0.181)			(0.211)

Notes: Standard errors (in parentheses) are clustered at the regional level. City-level controls in the initial year include the share of high-skill workers and the Krugman index of specialization. The instrument used is the concentration of heavy metals in soil in mining operations within a 500km radius from each city interacted with the export competition variable. The data came from the SICEP registration merged with data from the SII between 2007 and 2013.

Table A.6: Minc erian Wage Equations

	Log of Wages			
	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
Man (=1)	0.322***	0.322***	0.322***	0.297***
	(0.003)	(0.003)	(0.003)	(0.003)
Years of schooling	0.055***	0.055***	0.055***	0.043***
	(0.001)	(0.001)	(0.001)	(0.001)
High-school education (=1)	0.073***	0.073***	0.073***	0.056***
	(0.004)	(0.004)	(0.004)	(0.004)
College-level education (=1)	0.299***	0.299***	0.299***	0.288***
	(0.007)	(0.007)	(0.007)	(0.006)
Age	0.041***	0.041***	0.041***	0.035***
	(0.001)	(0.001)	(0.001)	(0.000)
Potential experience (Age^2)	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Worked hours per week	-0.002***	-0.002***	-0.002***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	11.061***	11.061***	11.061***	9.838***
	(0.031)	(0.031)	(0.031)	(0.028)
Occupation dummies		✓	✓	✓
Industry dummies			✓	✓
Year dummies				✓
Adjusted R^2	0.395	0.395	0.395	0.533
Observations	340,166	340,166	340,166	340,166

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. Residuals from Column (4) are used in main estimations. Robust standard errors in parentheses.

Table A.7: Heterogeneous Effects on Employment along the Value Chain

Panel a): First stage of primary production						
	Log Employment					
	Overall		Direct Related Activities		Indirect Related Activities	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	-0.388***	-0.466**	-0.623***	-0.853***	-0.576***	-0.808***
	(0.131)	(0.163)	(0.177)	(0.224)	(0.102)	(0.188)
Adjusted R^2	0.325	0.314	0.390	0.346	0.451	0.418
Observations	183	183	183	183	183	183
Panel b): Second stage of basic processing						
	Log Employment					
	Overall		Direct Related Activities		Indirect Related Activities	
	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	-0.011	-0.425**	0.108	0.042	-0.029	-0.456**
	(0.141)	(0.201)	(0.066)	(0.097)	(0.149)	(0.209)
Adjusted R^2	0.307	0.206	0.489	0.480	0.307	0.202
Observations	183	183	183	183	183	183
Panel c): Third stage of manufacturing processing						
	Log Employment					
	Overall		Direct Related Activities		Indirect Related Activities	
	(13)	(14)	(15)	(16)	(17)	(18)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	0.150	-0.034	0.023	0.044	0.153	-0.039
	(0.101)	(0.160)	(0.067)	(0.058)	(0.101)	(0.161)
Adjusted R^2	0.462	0.428	0.430	0.425	0.461	0.424
Observations	183	183	183	183	183	183

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors (in parentheses) are clustered at the regional level. 95% confidence intervals in square brackets. First stage: .

Table A.8: Effects on the TFP of Manufacturing Firms

	Change in Log TFP					
				Olley-Pakes Method		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV	OLS	OLS	IV
Log Upgrading	0.004	0.015	-0.101	0.008	0.016	-0.081
	(0.013)	(0.012)	(0.098)	(0.012)	(0.012)	(0.088)
Plant-level FEs & Controls		✓	✓		✓	✓
Adjusted R^2	0.000	0.026		0.000	0.018	
Observations	2,497	2,497	2,497	2,497	2,497	2,497
First-Stage:						
K-P F-stat			2.733			2.733
P-val endog. test			0.073			0.111
Log Resource Endowment			-0.572*			-0.572*
*(Log Export Competition)			(0.345)			(0.345)

Notes: Standard errors (in parentheses) are clustered at the regional level. The following model is estimated $\Delta \log TFP_{frt} = \beta \log Upgrading_{rt-1} + \mathbf{X'}_{ft-1}\gamma + \delta_f + \epsilon_{rt}$. Controls include the size of the plant, the type of property of the plant, the percent of shares of domestic ownership, the type of firm, and the value of exported goods. The TFP is computed by residualizing the value added against wages and labor and the total value of capital stock (results reported in the Appendix). The Olley-Pakes estimation includes the value of investments as a proxy variable of the probability of exit.

Table A.9: Heterogeneous Effects on Employment and Wages among Sectors

	Log Employment					
	Overall		Manufacturing		Services	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	-0.007**	-0.015***	-0.005	0.001	-0.010***	-0.026**
	(0.003)	(0.004)	(0.015)	(0.031)	(0.003)	(0.010)
	[-0.014, -0.001]	[-0.024, -0.006]	[-0.037, 0.026]	[-0.065, 0.068]	[-0.017, -0.003]	[-0.047, -0.005]
Adjusted R^2	0.206		0.194		0.104	
Observations	216	216	216	216	216	216
First-Stage:						
K-P F-stat		33.102		33.102		33.102
P-val endog. test		0.012		0.723		0.115
Log Mineral Concentration		-1.287*** (0.224)		-1.287*** (0.224)		-1.287*** (0.224)

	Log Wages					
	Overall		Manufacturing		Services	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	-0.004	-0.003	-0.007	-0.004	0.106***	0.228***
	(0.003)	(0.006)	(0.066)	(0.132)	(0.031)	(0.069)
	[-0.011, 0.003]	[-0.017, 0.010]	[-0.150, 0.135]	[-0.263, 0.255]	[0.039, 0.172]	[0.093, 0.364]
Adjusted R^2	0.658		0.002		0.074	
Observations	216	216	216	216	216	216
First-Stage:						
K-P F-stat		32.907		35.032		35.032
P-val endog. test		0.863		0.939		0.593
Log Mineral Concentration		-1.266*** (0.221)		0.633*** (0.154)		0.633*** (0.154)

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors (in parentheses) are clustered at the regional level. 95% confidence intervals in square brackets. First-stage results are reported in the Appendix. The loss in the number of observations when including controls is due to the temporal avaialability of these variiables. The exposure to mining shocks is computed as in Equation **??**. The instruments used are the concentration of heavy metals in soil (see Equation **??**) and the base metal price index. The loss of observations in the IV estimates is because the instrument of concentration of heavy metals is restricted to cities within a 500km radius from a mine. The data used in this set of regressions came from six waves of the household characterization survey between 2000 and 2013.

Table A.10: Heterogeneous Effects on the Agglomeration of Firms along the Value Chain

Panel a: First stage of primary production						
	Log Number of Firms					
	Overall		Direct Related Activities		Indirect Related Activities	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	-0.372***	-0.527***	-0.564***	-0.950***	-0.430***	-0.697***
	(0.087)	(0.127)	(0.136)	(0.161)	(0.056)	(0.111)
Adjusted R^2	0.552	0.509	0.565	0.380	0.655	0.541
Observations	176	176	183	183	183	183
Panel b: Second stage of basic processing						
	Log Number of Firms					
	Overall		Direct Related Activities		Indirect Related Activities	
	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	0.000	0.001	0.056	0.080*	-0.033	-0.040
	(0.053)	(0.071)	(0.036)	(0.041)	(0.043)	(0.058)
Adjusted R^2	0.515	0.511	0.649	0.643	0.545	0.541
Observations	174	174	183	183	183	183
Panel c): Third stage of manufacturing processing:						
	Log Number of Firms					
	Overall		Direct Related Activities		Indirect Related Activities	
	(13)	(14)	(15)	(16)	(17)	(18)
	OLS	IV	OLS	IV	OLS	IV
Log upgrading	0.102	0.063	0.023	0.044	0.099	0.060
	(0.060)	(0.087)	(0.067)	(0.058)	(0.058)	(0.085)
Adjusted R^2	0.630	0.622	0.430	0.425	0.634	0.626
Observations	183	183	183	183	183	183

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors (in parentheses) are clustered at the regional level. 95% confidence intervals in square brackets.

B Appendix: Data Description

B.1 Value Chain Related Activities (CIIU-4)

B.1.1 Copper and Mining-Related Value Chain Activities

Copper value chain activities can be divided into three categories based on the 4-digit CIIU industry classification: (1) extraction, (2) refinement, and (3) manufacturing (see Fig. A.1). Within these three broad categories, activities can be also distinguished into those that directly involve copper minerals and related minerals. Some non-copper minerals are obtained from the same copper mines and are usually classified as subproducts, such as molybdenum, whereas others correspond to related minerals, such as gold and silver. These related minerals tend to undergo similar processing and are usually subject to the same within sector-scale economies and economic shocks as copper. Furthermore, the mining sector has other activities for the processing of other mineral commodities, such as carbon, stone, sand, and petroleum. However, these commodities are more likely to be subject to different trends and shocks, and therefore, are separated into another category. Non-copper minerals constitute only a small part of the export basket.[24] The specific 4-digit CIIU activities that were classified in each of these categories are as follows

- Direct copper extractive activities:
  - (87) Copper extraction CIIU 133000
- Subproducts and related mineral extractive activities:
  - (81) Uranio and torio extraction CIIU 120000; (82) Iron mining extraction CIIU 131000; (83) Gold and silver mining extraction CIIU 132010; (84) Zinc and lead mining extraction CIIU 132020; (85) Manganeso extraction CIIU 132030; (86) Extraction of other metals minerals CIIU 132090; (89) Nitrate and iodine CIIU 133000; (91) Lithium and chloride CIIU 142300; (92) Other mining extraction CIIU 142900
- Other non-related minerals extraction activities:
  - (78) Carbon, stone, extraction CIIU 100000; (79) Crude petroleum and natural gas CIIU 111000; (88) Stone, sand, and CIIU 141000; (90) Salt CIIU 142200; (80) Services of mining petroluem and natural gas related activities CIIU 111000

The second stage of the value chain, of basic product transformation or refinement is sepa-

[24]For Chile, copper corresponds to 97% of the total mineral exports.

rated in two categories. A direct copper and related mineral transformation, and is conformed by the following activities

- Direct copper related refinement and basic transformation activities
  - (205) Manufacturing of primary copper products CIIU 272010; (207) Precious metals and other non-ferrous metals primary products CIIU 272090; (209) Smelting of non-ferrous metals CIIU 273200
- Subproducts and related mineral basic transformation activities
  - (203) Manufacturing of other non-metal minerals products CIIU 269990; (204) Basic iron and steel industry CIIU 111000; (206) Primary aluminium products CIIU 272020; (208) Smelting of iron and steel CIIU 273100

Given that information from the population and employment census has information at the CIIU-2 digit, activity 13 is classified as direct copper extractive activities, activities 12 and 14 as subproducts and related mineral extractives, respectively, and activities 11 and 13 as non-related mineral extraction activities. For the second stage of basic transformation, activity 27 was classified as direct copper and related refinement processing, and activity 26 as subproducts and other minerals basic transformation.