Essays on Globalization, Commodities, and Local Economic Development[*]

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I can confirm that part of the data used in chapter four was the result of previous study I undertook at the Latin American Center for Rural Development (Rimisp). A working paper with preliminary results of this study was completed during my first year of my PhD, and made available online on the Latin American and Caribbean Economic Association (LACEA) Working Paper Series for discussion and dissemination purposes, under the title: "How large are the contributions of cities to the development of rural communities? A market access approach for a quarter century of evidence from Chile".

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Abstract

Over the course of this dissertation, I will explore the market mechanisms through which the unintended consequences of commodity booms in resource-oriented local labor markets have been fostered by features of international trade, which has been intensified over the past few decades. These features include offshoring, the presence of multinational companies, and participation in global value chains. For this purpose, this dissertation explores the cases of the mining and agricultural sectors in two major, resource-rich, emerging economies and exploits the different sources of exogenous variation peculiar to these commodity sectors to identify the mechanisms of trade in these sectors for contemporaneous and long-term local economic development. The work is organized in four chapters and provides a wide range of policy recommendations for resource-rich, developing economies to encourage a production structure that is more consistent with long-term local economic development.

The first part of this dissertation comprises two chapters that explore the variation induced by the expansion of the copper industry in Chile, the largest copper producer, during the commodity price boom in the 2000s. The first chapter examines the heterogeneous economic impacts between multinational companies and domestic firms on the characterization of the long-term effects of a resource boom in local labor markets. On the side of firms, the empirical evidence suggests that although the linkage effect of multinationals can be lower than that of domestic firms due to offshoring, the local productivity spillovers induced by multinationals are slightly higher than those induced by domestic firms. These productivity spillovers can mitigate the productivity losses from crowding-out effects from the booming sector. Additionally, on the workers' side, multinationals in the resource sector can affect the local economy by indirectly increasing housing rents via higher wages, which may imply lower, overall, welfare gains from the resource boom in relation to domestic firms.

The second chapter analyzes the sectoral upgrading from low-processed mine copper to smelting and refined copper exports in Chile to estimate the local welfare and productivity gains from industrial upgrading in local labor markets. This chapter uses spatial variation in the relative importance between low-processed mine copper and smelting and refined copper production, with two main objectives: first, to measure the role of resource endowment and export competition in inducing industrial upgrading in the local labor markets; and second, to estimate the local welfare and productivity gains from industrial upgrading. The results suggest that the gains from this sectoral industrial upgrading in local labor markets are small and largely concentrated in the primary segment of mineral extraction.

The last two chapters provide a different perspective by studying the different contexts and

margins of adjustment of local areas to trade shocks to commodities. The third chapter examines the case of small-scale gold mining in the Peruvian Amazon to show how informal forms of extractive industries, relative to formal activities, are fostered by international demand shocks. For this purpose, this chapter estimates the heterogeneous effects of international price shocks on the intensity of activity of formal, informal, and illegal, small-scale gold producers. This chapter provides evidence that the differences in mining activity between illegal and legal producers disappear in the wake of high prices. The results suggest a rise in the profitability of illegal mining relative to formal and informal gold mining during price booms.

Finally, the last chapter departs from the mining sector to analyze the extent to which increases in market access lead to higher local economic development and growth in remote places with low density and different degrees of specialization in agriculture. For this purpose, following a market access approach, this chapter estimates the effects of urbanization and road-infrastructure development on the structural transformation of rural villages in Chile. The empirical strategy uses the spatial and temporal variation in urban growth and road-infrastructure development to estimate the elasticities of access to urban markets by the population as well as to the farm and non-farm employment of rural villages. The results suggest important heterogeneity across rural areas, revealing that the growth of the non-farm sector induced by market access is higher in locations with better conditions for agricultural production.

Introduction

> *"Show me your blood and your furrow; say to me: here I was scourged because a gem was dull or because the earth failed to give up in time its tithe of corn or stone".*
>
> Pablo Neruda, *The Heights of Macchu Picchu (1966)*

Since David Ricardo's illustrations of the gains from trade derived from specialization and comparative advantages (Ricardo, 1817), the literature in international economics has clearly highlighted the gains from trade liberalization (Samuelson, 1939, 1962; Arkolakis, Costinot, and Rodríguez-Clare, 2012).[1] Over the past few decades, this literature has emphasized that when this trade considers features of the structure of production of the global economy that have intensified during the so-called globalization 3.0 (Baldwin and Gonzalez-Lopez, 2015), such as trade in intermediate inputs (Broda and Weinstein, 2006; Amiti and Konings, 2007; Caliendo and Parro, 2015; Caliendo et al., 2018; Caliendo, Dvorkin, and Parro, 2019), firm heterogeneity (Pavcnik, 2002; Melitz, 2003; Bernard et al., 2003, 2007; Bernard, Redding, and Schott, 2007; Helpman, Marin, and Verdier, 2008; Melitz and Redding, 2014; Melitz and Redding, 2015; Gaubert and Itskhoki, 2021), global value chains (Antràs and Helpman, 2004; Grossman and Helpman, 2005; Antràs and Chor, 2013; Antràs, Fort, and Tintelnot, 2017; Antràs and de Gortari, 2020; Antràs, 2020), and production networks (Bernard, Moxnes, and Saito, 2019; Bernard et al., 2022), these gains tend to be even larger.

The gains derived from specialization in exploiting comparative advantages between dissimilar countries or regions (Dornbusch, Fisher, and Samuelson, 1977; Wilson, 1980; Deardorff, 1980; Eaton and Kortum, 2002), as well as the gains derived from exploiting economies of scale between more similar counterparts (Krugman, 1991b; Krugman and Venables, 1995; Redding and Venables, 2004), are the core of modern theories of spatial economics (Arkolakis, Costinot, and Rodríguez-Clare, 2012; Costinot and Donaldson, 2012; Costinot, Donaldson, and Komunjer, 2012; Costinot and Rodríguez-Clare, 2014). The state of the art of this literature suggest that even if we consider a situation in which the production and trade in goods is done by many heterogeneous firms that require a large variety of inputs, with complex buyer-supplier relationships, engaged in global production networks, we can say that the welfare and productivity gains from trade may remain and indeed become larger, even in less-competitive environments (Arkolakis et al., 2019). The channels through which these gains are materialized vary, including specialization gains from the division of labor (Rodríguez-Clare,

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[1] Some remarkable causal empirical evidence of this is the case of Japan (Bernhofen and Brown, 2004, 2005), the US (Irwin, 2009), and Spain (Carrasco-Gallego, 2012).

1996b), product variety (Broda and Weinstein, 2006), technological spillovers, and financial access (Manova, 2013), among the many mechanisms that have enriched the literature and that ultimately imply higher competition, a lower price of final goods, and higher consumer welfare.

The literature on gains from trade, however, is also clear in pointing out that these gains are not equally distributed, neither between countries (Krugman, 1991b; Krugman and Venables, 1995; Redding and Venables, 2004) nor within countries (Fujita, Krugman, and Venables, 1999; Allen and Arkolakis, 2014; Fajgelbaum and Khandelwal, 2016). On the one hand, the Ricardian logic suggests that in part, these unequal gains from trade arise from the simple fact that countries and regions specialize in the production of different types of goods and services, with different factor intensities and different externalities (Eaton and Kortum, 2002). On the other hand, the New Trade Literature/New Economic Geography suggest that these differences can also emerge from the increasing returns to scale from the geographical agglomeration of workers and firms (Krugman, 1980, 1991b, 1995, 1998; Krugman and Venables, 1995; Baldwin et al., 2003). The theoretical formalization of the mechanisms through which these unequal geographical patterns of specialization emerge and its implications for productivity and welfare motivated a large empirical body of literature in an attempt to deepen our understanding of these mechanisms and to identify those patterns (Ciccone and Hall, 1996; Davis and Weinstein, 1999, 2003, 2008; Duranton and Overman, 2005; Amiti and Cameron, 2007; Redding, 2010; Costinot et al., 2019; Adão, Arkolakis, and Esposito, 2020; Donaldson, 2022).[2]

In particular, a well established and foundational result of the so-called New Economic Geography, that tends to emphasize the role of economies of scale for the gains from trade, is that trade may induce a core-periphery pattern of development and specialization of regions in a productive (e.g., manufacturing) versus unproductive (e.g., agricultural) sector, even for locations that start with symmetric characteristics (Krugman, 1991b). Moreover, given that indeed locations start with initial conditions that are highly unequal (Sachs and Warner, 1999; Gallup, Sachs, and Mellinger, 1999; Acemoglu, Johnson, and Robinson, 2001, 2002; Beakley and Lin, 2012), and that trade tends to reinforce those patterns (Krugman, 1991a,b; Krugman and Venables, 1995; Allen and Donaldson, 2022a,b), it becomes critical to consider both the role of resource endowments and the local agglomeration in the study of the economic implications of trade in commodities, particularly the long-term and within-country productivity and welfare consequences of such a pattern of specialization.

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[2] However, despite their multiple rich insights, more recently, these formulations of the so-called New Trade Theory/New Economic Geography have been shown to be isomorphic and quantitatively compatible with Ricardian theories, obeying more general patterns of gravity trade, with similar welfare implications (Arkolakis, Costinot, and Rodríguez-Clare, 2012; Allen and Arkolakis, 2014; Allen, Arkolakis, and Takahashi, 2020).

1.1 Resource Endowments, the Pattern of Trade, and De-Industrialization

The understanding of the implications of the resource endowments driving these unequal trade patterns has been emphasized in the trade literature at least since the contributions of the factor-content theories of trade.[3] A notable result in this regard, known as the Hecksher-Ohlin-Vanek theorem, establishes that countries tend to specialize in those goods that use the factors of production with which they are abundantly endowed (Vanek, 1963, 1968; Romalis, 2004). This occurs through a mechanism of adjustment, stated in the Rybczynski theorem, through which an increase in the endowment of a factor leads to a more than proportional increase in the production of the good that intensively uses that factor and a decline in other tradable goods (Rybczynski, 1955). The Rybczynski theorem set the foundations for the de-industrialization hypothesis by presenting the conditions under which a resource boom in the form of an increase in the endowments of a factor (e.g., natural resources) would eventually lead to a decline in manufacturing output.[4]

A remarkable work that was inspired by the theories of the factor content of trade, which is central to the contributions of this dissertation, is the seminal study by James Corden and Peter Neary (Corden and Neary, 1982), entitled, "*Booming Sector and De-Industrialization in a Small Open Economy*." In an enlightening work, Corden and Neary formalized the mechanisms of the *Dutch disease* that were an important concern at the time, as discussed in a 1977 article in *The Economist* (Corden, 1984). They established a theory by which specialization in trade in primary commodities may have unintended consequences as a development strategy (Corden, 1984; Neary, 1988). The authors went further to examine the implications of factor abundance as stated in the Rybczynski theorem to establish the mechanisms through which the crowding out of the manufacturing sector due to a resource boom induced a loss of productivity in the long-term, which became evident during a bust period.

Corden and Neary use the Heckscher-Ohlin framework to establish the mechanisms of the

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[3] Eli Hecksher and Bertil Ohlin built the foundations for a theory of comparative advantages with factor endowments that challenged the predominant Ricardian view at the time (Jones, 1965; Deardorff, 1982). In particular, they provided novel insights into the pattern of trade and its general-equilibrium implications.

[4] However, at that stage, this does not necessarily imply a decline in manufacturing productivity, which in the end determines if this crowding-out effect is positive or negative for the aggregate economy (Corden and Neary, 1982). Furthermore, the Hecksher-Ohlin framework presents another novel, and more controversial, insight that will inform the debate and subsequent work on the long-term impacts of the resource sector, namely, the factor-price equalization (Trefler, 1993). This implies that even if countries engage in the production of very different goods based on their factor endowments and comparative advantages due to the specialization effect, trade will induce price equalization on the factors used in the production of final goods, as the prices of similar final goods will also equalize due to free trade. The theories of the factor content of trade had major policy implications, particularly by fostering the current pattern of trade, as they implied that countries would eventually catch up in terms of economic prosperity.

unsustainable, long-term, economic development induced by a commodity boom; unsustainable in the sense that the trade is not consistent with long-term economic development. These mechanisms of the negative, unintended consequences of specialization in the resource sector are specifically modeled through a *resource movement* and *spending effect*. The resource movement mechanism establishes that a booming sector will draw resources-labor-from other tradable sectors such as manufacturing, and that this crowding-out effect will induce a loss of productivity in the long term. The *spending effect* is a result of the appreciation of a local currency due to the massive inflow of foreign currency associated with a growth in exports from a booming sector, which will also negatively impact the manufacturing sector by lowering export-revenues and increasing the costs of imported, intermediate inputs.

The implications of this theory of the de-industrialization that is induced by a booming sector were vast, at a time when resource economics was much more in the mainstream.[5] Corden and Neary's study led to a whole new literature, commonly known as "*Dutch Disease economics*" (Bruno and Sachs, 1982; Corden, 1984; Krugman, 1987; Brunstad and Dyrstad, 1997; Caselli and Michaels, 2015; Venables, 2016), and induced a radical, notorious change of perspective in terms of economic theory, empirics, and policy design that departed from the predominantly positive view of commodity specialization that had previously been implied by the Ricardian and factor content of trade theories. Since then, the formalization of these negative effects from the resource sector in Corden and Neary's study, the literature on the effects of commodity specialization has experienced considerable growth (Bruno and Sachs, 1982; Corden, 1984; van Wijnbergen, 1984; Neary and van Wijnbergen, 1986; Krugman, 1987; Auty, 1993, 1997; Davis, 1995; Karl, 1997; Rodriguez and Sachs, 1999; Sachs and Warner, 1999, 2001; Torvik, 2001; Black, McKinnish, and Sanders, 2005; Humphreys, Sachs, and Stiglitz, 2007; Lederman and Maloney, 2007; Van der Ploeg, 2011; Aragon and Rud, 2013; Caselli and Michaels, 2015; Bjørnland and Thorsrud, 2015; Feyrer, Mansur, and Sacerdote, 2017; Allcott and Keniston, 2018).[6]

Corden and Neary's study, however, was among the first to formalize the mechanisms through which productivity was affected by the crowding out of manufacturing industries during a resource boom. The study therefore significantly contributed to our understanding of the implications of commodity specialization for long-term economic development. This study

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[5] However, economists' focus at the time was more associated with resource depletion (Hotelling, 1931; Dasgupta and Heal, 1974; Solow, 1974, 1986; Dasgupta, Eastwood, and Heal, 1978; Dasgupta and Heal, 1979; Dixit, Hammond, and Hoel, 1980; Lewis and Schmalensee, 1980; Pindyck, 1980; Stiglitz and Dasgupta, 1982) than with the implications of commodity specialization for economic development.

[6] Nonetheless, the short- and long-run economic implications of commodity specialization were already a major concern for many developing countries, particularly for Latin American economists who relied on insights from the Hecksher-Ohlin theories (Singer, 1950; Prebisch, 1950).

opened the door not only for macro-economists concerned with exchange rates and aggregate productivity, but also for micro- and development economists attempting to identify the existence of such crowding-out effects and loss of productivity at the firm level. A specific mechanism through which this process of loss of productivity induced by the crowding out of other tradable sectors occurs is by a loss of *learning-by-doing* (Arrow, 1962). That is, the long-term, potential, sectoral productivity losses that are a consequence of the crowding out of manufacturing industries during a short-term resource boom and that become visible after the booming period.

The contributions of the *Dutch disease* economics led to an influential body of literature on the *resource curse*, as it opened the door to the counter-intuitive but plausible result that commodity booms can negatively impact resource-dependent economies in the long-term (Sachs and Warner, 1999, 2001; Atkinson and Hamilton, 2003; Van der Ploeg, 2011; Venables, 2016). Over the following decades, these theories expanded furthermore from the mechanisms of the *Dutch disease* to a multi-dimension of outcomes that were first explored in studies by Auty (1993, 1997, 2001b,a); Bruno and Sachs (1982); Rodriguez and Sachs (1999); Sachs and Warner (1999, 2001). That helped to develop the basis for the concept of the *resource curse* and the theories of unsustainable development in resource-rich economies.[7]

The main concern for development economists who were influenced by the theories of the *Dutch disease* was, arguably, the study of the consequences of commodity booms for the industrialization of resource-rich developing countries. This is still relevant today, even with the growing importance of trade in services and vertical specialization, particularly because the *Dutch disease* mechanisms are not specific to the manufacturing sector but apply to the tradable sector generally, which can include services (Faber and Gaubert, 2019). Moreover, the mechanisms are not specific to a final-good industry but can also be generalized to an activity within a value chain.[8] Nevertheless, the within-country geography of these mechanisms was not explored until much more recently, in the remarkable study by Allcott and Keniston (2018) that laid the foundation for the first chapter of this dissertation.

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[7] However, the *resource curse* hypothesis, as well as the idea of sustainable development in resource-rich economies, is usually used to describe a more general case than the economic theory built on Corden and Neary's study suggests, by encompassing multiple dimensions such as rent-seeking behavior (Baland and Francois, 2000), corruption (Battacharyya and Hodler, 2010), conflict (Brunnschweiler and Bulte, 2008; Dube and Vargas, 2013), and institutions (Mehlum, Moene, and Ragnar, 2006a,b), among others (Auty, 1993).

[8] This de-industrialization hypothesis motivated an important body of literature, as early development economists conceptualized it as a type of development trap in the production of commodities.

1.2 A Subnational Approach to the De-Industrialization Hypothesis

Going back to the role of geography, and in particular the within country geography. Although modern theories of spatial economics that incorporate both increasing returns to scale and comparative advantages are informative of the within-country geography of trade impacts, they lack a key distinctive feature of the resource sector: the dynamics associated with resource booms and busts. More precisely, although the margins of adjustment to shocks are equivalent among the different theories, i.e., the inter-sectoral and inter-regional movements of labor and capital that induce the core-periphery pattern of development, the mechanisms that induce those adjustments are different.[9] To better understand these margins of adjustments of labor markets within a country in response to a resource boom and bust it is necessary to first describe the intuition behind the framework of local labor market responses to productivity shocks.[10]

The stylized view of local labor markets described in Moretti (2010a), building on earlier work on regional differences under spatial equilibrium (Rosen, 1979; Roback, 1982; Glaeser and Gottlieb, 2008, 2009), predominates in the literature on the (Kline, 2010; Busso, Gregory, and Kline, 2013; Kline and Moretti, 2013, 2014a,b; Fajgelbaum and Gaubert, 2020).[11] The key underlying intuition in Moretti's study on local labor markets was established using a static, simple framework, with two spatial units (e.g., local labor markets or cities), with symmetric characteristics, constant returns to scale for production with labor and capital, but differences in the endowment of amenities across locations. Real wage differences, therefore, would be driven by how workers respond to amenities and local productivity shocks. This led to an insightful characterization of the possible effects of a shock on a local labor market, and the relative effects with respect to other local labor markets. The adjustments of local labor markets to productivity shocks occur through restrictions on workers' mobility based on their idiosyncratic tastes. This implies that even under the spatial-equilibrium assumption, as in Roback (1982), real-wage differences will remain, given that workers' idiosyncratic tastes induce imperfect mobility between local labor markets that maps into differences in social

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[9] These margins of adjustment of the general-equilibrium effects of local productivity shocks are a feature of the modern theories of spatial economics that incorporate elements of the New Economic Geography in a quantitative framework, such as monopolistic competition and increasing returns to scale (Allen and Arkolakis, 2015; Redding and Rossi-Hansberg, 2017), but are difficult to empirically identify (Hornbeck and Moretti, 2022; Adão, Arkolakis, and Esposito, 2020).

[10] This question has gained increasing attention over the past few decades (Topel, 1986; Bartik, 1991; Moretti, 2010a,b; Hornbeck and Moretti, 2022; Adão, Arkolakis, and Esposito, 2020), with particular contributions for the case of productivity shocks from the resource sector (Marchand and Weber, 2018; Bartik et al., 2019).

[11] Moretti's study was especially insightful in dealing with idiosyncratic workers' tastes that led to interesting welfare implications (Kline and Moretti, 2014b), later generalized to other settings (Monte, Redding, and Rossi-Hansberg, 2018).

welfare between locations.[12]

It was not until much more recently, however, that this better understanding of the within-country geography responses to productivity shocks was linked to the mechanisms of the *Dutch disease* in Allcott and Keniston's (2018) insightful study on both theory and empirics, under the title, "*Dutch Disease or Agglomeration? The Local Economic Effects of Natural Resource Booms in Modern America*." Allcott and Keniston (2018) characterize the mechanisms of the local *Dutch disease* by adapting Moretti's (2010a) setting to a comparison of three static equilibrium points for a resource sector, dynamic agglomeration externalities, and *learning-by-doing*. Specifically, they formalize the local equivalent to *resource movement* and *spending effects*. These are the crowding out of tradable industries at the local level and a rise in local prices due to a shock to wages in the resource sector, respectively. The two mechanisms together may induce a loss of long-term productivity and social welfare following the booming period. Although Allcott and Keniston (2018) reject the local *Dutch disease* hypothesis based on data spanning almost half a decade on the US oil and gas sectors, developing countries' peculiarities, particularly in the Latin American context, present a remarkable opportunity to test these theories.

The reason that Allcott and Keniston (2018) do not find evidence to support the local *Dutch disease* hypothesis is likely to do with a consideration of missing channels that might mask the crowding-out of manufacturing firms and consequently the loss of productivity and social welfare. In particular, there are three key related elements that are explored in the first chapter of this dissertation: the role of local productive linkages (endogenous agglomeration of firms supplying the resource sector), multinational companies (MNCs), and local amenities. First, and highly relevant, is the consideration of local productive linkages, i.e., an intermediate sector. This has been highlighted in other studies, such as Aragon and Rud (2013) for the case of gold mining in Peru, as a potential reason for the observed positive effects of the resource sector on a local economy. However, it has not been explicitly accounted for in theory and empirics. This is important because policy makers in the resource sector tend to attach relevance to this mechanism as a way of fostering a process of resource-driven growth and economic development (Farooki and Kaplinsky, 2014; Korinek, 2020).

Second, and related to the consideration of productive linkages, are firms' ownership and strategies in the resource sector; in particular, sourcing strategies that will determine the size and scope of local productive linkages from the resource sector and, consequently, the within- and cross-sectoral productivity spillovers from a resource boom and bust. This has been particularly emphasized in the literature on economic geography, and has led to the controversial

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[12] This implies that real-wage differences are consistent with the equalization of workers' utilities across locations (Moretti, 2010a, 2013).

promotion of *local-content policies*, i.e., policies that require firms to source a share of their inputs locally, especially in the resource sector (Korinek, 2020; Atienza, Arias, and Lufin, 2020). The concentration of production in MNCs is a characteristic feature of the resource sector that is usually neglected in the economic literature on the local consequences of a resource boom and bust. The idea is that research on multinational firms' boundaries suggests that MNCs are more likely to offshore some of their inputs, or engage in arms-length strategies by establishing special supply arrangements that make them more productive than domestic firms, but simultaneously more likely to induce an *enclave*-type scenario (Arias, Atienza, and Cademartori, 2014).[13]

Finally, there is another, important, missing element in this literature that is explored in this dissertation, which is key in Moretti's (2010a) study on local labor markets and has been central to these theories since Roback (1982) study on spatial equilibrium: the role of amenities, which, in the context of the resource sector, are expected to be highly correlated with a resource boom and highly relevant.[14] This is because extractive industries might generate some form of negative externalities, such as environmental pollution, or the visible, negative effects related to living near an extraction site. On the other hand, firms in the resource sector can invest in local public goods to attract workers (Méndez-Chacón and Van Patten, 2022) directly via donations and local investments, or indirectly via fiscal windfalls. Moreover, these effects can be heterogeneous among domestic and MNCs in the resource sector. These two elements are central to the understanding of the *resource movement* and *spending effect* and, as I will show in the first chapter of this dissertation, provide a better picture of the impacts of the resource sector, determining the long-term equilibrium.

1.3 Local Productive Linkages, the *Cluster* and the *Enclave*

As the economics of the resource sector reverts to the mainstream due to rising commodity prices, this debate requires a much more deep conceptualization in the light of other, important, literature. In particular, the role of productive linkages is usually not well developed within the literature on the local economic impacts of the resource sector, especially its implications for the understanding of the general-equilibrium effects of the resource sector. Nevertheless, there has been a rich and informative debate on its relevance to the understanding of the impacts of the resource sector, informed by qualitative research and case studies (Auty,

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[13] Because MNCs are more intensive in the use of intermediate inputs than domestic firms but at the same time their offshore a larger share of those inputs in comparison to domestic firms (Rodríguez-Clare, 1996a).

[14] As Corden and Neary (1982) suggested, the resource sector tends to be capital-intensive and, consequently, the *resource movement* effect is likely to be negligible. Contrarily, it is expected that most of the adjustments occur through the *spending effect*.

1993; Morris, Kaplinsky, and Kaplan, 2012; Aragon and Rud, 2013; Arias, Atienza, and Cademartori, 2014; Phelps, Atienza, and Arias, 2015; Atienza, Lufin, and Soto, 2019).[15] To obtain a proper understanding of the market mechanisms underlying the implications of productive linkages for a resource boom in local labor markets, however, we need first to explicitly account for an intermediate sector in the modeling of the effects of a commodity boom, in both theory and empirics.

An appropriate consideration of local productive linkages provides a fundamentally different perspective on the size of the scale economies in each sector, as well as their cross-sectoral productivity spillovers. In particular, considering an intermediate sector allows the possibility of an externality in production that arises from the number of firms producing different input varieties in an economy. This implies productivity gains that are more than proportional to the use of factors of production and are an increasing function of the mass of input varieties (Ethier, 1982). A direct consequence of the existence of such externalities is a better understanding of the market conditions that give rise to a *cluster* or *industrial district*, i.e., a spatial agglomeration of firms within a specific sector (Krugman and Venables, 1995; Rodríguez-Clare, 1996b), as well to its opposite concept of *enclave*, i.e., sectors with low linkage creation in the local economy (Weisskoff and Wolff, 1977; Morris, Kaplinsky, and Kaplan, 2012; Arias, Atienza, and Cademartori, 2014).

The conceptual distinction and identification of these two extremes of market structure in production, namely, the *cluster* and *enclave*, as well as many intermediate notions of firm's agglomeration that have emerged in the literature, is a vast research area that has been especially important for the resource sector (Arias, Atienza, and Cademartori, 2014). This literature has provided a wide scope of insights from different fields, specially within economic geography and international business (Porter, 1990; Markusen, 1996; Gray, Golob, and Markusen, 1996; Gordon and McCann, 2000; Martin and Sunley, 2003; Bathelt, Malmberg, and Maskell, 2004; Bathelt, 2009; Phelps, 2008; Cruz and Teixeira, 2010), with particularly insightful applications for the mining sector (Phelps, 2008; Arias, Atienza, and Cademartori, 2014; Phelps, Atienza, and Arias, 2015).

As I will demonstrate in the first and main chapter of this dissertation, this ability of the resource sector to induce industrial agglomeration through local productive linkages is highly relevant to understanding the impacts of a resource boom. This is because it will determine the extent to which a resource boom can have positive, long-term effects on the local economy by offsetting the crowding out of manufacturing industries that are not linked to the resource sector and, consequently, limiting the loss of productivity caused by *Dutch disease* effects at

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[15] More generally, as a source of development strategy in emerging economies (Hirschman, 1958).

the local level. However, to properly understand the limitations of the linkage approach, we must consider features that may hinder development strategies that rely on linkage formation with a booming sector. Moreover, it is at this point that the role of foreign investment becomes a relevant feature to characterize these impacts, particularly how these investments respond to the local conditions of agglomeration by fostering or discouraging the formation of local productive linkages (Rodríguez-Clare, 1996a; Alfaro and Rodríguez-Clare, 2004).

1.4 Implications of Multinationals, Vertical Integration, and Offshoring

Among the first formalizations of the implications of MNCs and linkage creation for economic development is Rodríguez-Clare (1996a), which builds on Markusen (1984); Helpman (1984) and Ethier (1986), among others. The author considers sectoral differences in increasing returns to scale, as suggested by Ethier (1982), and by adding and intermediate sector and differentiating a final good sector with MNCs from a sector without MNCs in relation to the possibility of offshoring, he set the conditions fo an *enclave* equilibrium.[16]. The existence of an *enclave* equilibrium arises in situations in which MNCs are more likely to offshore intermediate inputs than domestic firms. This implies lower productivity gains from increasing returns to scale from this sector, and therefore, a shallow division of labor, compared to an equilibrium in which a sector purchases a considerable amount of its intermediates locally.[17]

The idea that an *enclave* equilibrium is possible in a market with increasing returns to scale, intermediate goods, and MNCs is a remarkable result. However, Alfaro and Rodríguez-Clare (2004) do not find empirical evidence in favor of such an equilibrium. This is because MNCs tend to be more capital-intensive than domestic firms; although they may consume a lower absolute amount of intermediate goods, they are also more intensive in terms of intermediate inputs per units of labor used, inducing higher productivity spillovers (Rodríguez-Clare, 1996a). Notwithstanding, given that a resource sector is not only capital-intensive but also tends to be concentrated with MNCs, it would be more plausible to find conditions for an *enclave* equilibrium, as suggested by economic geographers in a growing strand of literature commonly known as the "dark side" of economic geography (Arias, Atienza, and Cademartori, 2014), specially considering the post-booming implications during a resource bust.

An important contribution that revolutionized how an examination of the role of MNCs

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[16] This is supported by several case studies in the field of economic geography (Girvan, 1970; Weisskoff and Wolff, 1977; Girvan, 2005; Phelps, 2008; Phelps, Atienza, and Arias, 2015)

[17] Rodríguez-Clare (1996b) is particularly novel at suggesting that this shallow division of labor is linked to capital accumulation, while Rodríguez-Clare (1996a) is more specific in linking this to the presence of MNCs. This is because the *love-for-inputs* effect is lower for sectors that are less intensive in the use of intermediate inputs (Ethier, 1982).

in an economy is approached is Melitz (2003). This study changed the perspective from inter-sectoral heterogeneity, such as explored in earlier work, including Krugman's, to intra-sectoral, firm-level heterogeneity (Pavcnik, 2002). This changed the view of the theory of the firm (Antràs, 2016), leading to new mechanisms and results that consistently embraced the stylized facts of the theory of the firm, such as large heterogeneity, high entry and exit turnover, and persistence (Ericson and Pakes, 1995; Bartelsman and Doms, 2000; Foster, Haltiwanger, and Syverson, 2008). This new approach to this question turned out to be very useful, particularly to modeling and empirically testing these mechanisms; moreover, as firm-level data became more openly available, this led to new insightful contributions (Grossman and Helpman, 2002, 2005; Antràs, 2003; Helpman, Melitz, and Yeaple, 2004; Helpman, 2006; Grossman and Rossi-Hansberg, 2008; Ramondo and Rodríguez-Clare, 2013).

The new literature on the theory of the firm also departs, to some extent, from Rodriguez-Clare's (1996a) early contribution by making the decision of becoming a multinational endogenous to the firm, particularly the idea that a multinational firm's boundaries are defined by the intensity of use of the intermediate inputs that the firm can outsource, which determines the extent to which the company will choose a strategy of vertical integration or *arms-length* (Nunn and Trefler, 2008).[18] This new literature better understand the role of MNCs in the economy, for which previous evidence was mixed (Aitken and Harrison, 1999; Gorg and Greenaway, 2004; Javorcik, 2004).[19] However, this literature tends to be more distant from that on agglomeration spillovers, despite the similarities in how these effects are modeled (Kline and Moretti, 2014a; Greenstone, Hornbeck, and Moretti, 2016; Hornbeck and Moretti, 2022).

The better understanding of multinationals' outsourcing and vertical-integration decisions has provided key insights into the implications of these firms' strategies for labor markets, between-countries (Grossman, 2004), and more recently within-countries. This new strand of literature is more focus on the implications of the reallocation of activities due to increasing offshoring for local labor markets, in particular, the consequences of the substitution of local intermediates and final goods as a result of import competition. The evidence in this regard is mixed and relies heavily on the China shock as a source of identification (Author, Dorn, and Hanson, 2013; Autor, Dorn, and Hanson, 2013; Autor et al., 2015; Autor, Dorn, and Hanson, 2016, 2020). This is the massive reallocation of activities from US to China since the 1990's and

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[18] This is to be viewed against the particularly appealing stochastic formulation of firm-level, idiosyncratic, productivity shocks that are characteristic of the studies that followed Melitz (2003).

[19] But more recently, it points toward positive effects (Alfaro-Ureña, Manelici, and Vásquez, 2019, 2021), highlighting this intra-sectoral heterogeneity (Crescenzi, Gagliardi, and Iammarino, 2015; Crescenzi and Gagliardi, 2018).

later accession to the World Trade Organization (WTO).

Remarkably, not much evidence is available in activities that are specifically linked to the resource sector on the strategies and economic consequences for local labor markets of this massive reallocation of activities due to the China shock. This is a key issue, considering that the same shock trend is correlated with the historic commodity-price boom experienced worldwide during the 2000s. This issue is explicitly addressed in the second chapter of this dissertation, for the case of the copper industry in Chile, the largest copper producer.[20] The implications of this massive shock to mineral prices for local labor markets and overall strategies of resource-based economic development for commodity producers are vast and has gained increasing attention over the past few years along other relevant dimensions. In particular for commodity producers, and specially local labor markets, competition in the downstream segments of the value chain in international markets and the opportunity cost of moving from extractive industries with large comparative advantages create a situation of lock-in in these industries (Atienza, Lufin, and Soto, 2019), without much room for industrial policy, except for the upstream activities of these value chains (Korinek, 2020).

1.5 Productivity and Amenity Advantages of Locations

Other channels that are especially important for remote resource-oriented locations are their productivity and amenity advantages/disadvantages. The amenity channel, in particular, has been less explored in the economic theory of the impacts of the resource sector, despite a large body of empirical literature documenting its relevance for local labor markets (Blomquist, Berger, and Hoehn, 1988; Beeson and Eberts, 1989; Glaeser, Kolko, and Saiz, 2001; Rosenthal and Strange, 2001; Gabriel and Rosenthal, 2004; Albouy, 2008, 2016; Albouy, Leibovici, and Warman, 2013; Chen and Rosenthal, 2008). This channel can also be key in determining the formation of an *enclave* equilibrium, as locations that are close to resource-extraction sites tend to be remote and to have a low endowment of amenities, reducing the probability that workers and firms move to these areas in response to a resource boom. More generally, as has been established since the work of Sherwin Rosen (1979) and Jennifer Roback (1982), and later contributions by Glaeser and Gottlieb (2009) and Moretti (2010a), amenities can have an effect via wages and rents, affecting workers' responses to a productivity shock in a given local labor market.

The extent to which these amenities respond endogenously to the same productivity shock to the resource sector can lead to completely different predictions to those suggested by Allcott

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[20] Copper is an important commodity for different supply chains and key for energy transition, along with other critical minerals and metals, such as silver, lithium, cobalt, and gallium.

and Keniston (2018). In the first chapter of this dissertation, I precisely explore this issue and show that the implications for welfare from a resource boom and bust are substantially amplified by this effect. Empirical data support the importance of the amenity channel. This is because local prices, captured by housing rents, tend to be more elastic than wages to the demand induced by a productivity shock in the resource sector. To the extent that these amenities are negatively correlated with the resource boom, this induces limited, real-wage gains in resource-oriented locations. This is relevant because extractive industries that are linked to the resource sector tend to have negative externalities in the form of environmental impacts, which implies that, indeed, local amenities tends to be negatively correlated with the size of this sector.

However, these mechanisms also operate through first- and second-nature productivity advantages of locations. With particular reference to the second-nature geography, these can evolve over time through *urbanization* and *localization economies*; i.e., cross-sectoral and within-sector productivity gains from economies of scale derived from the agglomeration of firms and workers.[21] The literature on the micro-foundations and empirical identification of these agglomeration externalities is vast and robust (Ciccone and Hall, 1996; Combes, Duranton, and Gobillon, 2011; Combes, Démurger, and Li, 2015; Moretti, 2004; Duranton and Puga, 2004; Duranton, 2014, 2016; Glaeser and Mare, 2001; Glaeser and Gottlieb, 2009; De La Roca and Puga, 2017). The identification and disentangling of these productivity and amenity fundamentals is challenging. The first two chapters of this dissertation takes advantage, however, of exogenous features of the resource sector that allow these forces to be captured in the data.

1.6 The Strategy of Local Economic Development in Resource-Oriented Regions

Taking all these arguments into consideration, the questions about the economic impacts from the resource sector raise a critical concern for commodity producers about the effectiveness of development strategies that rely on the resource sector as a source of long-term economic growth and development. This is particularly true in the context of increasing fragmentation of production and participation in global value chains. A consideration of the within-country geography of these effects is especially important, given the coordination problems that may arise in the design of development strategies that balance national and sub-national interests

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[21] *Learning-by-doing*, meanwhile, is incorporated in Allcott and Keniston's (2018) framework. Notwithstanding, this is added indistinctly from *localization economies*, and modeling this more properly within a framework of heterogeneous firms remains future research work. The first chapter of this dissertation, however, incorporate endogenous contemporaneous agglomeration of —intermediate— firms in addition to the dynamic effects from Allcott and Keniston (2018).

(Lufin and Soto-Díaz, 2022). This is a fundamental concern underlying the design and implementation of place-based policies (Barca, McCann, and Rodríguez-Pose, 2012; Busso, Gregory, and Kline, 2013; Neumark and Simpson, 2015; Kline and Moretti, 2014a,b). Particularly, a conflict arises because the gains from trade in commodities have an implicit cost associated with reinforcing the core-periphery pattern that may lock-in the future development of regions highly specialized in the production of commodities. Consequently, measuring the intranational implications of these trade patters is key for the design of development strategies, both at the national and sub-national levels. To properly address these issues, we must have a proper understanding of policy tools that promote within-sector and cross-sectoral scale economies in local labor markets.

1.6.1 The Space for Industrial Policy

The new insights into the theory of the firm have informed the debate on industrial policies, i.e., policies that aim to exploit within-sector scale economies. Despite the fact that the evidence on the effectiveness of these policies is mixed, pointing out difficulties in the implementation and limited potential gains, the discussion has arisen again in recent years (Aiginger and Rodrik, 2000; Liu, 2019; Bartelme et al., 2019). This debate points toward a more intelligent and pertinent type of industrial policy in the era of global value chains that takes advantage of the fragmentation of production to exploit scale economies from participation in international trade (World Bank, 2019; Liu, 2019). More precisely, policies that foster the formation of scale economies can be much more easily implemented when they are directed at specific parts or components rather than at a whole product or sector. The large fall in transport and trade costs experienced during the past few decades, together with the vertical specialization in a specific, narrow, range of activities of highly complex products makes the case for industrial policies much more prone to succeed and less costly. This is because vertical specialization tends to exploit these specific segments of value chains in which countries and regions within a country can more easily develop comparative advantages.[22]

A particular objective of many of these policies is to attempt to exploit sectoral scale economies by developing activities with more value added, exploiting comparative advantages in specific segments of a value chain. For example, governments attempt to promote industrial agglomeration by fostering a reallocation within borders of activities that involve more manufacturing processing within commodity value chains, such as reshoring strategies. The extent to which this can be within-firm or within a sector within a value chain is a matter of

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[22] However, recent global supply-chain disruptions have make the case more difficult to implement and succeed.

the potential scale economies to be developed and the competitiveness of those segments in international markets. This is especially relevant for the case of mineral commodities, as the development of extractive activities that involve natural resources tends to be associated with little value creation for resource-oriented regions, with production largely concentrated in a few MNCs. Meanwhile, however, this has provided countries and regions with strong comparative advantages in those sectors and segments within a value chain, and therefore room for the implementation of such policies.

Consistent with these arguments and in an effort to exploit productivity spillovers from the increasing participation of local firms in global production networks, policy makers in resource-rich economies are increasingly adopting policies that focus on increasing the value of domestic content (Korinek, 2020). A remarkable example of this policy approach in mineral economies, stimulated by the recent growth of trade in services, is the promotion of mining companies' local service suppliers.[23] The competitiveness of local supplier firms is fostered by promoting quality upgrading and the export of their services.[24] These alternative forms of upgrading in upstream segments of the value chain present a more feasible way of industrial policies for policy makers in resource-rich economies than the traditional approach. Given these two different, albeit complementary, policy approaches targeting two segments within a value chain, and considering the large costs of such policies, it is important to provide more evidence on their effectiveness.

In addition, the growing fragmentation of production and participation in global production networks has shaped an economic environment in which even if a country creates the incentives to internalize a production process with more value added, by raising tariffs on low value-added exports or subsidizing a specific activity, market imperfections might hinder the effectiveness of industrial upgrading to generate local productivity spillovers or social welfare gains. For example, foreign multinationals tend to rely much more on foreign intermediates for their production and may offshore most of the expected linkages that the policy intends to create (Atienza, Lufin, and Soto, 2019). Meanwhile, other countries can retaliate, imposing tariff escalation to reduce the competitiveness of those activities in foreign markets (Antràs et al., 2022), which can be very harmful for developing economies, considering the

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[23] For example, developing countries that specialize in the production of mineral commodities tend to promote the participation of mining service suppliers (Atienza, Lufin, and Soto, 2019; Atienza, Fleming, and Aroca, 2020; Korinek, 2020).

[24] Imports of intermediate goods can also induce pro-competitive effects on these suppliers Broda and Weinstein (2006). This channel of gains from trade is not explored in this dissertation but it can be an important source of local productivity gains (MacGarvie, 2006; Kasahara and Rodrigue, 2008; Goldberg et al., 2010; Bøler, Moxnes, and Ulltveit-Moe, 2015; Kee, 2015; De Loecker et al., 2016; Pierola, Fernandes, and Farole, 2018; Oberfield, 2018; Bisztray, Koren, and Szeidl, 2018; Lu, Mariscal, and Mejia, 2022).

opportunity costs of diverting investments from activities in which the country already has a comparative advantage.

The topic of industrial upgrading has gained increasing interest in recent years, especially those strategies that point toward firm-level quality and technological upgrading (Gereffi, 1999, 2019; Verhoogen, 2008; Bustos, 2011; Amiti and Khandelwal, 2013; Bas and Strauss-Kahn, 2015; Fieler, Eslava, and Xu, 2018; Hansman et al., 2020; Bai et al., 2020; Verhoogen, 2021). However, the mechanisms through which industrial upgrading impacts local labor markets, as well as how this upgrading within local labor markets responds to exogenous, global shocks in the value chain segments involved in the process of upgrading, remain a question with scarce evidence. Chapter two of this dissertation specifically addresses this issue and provides evidence on these mechanisms.

Notwithstanding, an important channel not explored in this dissertation are the pro-competitive effects induced by the import of intermediate inputs. This channel have shown to be important in explaining the gains from trade (Broda and Weinstein, 2006; MacGarvie, 2006; Amiti and Konings, 2007; Kasahara and Rodrigue, 2008; Goldberg et al., 2010; Bøler, Moxnes, and Ulltveit-Moe, 2015; Kee, 2015; De Loecker et al., 2016; Pierola, Fernandes, and Farole, 2018; Oberfield, 2018; Bisztray, Koren, and Szeidl, 2018; Lu, Mariscal, and Mejia, 2022). As the import of inputs with induce to competition from domestic suppliers that might lead to a process of upgrading. In addition, to the gains in scale from the growth of variety of inputs (Krugman, 1980; Ethier, 1982; Rodríguez-Clare, 1996b). Particularly to the resource sector, this can be another source of space for industrial policy. As MNCs rely more on intermediate inputs than domestic firms, they would tend to induce larger productivity spillovers through this channel. In this sense the estimates from Chapter one represent a lower bound of the productivity spillovers from MNCs. Considering this, the attraction of foreign direct investment in the resource sector is beneficial due to these productivity spillovers. However, the extent to which these gains from importing are captured by resource-oriented regions, still depends on the scale of these local labor markets.

1.6.2 Moving Away from the Production of Commodities?

Since Krugman's contributions to the field of economic geography, an important amount of work has helped us to better understand the mechanisms that help regions to divert from undesirable development paths (Martin and Sunley, 2006). A major proposition of this research is the promotion of diversification policies in an attempt to move out of these activities, at least to some extent (Breul and Atienza, 2022). However, for regions highly specialized in the production of raw materials, such a diversification process seems implausible (Lufin and Soto-

Díaz, 2022). Regarding the development of cross-sectoral scale economies, a promising line of empirical research suggests building this diversification process by means of developing local capabilities through related activities (Haussman, Hwang, and Rodrik, 2007; Haussman and Hidalgo, 2011; Hidalgo et al., 2007). This is a more general argument than the linkage approach. However, the implications and scope of those policies, as well as the formalization of how those mechanisms arise within our understanding of trade theories, is still a work in progress (Atkin, Costinot, and Fukui, 2021; Boehm, Dhingra, and Morrow, 2022), particularly the welfare and productivity consequences for local labor markets, as these policies still tend to rely on a minimum level of scale economies to work.

Diversification as a development strategy for resource-rich regions is particularly popular now in the field of economic geography, as many authors point to diversification through productive linkages with the resource sector as possible ways of development for these locations (Morris, Kaplinsky, and Kaplan, 2012; Farooki and Kaplinsky, 2014; Figueiredo and Piana, 2016; Atienza, Arias, and Lufin, 2020). Within this discussion, and given the current global context, there is an interest by policy makers in strategies of reshoring/onshoring activities that were reallocated in the past decades. Nonetheless, this strategy also has limitations. This is because the main reason that these activities were reallocated in the first place were the lower average costs of production, given economies of scale and low transport costs, while it is unclear how these can be compensated for by reshoring in some industries. With particular reference to the resource sector, this is also driven by the implications of environmental regulations in each country.

Another particularly popular policy to foster the formation of scale-economies and structural transformation is infrastructure development: specifically, transport infrastructure development, given its role in fostering the movement of factors of production across regions (Donaldson, 2018; Donaldson and Hornbeck, 2016). These policies that reduce restrictions on workers' mobility and costs of goods can also have unintended consequences in terms of spatial development (Faber, 2014); for example, by favoring migration to more attractive places to the detriment of remote areas. This is especially important in the case of urbanization and rural growth and development, given the high heterogeneity of the impacts through improvements in market access. This is explored in the fourth chapter of this dissertation. In particular, the relationship between urbanization and rural growth and development that underlies the process of structural change out of agriculture is explored.

1.6.3 The Context of Emerging Commodity Producers

An appropriate evaluation of the context in which these policies are implemented is crucial, particularly given that competition in international markets can take away the potential gains from a given industrial policy, for example. It is also necessary to consider the opportunities in terms of potential demand that some trends, such as the green energy transition, might imply. In this regard, the China shock, as denoted in the academic literature, is not only a major source of exogenous variation for small-open economies engaged in trade with China; there are also economic mechanisms behind this trade relationship that must be highlighted, specifically regarding trade in commodities. Particularly relevant for the following decades will be the trade in critical and rare-earth minerals, which are essential for the production of high-tech devices such as smartphones and for the transition to renewable sources of energy, such as the production of lithium batteries and photovoltaic solar panels. This also constitutes a major direction for future research.

Also related to the particular context in which these policies are implemented, a key feature of many developing countries, especially Latin American economies, is the size and persistence of the informal sector. Neglecting this feature might lead to wrong predictions of the implications of the resource sector for the economy. This is because the informal sector can act as a different margin of adjustment to the demand shocks from the resource sector (Ulyssea, 2018), inducing ambiguous predictions in labor markets and firms' productivity outcomes. A good understanding of the implications of the informal economy, however, also requires appropriate data, which are frequently unavailable. This matter is examined in the third chapter of this dissertation, for the case of small-scale gold producers in the Peruvian Amazon.

The case studies of Chile and Peru have a particularly motivating context, both theoretically and empirically. In particular, the region has influenced early and long-standing discussion on the topics that inspire this dissertation, including the following: industrialization, linkages, and resource dependence (Myrdal, 1957; Hirschman, 1958); the role of trade in commodities for economic development (Prebisch, 1950; Singer, 1950; Harvey et al., 2010); and the historical role of multinationals in the commodity sector (Méndez-Chacón and Van Patten, 2022). This debate continues to guide policy making in many resource-rich emerging economies. To rigorously evaluate these questions, this dissertation explores different sources of available data that are important in the context of developing countries. By combining official sources of data such as economic censuses and household surveys with openly available sources of information such as medium-resolution day-time and night-time satellite data (Donaldson and Storeygard, 2016), these chapters provide a comprehensive view of these topics in the context of the local economic development of resource-oriented regions.

1.7 Globalization, Commodities, and Local Economic Development

Although the exposition of the previous theoretical and empirical arguments tends to be rather pessimistic for commodity producers, it is not intended to establish that trade in commodities in the developing world is generating underdevelopment, as was hypothesized by early development economists between the 1950's and 1970's (Singer, 1950; Prebisch, 1950; Gerschenkron, 1952; Baran, 1952; Hoselitz, 1955; Myint, 1958; Furtado, 1964; Frank, 1966; Beckford, 1972; Palma, 1978; Cardoso and Faletto, 1979). Instead, this dissertation explores a more plausible hypothesis proposed by economic geographers in current times:

The idea that some specific negative features of the exploitation of natural resources are fostered by the hyper-specialization induced by the increase in trade in value chains experienced over the last decades. Given the market structure of those regions specialized in the production of commodities, this may reinforce and perpetuate a pattern of economic growth that is not consistent with long-term economic development. These negative externalities can, in the long-term, induce underdevelopment for some groups of the population exposed to these areas and sectors, thus necessitating policy intervention.

This dissertation proposes novel theoretical and empirical insights as well as methodological innovations to provide a comprehensive view of these issues and inform policy discussion. The topics explored in these chapters have been at the center of academic and public-policy debates in recent decades: the interrelation between offshoring, productive linkages, global value chains, industrial policy, structural transformation, and local labor markets. Furthermore, the exogenous variation induced by the commodity-price boom and the exogenous nature of the predetermined geology driving the profitability of the mining sector presents a remarkable opportunity to provide plausible, causal evidence on the mechanisms behind these patterns. This facilitates a better understanding of the nature and consequences for the within-country economic geography of this increasing specialization in the production of commodities, which is relevant to understanding the potential implications of global value-chain participation for developing resource-rich economies. The contributions of this dissertation, which are described in the following subsections, are pertinent to the study of the following:

1. the role of MNCs in the resource sector and its implications for long- term local economic development;
2. the incentives for and consequences of moving up in the value chain, exploiting the comparative advantages of these extractive industries;
3. the rise of informal and illegal forms of resource extraction to cope with large, foreign

demand shocks to these commodities; and

4. the improvements in market access that fosters structural transformation out of agriculture for small and remote locations.

To deal with these topics, this dissertation combines multiple key insights within the literature on resource economics, international trade, and economic geography: the effects of the resource sector within the *Dutch disease* framework; the implications of the fragmentation of production and export competition, offshoring, and MNCs in the resource sector for local labor markets; the importance of the informal and illegal sector as a major feature of the resource sector in developing and emerging economies; and transport-infrastructure development as a key component to spread the gains from trade integration.

1.7.1 Booming Sector, Multinationals, and Local Economic Development

Chapter 1 deals with a key issue highlighted from the previous academic debate. Specifically, most of the previous arguments relating the role of the resource sector for local economic development can be summarized in a central one underlying these policies: how and to what extent can the resource sector induce sustainable long-term local economic development? However, the theories that deal with this topic tends to simplify the market structure that characterizes production in the booming sector. These mechanisms, however, have been more discussed in case studies in the literature in economic geography and resource economics (Bridge, 2008; Morris, Kaplinsky, and Kaplan, 2012; Arias, Atienza, and Cademartori, 2014; Iammarino and McCann, 2013; Farooki and Kaplinsky, 2014; Figueiredo and Piana, 2016; Katz and Pietrobelli, 2018; Dobra, Dobra, and Ouedraogo, 2018; Atienza, Lufin, and Soto, 2019). In particular, the fact that in many cases the production in the resource sector is highly concentrated and organized by large MNCs integrated in global production networks. Consequently, mechanisms such as offshoring, the increasing fragmentation and reallocation of production across national borders, and the heterogeneous performance between domestic firms and MNCs, are usually overlooked or neglected from the analysis. Knowledge that is critical for the effective design of a growing number of public policies that promote the expansion of the resource sector as a source of local economic development.

This first chapter of this dissertation, therefore, studies the heterogeneous effects between MNCs and domestic firms in the mining sector in determining the contemporaneous and long-term effects of a resource boom and bust in local labor markets. In doing this, this chapter introduces a novel framework that extend beyond the existing understanding based on Corden and Neary (1982) and Allcott and Keniston (2018). The chapter emphasizes the concentration of MNCs in the large scale mining sector. This is critical, given a context in which many local policies try to exploit the formation of local productive linkages with the mining sector, the development of thick and specialized local labor markets and knowledge spillovers, in contexts where the lack of local amenities, and more generally, the size of those local economies and low market access, does not favour the formation of localization incentives of firms and workers. In consequence, a high presence of MNCs in relation to domestic firms might not foster the generation of positive productivity spillovers to local firms that can generate the necessary within- and between-sector economies of scale that are required to induce a process of industrial agglomeration.

These heterogeneous effects between MNCs and domestic firms are reinforced by the cyclical nature of booms and busts of the resource sector, which implies that even in the presence of contemporaneous positive effects, there might be limited welfare and productivity gains in the overall due to high local prices and foregone agglomeration externalities and *learning-by-doing*. These conditions explains the tendency of the resource sector to generate a *enclave* equilibrium, given the insufficient size of the local economy (lack of agglomeration effects). This leads to formulate an important proposition about the capacity of the resource sector to generate sustainable forms of local economic development in resource-oriented regions. The chapter formalizes this proposition with an economic model to inform the empirics. This is built over a key fundamental and empirically grounded assumption. Which is the fact that MNCs, in comparison to domestic firms, would have a propensity to import inputs rather to consume them locally. Then, the chapter will compare the contemporary and long-term predictions of a resource boom in which the production in the resource sector is not organized by MNCs, as in Allcott and Keniston (2018), against the predictions and welfare implications that the presence of MNCs induce in this framework, adapting from the mechanisms introduced in Rodríguez-Clare (1996a).

The effects of a resource boom in a city would be given by first considering the Local *Dutch disease* mechanisms, by which the resource boom would induce: a short-term local growth by increasing local population and employment in the non-tradable sector; which is a consequence of higher local wages that are outweighed by higher local rents. The higher local wages and prices contracts the size of the local non-resource tradable sector; which induces a decline in the productivity of those firms. On the other hand, the consideration of an intermediate sector and MNCs in the resource sector implies that: the effects of the resource boom and bust on productivity are driven by demand linkages which are different between MNCs and domestic firms; and depends on the size of the local economy as a predictor of the amount of intermediate varieties offered by local supplier firms to mining companies. A case of local *Dutch disease* with weak linkage effects, would characterize an *enclave* scenario. An equilibrium with MNCs in the resource sector is more likely to induce a local *enclave*, characterized by productivity losses due to foregone scale economies and limited welfare gains from the resource boom.

This chapter is part of a large literature studying the economic impacts of natural resources on local economic development. But contributes by offering a more comprehensive approach to this question, by connecting three important economic areas of research that are usually not considered together. First, it incorporates to the discussion of *Dutch disease* at the local level, the role of productive linkages and the heterogeneous effects among MNCs and domestic firms (Méndez-Chacón and Van Patten, 2022), both in the labor market (Alfaro-Ureña, Manelici, and Vásquez, 2021) and firms linkages (Alfaro-Ureña, Manelici, and Vásquez, 2019). This framework allows to have a more complete picture of the potential contemporary and long-term effects of a resource boom which can inform the design of such policies. Second, I include endogenous negative externalities from the resource sector as a negative discount over the agglomeration productivity effect that grows with the size of mining production as a type of dis-amenity effect. Finally, the empirics complement official data with satellite images to present a methodology that can be scaled-up to other countries or replicated, by using standard measures that are more reliable and do not depend entirely on local statistical agencies or official reports of mining companies.

1.7.2 Global Value Chains and Industrial Upgrading in Local Labor Markets

Chapter 2, deals with the local economic implications from policy strategies that intend to capture more value added from the resource sector. In particular, countries that try to exploit their comparative advantages to have a more important role in global value chains, now have to deal with new elements such as a growing fragmentation of production and more complex business strategies. Given the relevance of this phenomenon and the controversial impacts that some industrial policies have in past experiences, policy makers in resource-rich developing countries now face a more difficult environment to find strategies to capture more value added and diversify their economies. Accordingly, these economies constantly try to move away from low value added activities by implementing industrial policies that promote higher-value added and more knowledge-intensive sectors in activities around a key sector with strong comparative advantages.

As an example, it is usually the case that governments attempt to develop a cluster around the resource sector to foster other industries in the way and strength its position in the global economy. This chapter studies the within-country geography of the copper value chain in

Chile to provide evidence on this issue. Specifically, the extent to which integrating downstream activities locally induced local productivity and welfare gains. For this purpose, the empirical strategy uses the spatio-temporal variation in the upgrading from low process copper production to smelting and refined copper to identify the cost/gains of such process of industrial upgrading in local labor markets. The chapter explores this issue along two main parts. The first part is devoted to understand how industrial upgrading in local labor markets is affected by shocks in international markets and resource endowments. The second part explores how local labor markets respond to changes in industrial upgrading.

Results shows that this type of industrial upgrading within the copper-value-chain is associated with small gains in relative social welfare and productivity of manufacturing firms in local labor markets. Moreover, industrial upgrading in local labor markets is shown to have induced a crowding-out effect of activities in the primary segment of low-processed copper production. These results are in line with the existence of heterogeneity in the different goods and services that are provided by these firms, and its substitutability among the two segments in the copper value chain involved in industrial upgrading. As estimates shows that the effects of industrial upgrading in the growth of the size and profitability of mining services suppliers firms in local labor markets are positive albeit small in magnitude.

1.7.3 When Does Illegal Mining Pay?

A controversial aspect of participation in international trade, that is increasingly capturing the attention of scholars, are the responses of local economies to global demand shocks. In particular, foreign demand shocks might induce unintended consequences reinforcing unsustainable patterns of economic development in emerging economies, by fostering illicit and informal activities. Which, together with the poor quality of institutions that characterizes many of emerging commodity producers, might imply a rise and persistence of illegal activities in order to cope with the increasing foreign demand for commodities. Such critical view of trade, has been highlighted in the literature in economic geography, commonly known as the "dark side" view of supply chains. Which put an emphasis on the unequal gains from participation in global production networks (Phelps, Atienza, and Arias, 2018). But also relying in the insights from the literature on the *resource curse*, where extractive industries are a clear example of such situations, with remote areas in low and middle-income countries with large endowments of natural resources being the most exposed to the unintended consequences of these industries.

The consideration of these unintended consequences of commodity booms is critical for the design of "sustainable global value chains", i.e. value chains that are socially inclusive and environmentally responsible. Moreover, considering that the negative effects are unevenly distributed along the value chain and the geographical space. In particular, remote areas in low and middle-income countries with large endowments of natural resources concentrate much of these welfare and productivity losses in the form of negative externalities induced by extractive industries supplying global production networks. For resource-rich emerging economies, trade based on comparative advantages has implied an increasing specialization in these environmental-intensive industries, which might reinforce unsustainable patterns of economic development. This implies that understanding the context by which these activities responds to different shocks global markets in relation to more formal extractive industries, is crucial to inform policy making.

This chapter estimates the heterogeneous responses between informal and illegal small-scale gold mining relative to formal mining activity to variations in the global price of gold. Results show that a price shock particularly high can lead to the faster expansion of the illegal gold mining sector relative to the formal small-scale gold mining in the Peruvian Amazon region. This has important implications given the large scale impacts in deforestation and water poisoning of illegal gold mining activity. And also suggest the limitations of local governments to discourage these activities in periods of high prices. Further research in this topic is needed to understand better the existence of substitution effects between mining activity and agricultural activities in the area, and the role of intermediaries in inducing these heterogeneous responses among illegal and non-illegal gold mining activity to price shocks.

1.7.4 Urbanization and the Optimal Routes to Structural Change

Structural transformation is the core of the process of economic development (Lewis, 1954; Harris and Todaro, 1970; Herrendorf, Rogerson, and Valentinyi, 2014), for which there is a large amount of theoretically and empirical evidence documenting the trends and the mechanisms through which this process occur. In particular, a well established relationship, is the effect of urbanization on structural change out of agriculture (Gollin, Jedwab, and Vollrath, 2016). An overwhelming amount of this literature focuses on macro-economic aspects or deal with data that is particularly aggregate. To properly study this question, however, requires a a better understanding of these effects at small-spatial scales, given the large heterogeneity that characterizes the rural economic space, and the fact that these are subject to direct policies oriented to foster this process of economic development.

This chapter estimates the effects of urbanization and road transport infrastructure development in the growth and structural change out of agriculture of rural villages in Chile using a market access approach. For this purpose, in this chapter a granular spatial database is constructed combining population censuses from 1992, 2002, and 2017, with information from the road network and agricultural productivity in rural communities in Chile. The empirics is guided by a standard Ricardian trade model that relates changes in market access to changes in population and agricultural and non-agricultural employment for each location. The heterogeneous effects of market access on structural change out of agriculture are explained by exogenous productivity shocks in the agricultural sector. A first-order approximation of the market access variable from rural to urban areas is constructed using road infrastructure and nighttime lights in cities. The agricultural productivity is approximated using standard remote sensing indicators of agricultural potential derived from satellite images.

The results at this more granular level of spatial aggregation reveal the existence of important heterogeneity and nonlinearities in the relationship between access to urban markets and structural change out of agriculture in rural communities. This heterogeneity is driven by an important variation in agricultural productivity and accessibility to urban areas. Despite important average gains in local rural population and farm and non-farm rural employment derived from increases in market access due to urbanization and transport infrastructure development, rural locations with better conditions for agriculture experienced larger gains from market access. These results have important policy implications by prioritizing infrastructure development that foster agricultural productivity and better accessibility to medium- and small-size cities, as a way of inducing a faster process of structural transformation.

1.7.5 Acknowledgment of Limitations

Consistent with a growing literature in international trade that have revived the role of comparative advantages, driven by an expansion in world trade between dissimilar countries (Eaton and Kortum, 2002), this dissertation has emphasised the role of comparative advantages in trade and development. In particular, to highlight the strength of the resource sector as a source of local economic development. Notwithstanding, an important reason that countries engage in trade that is still missing in the literature of the *Dutch disease*, is to exploit economies of scale. This is the reduction in the average cost of production due to the large scale of production derived from the agglomeration of firms and workers. This allow firms participating in international trade to have access to cheaper goods. Then, even small open economies can have large gains from trade by having access to a large variety of intermediate inputs at a lower price. Which might also further specialization in those goods in which countries have comparative advantages. In particular trade scholars recently have established insightful mechanisms of the gains from trade derived from global value chain participation, through productivity spillovers associated with importing and exporting intermediate inputs, through technological improvements, learning-by-doing, and different forms of upgrading in global value chain participation.

However, despite the role of increasing returns to scale is well established since Krugman (1980), this debate has not being framed within more contemporaneous insights from the literature on resource economics. An although the first chapter of this dissertation explores the gains from input varieties for the industrial agglomeration in the light of Krugman (1991b) and subsequent contributions to economic geography, this is only explored within the domestic market. More precisely, given the assumptions of the behaviour of MNCs in relation to domestic firms in the resource sector, the extent of the decision to import, and therefore, the boundaries of MNCs are not explored (Nunn and Trefler, 2008; Helpman, Marin, and Verdier, 2008). I.e., the gains from input varieties is only explored within the domestic market and not in terms of the access to varieties abroad that importing firms can have and its effects on productivity. This channel is shutdown in the modeling and empirics in this dissertation to focus the discussion on the implications of foregone externalities, in the form of agglomeration effects and *learning-by-doing*, due to the heterogeneous propensity of firms to import inputs rather than to source them locally.

This dissertation is also limited, therefore, in the extent to which current discussions of how international trade affects the domestic economy are included. Specially, with mechanisms that are more notoriously unequal at the sub-national level and that the literature on resource economics tends to overlook. In particular, going more deep into the firm-level exploration of the hypotheses discussed in this dissertation, open the door to a new strand of literature that highlights the importance of firm upgrading in multiple dimensions, such as process, functional, inter-sectoral, learning, quality upgrading, technology adoption, and product innovation (Gereffi, 1999; Gereffi et al., 2001; Cattaneo et al., 2013; Gereffi, 2019; Verhoogen, 2008, 2021). These forms of upgrading can be faced by final good firms but also for input suppliers of the resource sector, and can be a major *reason d'être* for industrial policies. This goes farther from *learning-by-doing* to include the firm *know-how*, techniques, and capabilities, such as management (Verhoogen, 2021). These features are essential to understand how suppliers from the resource sector adapt to the resource boom and bust, as a trade shock. However, a proper understanding of these effects require new sources of information at the firm level, such as the product-level data with information of prices and quantities and trade on intermediate inputs.

Booming Sector, Multinationals, and Local Economic Development

> *"...nations appear interfered in their fundamental decisions [...] by global organizations which do not depend of any state and their activities do not answer any public interest".*
>
> Salvador Allende, *United Nations Speech (1972)*

Abstract

Can a resource boom induce long-term local economic development? Do multinational companies (MNCs) foster such equilibria or move away the economic gains from the booming sector? This study examines the heterogeneous economic impacts of MNCs and domestic firms on the characterization of the contemporaneous and long-term effects of resource booms in local labor markets. Informed by a spatial equilibrium model that features a pre- and post-booming economy with productive linkages and endogenous amenities, the empirical analysis exploits predetermined geology to identify the average and heterogeneous local economic impacts of a resource boom in an emerging resource-oriented country. Consistent with the model's predictions, the evidence suggests that spillovers from local productive linkages of the booming sector can prevent productivity losses by crowding-out effects in the form of local Dutch-Disease, with higher productivity spillovers for MNCs in comparison to domestic firms. However, these spillovers are mediated by dis-amenities rising from externalities in production, and limited by the MNCs' propensity to offshoring.

2.1 Introduction

A common feature of many modern resource-rich economies is that production in the booming sector is dominated by large multinational corporations (MNCs).[25] Notwithstanding, the literature exploring the local economic impacts of a resource boom usually overlooks this fact.[26] In this study, I show that the consideration of this feature has important implications for the long-term effects of a resource boom. Specifically, if MNCs have a propensity to outsource more productive activities to foreign locations, the productivity losses caused by the crowding-out effects of the resource boom are unlikely to be entirely offset by the positive spillovers from productive linkages generated during the boom. This idea implies that the resource sector tends to generate a pattern of development consistent with the *enclave* hypothesis. Questioning the long-term gains of linkage policies for economic development in resource-rich regions.[27]

In the seminal study by Corden and Neary (1982) and subsequent contributions, the *Dutch disease* is caused by a sector-specific boom in an *"enclave traded-good sector, which has no production links with the rest of the economy. (Natural resource sectors are an obvious example.)"* (Neary, 1988), leads to de-industrialization. It also induces a loss in productivity and, consequently, a decline in economic growth.[28] This de-industrialization is caused by the resource boom, which increases the marginal productivity in the booming sector and absorbs resources from other sectors. This *resource movement effect* causes an excess of demand in the non-tradable sector, which produces a real appreciation, known as *spending effect*. The real appreciation indirectly induces de-industrialization by reducing the revenue of exporting goods. However, the *resource movement effect* directly decreases manufacturing employment and the subsequent output.

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[25] Notably, nearly 90% of global mining production is undertaken by large-scale mining companies, and 75% of all mining companies are headquartered in Canada (Global Affairs Canada, 2022).

[26] For example, MNCs can easily adapt to negative economic shocks in the intensive margin. After closing plants in less productive places (Helpman, Melitz, and Yeaple, 2004), they gain more bargaining power to negotiate forward contracts with local suppliers (Antràs and Helpman, 2004) and avoid price fluctuations, access to cheaper intermediate inputs (Halpern, Koren, and Szeidl, 2015), and have less incentives to enforce local law (Herkenhoff and Krautheim, 2022), among other differences attributed to ownership structure, such as management (Boom and Van Reenen, 2010; Bloom et al., 2013), and more generally efficiency (Chari, Ouimet, and Tesar, 2010; Bircan, 2019).

[27] The enclave hypothesis has a long tradition among Latin American economics and formally suggests a scenario in which the extractive sector induces negligible impacts in the local economy (Prebisch, 1950; Singer, 1950; Myrdal, 1957; Hirschman, 1958; Weisskoff and Wolff, 1977; Auty, 1993; Robinson and Conning, 2009).

[28] Here, the resource boom is modeled in a two-sector Hecksher-Ohlin framework as a Hicks-neutral technological shock, which implies that as a direct consequence of the Rybczynski theorem (Rybczynski, 1955), the decrease in the output of the manufacturing sector result from the increase in the size of the sector that intensively uses the factor subject to the shock, i.e., the resource sector.

In the spirit of Moretti (2010a), a within-country version of the *Dutch disease* was introduced by Allcott and Keniston (2018). In this framework, the key mechanisms that determine the effects of the resource sector on the local economy are firm-productivity gains due to local population and sector-specific employment growth, defined as *agglomeration spillovers* and *learning-by-doing* respectively.[29] This higher local population and employment arise out of the resource boom that increases the revenue productivity of the booming sector. This generates higher local wages in this sector. Higher local wages induce a local version of the original *resource movement effect* by raising the cost of labor for firms in other sectors. Simultaneously, higher local wages also increase the demand for non-tradable goods and their price. A type of *spending effect* that might imply no relative local real wage gains arising from the resource boom.

However, the central argument in Allcott and Keniston (2018) proposes that this local de-industrialization or crowding-out effect of the resource boom causes a loss of externalities in the form of foregone *agglomeration economies* or/and *learning-by-doing*. This induces long-term productivity losses that might become evident during a bust period. This connects with the idea of unsustainable development induced by the resource sector mentioned in Corden and Neary (1982), referring to the between-country version of the *Dutch disease*.[30] Here, the *Dutch disease* is generated only when the shrink in the tradable—manufacturing—sector induces a loss in productivity and negatively impacts economic growth. Without such productivity losses, the de-industrialization is merely a consequence of specialization induced by the increase in factor endowments on natural resources (Rybczynski, 1955). This might happen due to newly discovered natural resources or a more general increase in the revenue productivity of the sector. However, by itself, this effect does not generate a long-term decline in economic growth.

Nevertheless, there is no strong evidence in favor of "local" *Dutch disease*.[31] Empirically, this effect is complex to study because it requires the identification of between-sector spillover effects generated by the resource sector that follows the chain of events inducing the decline in the productivity of the local tradable or manufacturing sector—the local *resource movement*

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[29] Although Allcott and Keniston (2018) define the concepts modeled as *agglomeration effects* and *learning-by-doing*, these effects are equivalent to persistent *urbanization* and *localization economies* or simply between- and within- sector productivity spillovers. Previous studies incorporating *learning-by-doing* in *Dutch disease* models include van Wijnbergen (1984); Krugman (1987); Torvik (2001); Bjørnland and Thorsrud (2015).

[30] Here, the concept of sustainable development refers to the contemporaneous growth induced by the resource sector consistent with long-term economic development (Corden and Neary, 1982).

[31] Apart from the evidence provided in Allcott and Keniston (2018), which is based on the oil and gas sectors in the US, Aragon and Rud (2013) explore similar mechanisms for the impacts of the discovery of the Yanachocha Peruvian mine, the second largest gold mine in the world. Both of these studies fail to identify a loss of productivity spillovers caused by crowding-out effects.

and *spending effects*. Scholars usually justify the positive effect of a resource boom in other sectors and the overall economy by arguing that productivity spillovers from backward linkages of resource sectors are a strong force offsetting the productivity decline induced by a crowding-out effect over other industries.[32] In fact, based on this argument, a significant number of resources are allocated toward policies that foster the creation of these linkages between firms and local suppliers in the resource sector.[33]

However, the productivity spillovers from backward linkages argument depends on the extent to which firms in the resource sector pass cost reductions to upstream suppliers. This necessarily implies that these suppliers operate in imperfect competitive markets that involve the existence of external economies, and that there is a minimum scale within those firms in the supply chain of extractive industries. Consequently, productivity spillovers from backward productive linkages are a key feature in understanding the impacts of the booming sector. This is because they denote the existence of these external economies that eventually lead to more agglomeration and long-term local economic development. Nevertheless, such mechanisms escape the formalization of the *Dutch disease* from the spatial equilibrium view of the local economic impacts of resource booms of Allcott and Keniston (2018), in which there are no external economies generated by the resource sector through productive linkages with local firms.[34]

More importantly, this rationale underestimates the fact that the effectiveness of those productive linkages is highly mediated by MNCs (Rodríguez-Clare, 1996a), which is a dominant feature of the resource sector.[35] The evidence on the role that MNCs' productive linkages play in fostering the productivity of domestic firms in the host country is mixed (Aitken and Harrison, 1999; Javorcik, 2004; Haskel, Pereira, and Slaughter, 2007; Keller and Yeaple, 2009; Alfaro and Chen, 2018; Alfaro-Ureña, Manelici, and Vásquez, 2019, 2021). And although most recent compelling evidence supports the notion of positive productivity spillovers from MNCs to domestic firms via productive linkages (Alfaro-Ureña, Manelici, and Vásquez, 2019), in the-

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[32] This argument is considered more as an implicit mechanism not usually tested within the literature but used to justify the evidence of positive productivity spillovers and positive effects of the resource sector in the local economy.

[33] See for example: Battat, Frank, and Shen (1996); Altenburg and Meyer-Stamer (1999); Javorcik (2004); Alfaro-Ureña, Manelici, and Vásquez (2019). For a critical analysis of these policies specific to the resource sector, see Ramos (1998); Perez (2010); Korinek (2020); Bravo-Ortega and Muñoz (2021).

[34] More recently, Faber and Gaubert (2019) have proposed a framework that, although conceptualized for the tourism sector, is more ad-hoc for analyzing the local and aggregate economic impacts of the resource sector. This static spatial quantitative trade model is particularly useful to understand the formation of productivity spillovers from local productive linkages that emerge from scale economies at the firm level.

[35] However, MNCs in the resource sector have been a source of major concern in the literature on resource economics and economic geography (Arias, Atienza, and Cademartori, 2014), especially given the historical role of MNCs in Latin America (Méndez-Chacón and Van Patten, 2022).

ory, a higher number of MNCs in the local economy in comparison to domestic firms might also lead to productivity losses in the host country in the form of foregone economies of scale.[36] These losses happen when the share of domestically purchased intermediates inputs by MNCs per unit of labor is lower than that of domestic firms (Rodríguez-Clare, 1996a). This is because the number of locally offered varieties is a function of the share of domestically purchased inputs per unit of labor. Further, if MNCs have a lower demand for local inputs than the domestic firms displaced by them (Javorcik and Spatareanu, 2008), then the number of varieties and subsequent linkages would be a decreasing function of the number of MNCs.[37] This might amplify the foregone *agglomeration economies* and *learning-by-doing* from crowding-out effects of the booming sector.

In the end, if MNCs are incentivized to source inputs from abroad because the size of the local economy is providing insufficient increasing returns to scale and diminishing the cost of specialized inputs, a type of *enclave* equilibrium might take place (Rodríguez-Clare, 1996a).[38] Accordingly, a resource boom may not induce sufficient productivity spillovers, and a local economy may not be endowed with a sizable scale. Moreover, considering that productivity spillovers to local supplier firms arises only when the lower average cost induced by the increase in the demand for intermediates is not directly internalized by firms in the resource sector.[39] Furthermore, given that MNCs can access specialized inputs in other countries at a lower cost and, arguably, possess more bargaining power to negotiate contracts with local suppliers, they would more likely require a lower amount of intermediate goods domestically than domestic firms in the resource sector.

This complementary view of local Dutch Disease with MNCs better describes the case of emerging mineral economies. These economies are characterized by *enclave* features such as high levels of foreign direct investments with weak local productive linkages, high participation of unskilled labor force, and a lack of knowledge spillovers in the local economy.[40] The lack of amenities and agglomeration economies characterize places with large endowments of natural resources in remote locations. These attributes are usually reinforced by the presence of negative environmental externalities in the resource sector that reduce the localization incentives for workers and firms, as a type of disamenity effect. These features hamper the

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[36] This argument is more exploited in case studies on extractive industries to support the idea of an *enclave* generated by the resource sector (e.g., Arias, Atienza, and Cademartori, 2014; Atienza, Lufin, and Soto, 2019).

[37] The empirical evidence of large-scale mining MNCs indicates that they source an important amount of their inputs from abroad.

[38] The literature on economic geography discusses the distinction between a modern and traditional *enclave* (Arias, Atienza, and Cademartori, 2014).

[39] For example, by asking for lower prices in intermediates supplied by local firms.

[40] It is also a potential explanation for how difficult it is to observe effects of *Dutch disease* in the aggregate, given that they can be masked due to the growth in linked activities.

development of within- and between-industries' increasing returns to scale that foster the formation of *agglomeration economies* or *learning-by-doing* and, consequently, forms of long-term local economic development based in the resource sector.

This study aims to integrate these theoretical mechanisms in a framework consistent with the different sets of empirical evidence attained from emerging mineral economies. Accordingly, I expand the theoretical model of local—within country—*Dutch disease* to consider how the potential of the booming sector to offset the negative effects of the resource boom by inducing within and cross-sectoral spillovers from productive linkages, are limited by how MNCs organize their production. Furthermore, by combining these frameworks, I test the heterogeneous effects between domestic firms and MNCs in the series of mechanisms related to the local *Dutch disease*. The specific role played by these firms in the formation of productivity spillovers through local productive linkages is also studied as a source to offset the long-term negative effects of the resource sector. Pertinently, the present framework also acknowledges the role of endogenous local amenities that mitigate or foster these effects and, consequently, determine the welfare and productivity effects of resource booms and busts.

To provide compelling and rigorous empirical evidence on the set of mechanisms described previously, this study exploits heterogeneous spatio-temporal variation for the mining activity between domestic firms and MNCs in Chile, an emerging economy concentrating several of the world largest copper mines, and with a thought-provoking role and history of MNCs in the mining industry. For this purpose, I combine population and economic censuses, households surveys, and satellite data. For the mining sector, I construct detailed data for each mining plant for almost two decades with information on production and ownership. The causal identification of the effects of mining activity on a wide range of local economic outcomes is performed by a novel instrumental variable introduced in this study. This variable uses plant-specific exogenous shocks resulting from the spatio-temporal variation in the concentration of heavy-metals found in mining sites. It also predicts the geology-driven profitability of each mine. This instrumental variable is constructed annually using a combination of different spectral indices computed using the non-visible range of satellite images relying on the remote sensing literature.

The contributions of this paper are various. First, this study complements the predictions in Allcott and Keniston (2018). In particular, I show that the linkage effect can offset the crowding-out induced by the resource sector. Moreover, an increase over linked tradable inputs tends to prevail over the crowding-out induced through final tradable goods. This is consistent with the results found in Black, McKinnish, and Sanders (2005), Michaels (2011), Aragon and Rud (2013), James (2015), Allcott and Keniston (2018) and De Hass and Poelhekke (2019) by accounting for the productivity gains from linkage formation. However, I also allow for the potential negative correlation between resource booms and local amenities, for example, the negative environmental effects or workers' perceptions from living in close proximity to resource extraction sites. I show that this dis-amenity effect can prevail in the long-term, explaining the long-term population losses taking place in cities highly specialized in the resource sector. Usually, depicted in the literature as *"company towns"*.

Second, by providing a new set of empirical insights on the use of remote sensing data for causal identification in the context of understanding the local economic impacts of mining activity (especially large-scale mining), this study provides evidence on the role played by MNCs in the resource sector to induce long-term local economic development. This has been a longstanding policy discussion for many resource-rich emerging economies, including Chile. Specifically, this study explores the heterogeneous generation of spillovers from productive linkages with the local economy and its potential long-term consequences within the local *Dutch disease* chain of events. Accordingly, this study demonstrates that, although the linkage effect of MNCs is lower than that of domestic firms due to offshoring, the empirical evidence suggests that slightly higher local relative productivity spillovers are induced by MNCs than domestic firms. This is consistent with similar empirical evidence in other contexts, such as Alfaro-Ureña, Manelici, and Vásquez (2019, 2021) and Méndez-Chacón and Van Patten (2022). And provide key evidence against the hypothesis that MNCs foster a local *enclave* more relative to domestic firms in the resource sector.

Finally, across the wide range of local economic outcomes that have been explored, an important channel in the consumption side that displays robust large differences in magnitude between MNCs and domestic firms are local rents. Given the general equilibrium effects, MNCs in the resource sector can affect the local economy by indirectly increasing rents via higher wages. This partially explains the empirical evidence provided in this study, showing limited welfare gains for Chile, which were caused by the booming sector induced by MNCs in relation to domestic firms. It is also consistent with the empirical evidence that suggests a higher cost-of-living in mining compared to non-mining municipalities in the context of Chile (Iturra and Paredes, 2014). Similar evidence has been attained for Peru (Aragon and Rud, 2013). These results suggest that the policies promoting long-term local economic development in resource-rich emerging economies via investments in local amenities should be emphasized to mitigate the potential welfare long-term losses from a resource bust.

The remainder of the paper is organized as follows. Section 2 describes the background, and Section 3 discusses the theoretical mechanisms. Subsequently, Section 4 details the data, and Section 5 presents the empirical strategy. Further, Section 6 shows the reduced form and causal evidence. Finally, Section 7 concludes the study by providing policy implications.

2.2 Background

In the resource sector, mining activity is especially relevant, particularly the extraction of hard minerals such as gold, silver, copper, and iron, among others. Hard minerals account for an important proportion of total global trade of minerals. They form a fundamental export base for many emerging economies and key inputs for the production of a large variety of intermediate inputs. The demand for these minerals is expected to rise with the increasing use of renewable energies and electric mobility.[41] The vast production of hard minerals is dominated by large-scale mining, which currently accounts for more than 80% of the global transactions related to hard minerals. Mining operations are spatially concentrated in Latin American and Sub-Saharan Africa and are usually owned by large international MNCs, such as Rio Tinto, Glencore, and BHP.

Several Latin American economies rely on mineral commodities, in which large-scale mining concentrates an important percentage of total mineral exports, especially surface mining or open-pit mines that contribute to approximately 90% of total global mineral output. Chile comprises seven of the 20 largest open–pit mines in the world and is the main extractor of copper. Since its return to democracy in 1990, Chile has experienced large inflows of foreign direct investments.[42] A considerable amount of these inflows has been dedicated to the mining sector. As shown in Figure 2.1, in less than 10 years, the production in this sector changed from being predominantly dominated by domestic (mostly state-owned) firms to being largely owned by foreign MNCs.[43] Nowadays, MNC-based production comprises approximately 75% of the total production in Chile, with the mining sector representing 26% of total FDI, 55% of total exports, and 10% of GDP.

Note that the large-scale mining sector has a complex and long-term oriented production structure. The life-cycle of a mine is composed of the following four stages: (1) projection and exploration, (2) development, (3) extraction, and (4) closure. Usually, most local investments

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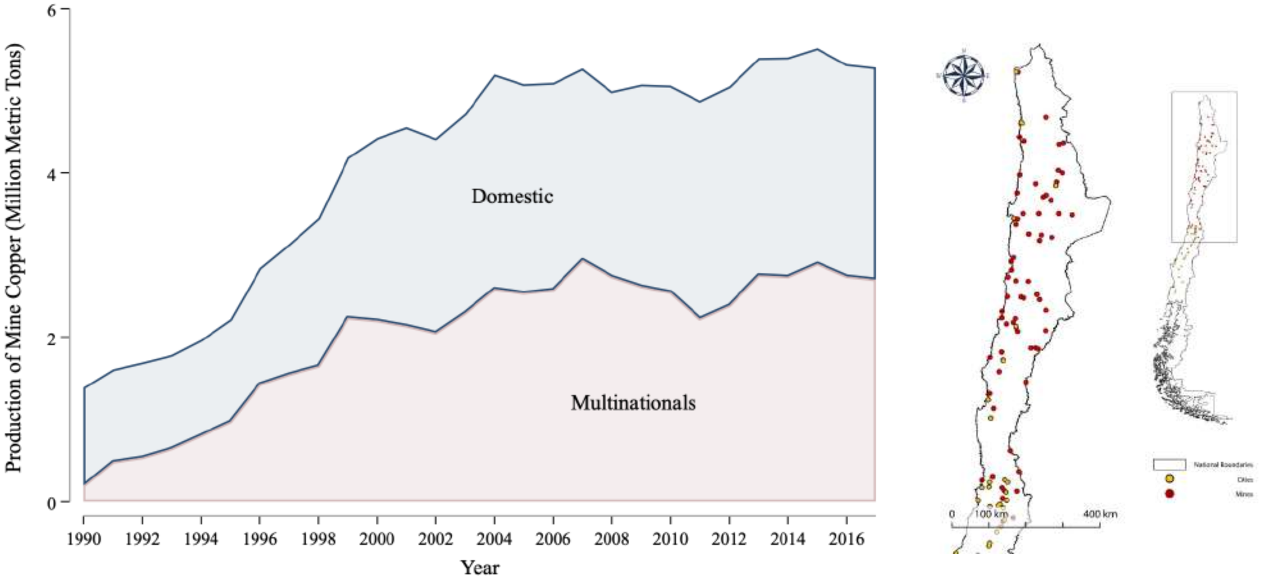
[41] The amount of minerals extracted in the last two decades is estimated to be higher than those extracted previously. For some of these minerals, the demand is expected to double in the next 20 years. Chile is expected to receive investments worth a total of 75 billion US$ by 2028. Demand for these commodities tends to be volatile in the short-term but relatively stable in the medium- and long-terms.

[42] This is different from the documented productivity spillovers in the manufacturing sector during military dictatorship (Pavcnik, 2002) and coincides with a global trend in privatization of the mining sector during the 1990s (Humphreys, 2015). Many foreign countries likely did not invest in Chile until the end of its dictatorship. This is more likely the case of the mining sector.

[43] Interestingly, Chile experienced nationalization of the Copper industry between 1960 and 1973, which was not reverted during the military dictatorship. This was induced by the large rents of the industry and reluctance of foreign investors to invest during the years of the dictatorship.



(a) Production by Ownership **(b)** Cities and Mines

Notes: The figure displays the temporal evolution of production of mine copper among MNCs and domestic firms. As well as the variation of the price of copper. The state-owned corporation, Codelco, concentrates 31.5% of national copper production, and 68.5% is private investment. The total contribution of the mining sector to the GDP is about 10%. For some regions, this is 54% of the GDP (in the Antofagasta Region). The correlation between prices and production is not strong due that large-scale mining projects are long-term oriented investments that can take several years from the stages of exploration to production, even when a mine is operating can have limited production in the early phases. The figure shows the geographical distribution of cities (with population over 25,000 at the beginning of the sample), and large-scale mines. While population distribution is highly concentrated in the central part of the country, mines are more spread over the central-north and northern regions. These regions are characterized by dry land less favourable to agriculture. This particular spatial distribution yields heterogeneous exposure to mining activity for cities in the north in comparison to cities in the central and south of Chile. *Source:* Own elaboration based on data from the Chilean Copper Corporation (Cochilco).

Figure 2.1: Expansion of the Chilean Copper Industry

in the mining sector are received in the first two phases and given that this sector is capital-intensive, most of the labor is hired during the development phase of the mining project.[44] The opening of a large-scale-mining plant is usually a long process that takes several years. Even when the mine is ready for operation, it can take a few more years to remove the waste material before high concentrations of minerals are extracted. In fact, the closure of a large mine can take up to 10 years to minimize the potential environmental damage. Along these lines there is evidence of heterogeneous behaviour on the compliance to environmental regulations in favour to MNCs.[45] Additionally, to avoid fluctuations in mineral prices, large-scale

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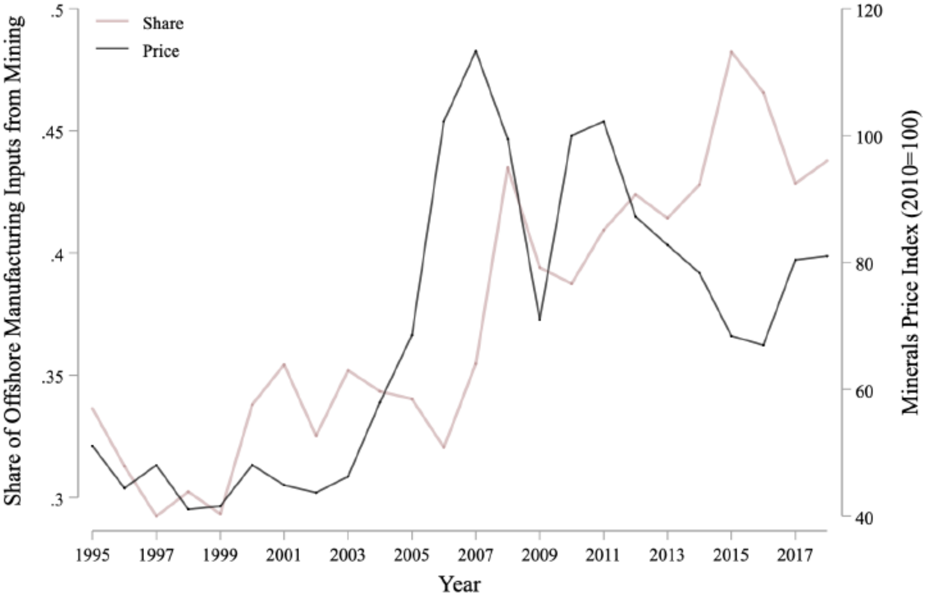
[44] This makes the direct effects in employment negligible in comparison to its indirect effects (Corden and Neary, 1982).

[45] MNCs tends to have higher standards of environmental quality in their operations in the host country in

mining companies can negotiate several decades of future production in forward contracts in which MNCs have more bargaining power. In some cases, these contracts can be traded in stock markets, which can also affect mineral prices.[46] All these conditions might affect the price-elasticity of mineral production and, consequently, its contemporaneous economic impacts.[47]



Notes: The figure shows the surge in offshoring of manufacturing inputs in the Chilean mining industry during the super-cycle of mineral prices. Offshoring is measured as the ratio between manufactured inputs imported by the mining sector over the total manufactured inputs used by the sector. Domestic purchases can be considered a potential indicator of the creation of productive linkages in the national economy. The tendency of purchases follows the super-cycle of mineral prices. The mining within-sector purchases follows the same path. *Source:* Own elaboration based on data from OECD Input-Output Tables and World Bank.

Figure 2.2: Offshoring and the Minerals Price Boom

Finally, the participation of mining MNCs presents a spatial sorting (see Figure 2.1, Panel b, for the geography of cities and large-scale-mining in Chile). While extractive activities are mainly localized in small and medium-sized cities, higher-order urban centers house more knowledge-intensive activities, as seen in Chile (Arias, Atienza, and Cademartori, 2014; Atienza, Lufin, and Soto, 2019). These elements may limit and determine the nature of agglomeration economies across the urban system because these cities have not reached a mini-

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comparison to domestic firms, in order to comply to international regulations in the parent country.

[46] For example, forward contracts of one of the subsidiaries of the largest state-owned copper producer CODELCO, signed between 2005 and 2007, are estimated to have cost approximately MMUS$ 4.66 in future revenues to the company.

[47] However, small-scale and artisanal mining tends to be much more cyclical with price booms, especially in the production of precious metals, such as gold and silver.

mum level of development to capture the growth effects of foreign direct investment (Phelps, 2008). Likewise, the 2000's commodity prices super cycle induced an increase of investments in the mining sector, as a supply response of mining companies to the demand shock from Asian economies. This led to an increase in purchases within- and between the resource sector and other sectors in the local economy. However, as Figure 2.2 shows, during this time mining companies also experienced an increase in offshoring, which implies that an important proportion of these domestic purchases were not spent locally. In fact, it is estimated that more than 90% of purchases from the mining sector were made to suppliers located in the capital region and not in the regions in which those mines are located, and approximately less than 6% of the increase in domestic purchases was spent locally (Atienza, Lufin, and Soto, 2019). These low incentives for local investment are reinforced by the lack of local productive advantages in mineral zones, as the *enclave* hypothesis suggest (Arias, Atienza, and Cademartori, 2014; Phelps, Atienza, and Arias, 2015).

2.3 Theory

2.3.1 Booming Sector, Multinationals, and Local Economic Development

The model is built directly over the within-country version of the *Dutch disease*, in which the contemporary productivity of each sector in each city is a function of past *agglomeration effects* and *learning-by-doing*. This is done by comparing three static equilibrium points that describe a pre- and post-booming economy in which the resource boom might undermine the formation of these *agglomeration effects* or *learning-by-doing* due to local *Dutch disease*.[48] The model setting adapts this framework to include an intermediate sector, endogenous amenities, and MNCs.[49] By modeling an intermediate sector, I explicitly incorporate the formation of backward productive linkages generated by the resource sector and its productivity spillovers through this channel. Additionally, by allowing for the heterogeneous effects of domestic firms and MNCs in the formation of these local productive linkages, I capture the heterogeneity in how MNCs and domestic firms foster local *agglomeration externalities* or *learning-by-doing*.[50] Finally, endogenous amenities play an important role capturing the nega-

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[48] The sustainability of the local economy is a concern considering the long-run equilibrium of the economy instead of the dynamics required to reach a steady state.

[49] This is because the introduction of MNCs in the resource sector implies modeling the production of intermediate goods in the economy, as explored in Rodríguez-Clare (1996a). Besides, this study follows the notation of Allcott and Keniston (2018) as much as possible.

[50] Rodríguez-Clare (1996b) describe the conditions for an *enclave* formation at the country level, although enclaves are local by nature. Rodríguez-Clare (1996a) further show that, generally, the extent of the market is characterized by the production of a wide variety of intermediate goods and primarily explains the persistence of underdevelopment. It also induces an under-develop trap. Nevertheless, recent evidence points toward a

tive externalities of the resource sector, which ultimately translates into heterogeneous effects in productivity and social welfare.

2.3.1.1 Model Environment The environment comprises a small open economy with two cities, indexed by $c \in \{a, b\}$. Time is discrete and composed of three periods denoted by $t \in \{0, 1, 2\}$. Each city c is endowed with L_c amounts of labor. There are three final goods sectors $j \in \{m, l, r\}$, where m denotes tradable goods, l local non-tradable goods, and r the booming sector. There is an intermediate goods sector z that supplies the three final goods sectors. Additionally, there is a housing sector h with absentee landlords, which does not require labor, and its inverse supply is given by

$$r_c = H_0 L_c^h, \tag{1}$$

where r_c is the rent of housing in city c, H_0 is a specific supply component common to both cities, and h is the elasticity of housing supply. Labor is assumed to be imperfectly mobile across cities but perfectly mobile amid sectors within cities.

2.3.1.2 Production Each sector producing final goods $j \in \{m, l, r\}$ is composed by a representative firm that can be a domestic firm or a MNC, denoted by $k = \{DOM, MNC\}$. These firms employ L_{jc}^k workers and use Z_{jc}^k intermediate inputs to produce Q_{jc}^k amounts of a final good, using Cobb-Douglas technology $Q_{jc}^k = A_{jc}^k \left(L_{jc}^k/\delta_k\right)^{\delta_k} \left(Z_{jc}^k/(1-\delta_k)\right)^{1-\delta_k}$ with $\delta_k \in (0, 1)$. The intermediate inputs used for final production of a firm k in sector j and city c, are derived from a discrete set of non-tradable differentiated intermediate goods produced according to the following standard CES specification,

$$Z_{jc}^k = \left(\sum_{N_{jc}^k} (z_{njc})^{\alpha} \right)^{\frac{1}{\alpha}}, \tag{2}$$

where $0 < \alpha < 1$, implying that intermediate varieties n are imperfect substitutes. Each firm in the intermediate goods sector produces one variety with one unit of labor. There is monopolistic competition in the production of intermediate goods and free entry and exit of firms, with mark-up pricing $P_{zjc} = w_{zjc}/\alpha$. Consequently, the scale of firms selling in-

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modern *enclave* (Arias, Atienza, and Cademartori, 2014). Note that this model does not determine whether a firm can become multinational, which has been extensively studied in the literature (e.g., Grossman and Helpman, 2002; Antràs, 2003; Antràs and Helpman, 2004; Grossman and Helpman, 2005; Helpman, 2006; Grossman and Rossi-Hansberg, 2008; Antràs, 2016). Nonetheless, it examines the implications for local economic development, given the amount inputs offshored by MNCs.

termediate goods is $z_{njc} = l_{zjc} = \left(\frac{\alpha}{1-\alpha}\right)\frac{1}{w_{zjc}} = \theta/w_{zjc}$, where $\theta \equiv \left(\frac{\alpha}{1-\alpha}\right)$ is the elasticity of substitution of input varieties. Firms in final good sectors use symmetric quantities of intermediate inputs but locally source a proportion $\lambda^k_{jc} \in (0,1)$ of these inputs, which implies that $\left(\sum_{N^k_{jc}}(\lambda^k_{jc} z_{njc})^{\alpha}\right)^{\frac{1}{\alpha}} = (\lambda^k_{jc}N^k_{jc})^{\frac{1}{\alpha}-1}L^k_{zjc}$, where λ^k_{jc} is assumed as given.[51] Due to these assumptions, the Cobb-Douglas production function of final-good producers can be formulated in the following Dixit-Stiglitz-Ethier form.

$$Q^k_{jc} = A^k_{jc}(\Omega^k_{jc})^{\eta_k}\left(\frac{L^k_{jc}}{\delta_k}\right)^{\delta_k}\left(\frac{L^k_{zjc}}{1-\delta_k}\right)^{1-\delta_k} \tag{3}$$

where $\Omega^k_{jc} \equiv \lambda^k_{jc}N^k_{jc}$, and $\eta_k \equiv \frac{(1-\delta_k)(1-\alpha)}{\alpha} = \frac{1-\delta_k}{\theta}$ is the *love-for-inputs* effect, which states that an expansion in the number of local varieties N^k_{jc} will induce a more than proportional increase in the productivity of firms in the final good sector j and city c, but only in the proportion of intermediate inputs that firms source locally λ^k_{jc}. In other words, the variety effect —or equivalently the extent of the market of intermediate inputs— is limited by the propensity of firms to offshore $1-\lambda^k_{jc}$.

2.3.1.3 Multinationals Following Rodríguez-Clare (1996a) and Alfaro and Rodríguez-Clare (2004), the production of final-good producing MNCs and domestic firms will differ in the input elasticities and total quantity of inputs demanded. This would induce differences in the size and intensity of the local backward productive linkages generated by them. Formally, the following assumptions are established: MNCs use more intensively intermediate goods than labor ($\delta_{MNC} < \delta_{DOM}$), and MNCs offshore a larger proportion of intermediate inputs ($\lambda^{MNC}_{jc} > \lambda^{DOM}_{jc}$). Note that the first assumption establishes that MNCs rely more on intermediate goods, implying that they have a greater *love-for-inputs* effect $\eta_{MNC} > \eta_{DOM}$, have a lower unit cost, and pay higher wages than domestic firms.[52] These assumptions imply heterogeneous backward productive linkages between MNCs and domestic firms. In particular, these productive linkages in each city are given by

$$L^k_{zc} = \alpha\left(\frac{1-\delta_k}{\delta_k}\right)\sum_j w_{jc}\lambda^k_{jc}L^k_{jc}. \tag{4}$$

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[51] Rodríguez-Clare (1996a) shows that the parameter λ_j increases with the variety of intermediate inputs in the home country, and decreases with transportation costs. Empirical evidence supporting these heterogeneous sourcing between MNCs and domestic firms can be found in Harrison and McMillan (2011).

[52] This assumption is also consistent with the fact that MNCs tend to be more capital-intensive than domestic firms (Alfaro and Rodríguez-Clare, 2004).

Note that the offshore parameter λ^k_{jc} and the labor input elasticity δ_k will drive the difference in productive linkages between MNCs and domestic firms. Precisely, it follows directly from $\lambda^{MNC}_{jc} > \lambda^{DOM}_{jc}$ that the size of backward productive linkages for MNCs is lower than that for domestic firms.[53] However, this is contrarrested by the fact that MNCs are more intensive in the use of intermediate inputs and, consequently, the linkage multiplier $\frac{1-\delta_k}{\delta_k}$ would be higher for MNCs than for domestic firms. Furthermore, given that MNCs have a greater *love-for-inputs* effect, the productivity spillovers from MNCs will be larger than those of domestic firms.[54] This may be because MNCs are more intensive in intermediate inputs, which is why they would induce a larger variety of intermediate firms in the domestic market and a proportionally higher output increase in final-good producers per unit of intermediate input used.[55]

2.3.1.4 Agglomeration Externalities The physical productivity A^k_{jc} of a representative firm $k = \{DOM, MNC\}$ in each final good sector j and each city c evolves over time with past labor in sector j and city c, total labor in city c, and a sector-specific idiosyncratic component ζ^k_j. According to the following law of motion,

$$A^k_{jct+1} = {A^k_{jct}}^{\psi_j} {L^k_{jct}}^{\phi_j} {L^k_{ct}}^{\Lambda} \zeta^k_j. \tag{5}$$

Further, analogous to the idea of dynamic localization economies, the existence of *learning-by-doing* implies that $\phi_j > 0$, which indicates the sector's current productivity, increases with sector past employment. Agglomeration spillovers are more similar to the concept of urbanization economies, implying that $\Lambda > 0$—the sector's current productivity increases with past local population. In addition, Eqn. 5 also captures heterogeneity among MNCs and domestic firms in the persistence in the productivity of each sector, given by $\psi^k_j > 0$, and the idiosyncratic differences between sectors ζ^k_j.

2.3.1.5 Consumption On the consumer side, each individual i in city c consumes C_i units of a local good l, a tradable good m, and H_i units of housing, at prices p_{lc}, p_{mc} and r_c respectively. p_{lc} is endogenous, p_m is set as the numeraire (exogenous), and r_c follows Eqn. 1. Additionally, consumers receive a utility $B_c \epsilon_{ic}$ for living in city c, with B_c level of amenities.

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[53] Note that these conditions are slightly different from Rodríguez-Clare (1996a) and Alfaro and Rodríguez-Clare (2004). This is because, in this study, the equilibrium determination of the endogenous number of MNCs compared to domestic firms is not explored. Specifically, this implies that the unit cost function does not have a term to specify the relative differences between the prices charged by MNCs and domestic companies.

[54] Recall that $\delta_{MNC} < \delta_{DOM}$ implies $\eta_{MNC} > \eta_{DOM}$.

[55] The differences in productivity spillovers of MNC firms have been largely documented in empirical studies (e.g., Aitken and Harrison, 1999, Javorcik, 2004, and Alfaro-Ureña, Manelici, and Vásquez, 2019).

ϵ_{ic} is the individual idiosyncratic taste for city c. Individuals have Cobb-Douglas preferences, maximizing $U_{ic} = C_{il}^{\gamma} C_{im}^{\varrho} H_i^{\varphi} B_c \epsilon_{ic}$ subject to a budget constraint $p_{lc} C_{il} + C_{im} + r_c H_i = w_c$, with γ, φ, and $\varrho \in (0,1)$, and $\gamma + \varphi + \varrho = 1$. Then, the indirect utility function yields

$$U_{ic} = \frac{w_c B_c \epsilon_{ic} \kappa}{p_{lc}^{\gamma} r_c^{\varphi}} \tag{6}$$

where $\kappa = \gamma^{\gamma} \varphi^{\varphi} \varrho^{\varrho}$. ϵ_{ic} is assumed distributed type I extreme value with scale parameter ξ^2 with $\xi \in (0, \infty)$. Individuals choose to live in a instead of b, if $U_{ia} > U_{ib}$. Therefore, under spatial equilibrium $U_{ic} = \overline{U}$, and the relative inverse labor supply is $L_a / L_b = \left(B_a w_a / p_{la}^{\gamma} r_a^{\varphi}\right)^{\xi} / \left(B_b w_b / p_{lb}^{\gamma} r_b^{\varphi}\right)^{\xi}$.

2.3.1.6 Equilibrium Given the assumptions of differences in the intensity and use of intermediate inputs between MNCs and domestic firms, an equilibrium with either only domestic firms or only MNCs is the particular case in which $\lambda_{jc}^{MNC} = \lambda_{jc}^{DOM}$ and $\delta_{MNC} = \delta_{DOM}$. Consequently, for simplicity, here onward I omit the subscript k distinguishing both types of firms, to focus on the equilibrium relationships regarding the resource boom and bust. Then, I will describe the comparative statics between an equilibrium dominated by MNCs and a scenario with a high presence of domestic firms by comparing how these relationships change for different values of the parameters λ and δ. For convenience, for the aggregate tradable sector n —denoting both the tradable manufacturing and resource sectors— the local —onshore— revenue productivity in each city is $X_{nc} \doteq \lambda_c^{\eta} \sum_{j=m,r} p_{jc} A_{jc}$.[56]

For the local good, the equilibrium price in the local non-tradable goods sector is obtained by equalizing the local demand, which is individual demand times number of workers in the city L_c, with local supply. Further, the fact that there is perfect mobility of workers between sectors within a city implies that $w_{jc} = w_c$. Hence, the relative equilibrium price for the local good is $\log \hat{p}_l = \delta \log \hat{w} + \log \hat{L} - \log \hat{X}_l$. The price in the resource sector p_{rc} is exogenously determined in international markets, while that in the tradable sector is defined as the unitary $p_{mc} = 1$. Thus, the equilibrium relative population is

$$\log \hat{L} = \rho\tau \Bigg(\log \hat{X}_n + (1+\eta) \log \hat{L}_n \Bigg) + \gamma\tau \log \hat{S} + \tau \log \hat{B} \tag{7}$$

where $\rho \equiv 1 - \gamma$ and $\tau \equiv \frac{1}{1+\varphi h+\xi}$. Eqn. 28 is known as the migration equation and is impor-

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[56] Given the assumption that $\lambda_{jc}^{MNC} > \lambda_{jc}^{DOM}$, MNCs will shift-abroad a larger proportion of their revenue productivity. This offshoring effect is intensified by the fact that MNCs rely more on intermediate inputs, implying $\eta_{MNC} > \eta_{DOM}$. This is consistent with a growing literature on the profit-shifting behaviour of MNCs (e.g., Dowd, Landefeld, and Moore, 2017 and Tørsløv, Wier, and Zucman, 2022).

tant to notice that in terms of the impact of the booming sector, migration would be higher if $\rho\tau$ is larger—if the production is more labor-intensive—or equivalently if δ is smaller. Additionally, if housing supply is more elastic—h is smaller—or the housing expenditure share φ is lower, the location preferences of the individual are weak—ξ is smaller. By substituting this population difference in the relative inverse labor demand, we get the equilibrium relative wage difference,

$$\log \hat{w} = (1 - \rho\tau)\bigg(\log \hat{X}_n + (1 + \eta) \log \hat{L}_n \bigg) - \gamma\tau \log \hat{S} - \tau \log \hat{B} \tag{8}$$

which shows that an increase in the productivity of the tradable or resource sector would induce higher nominal wages. Simultaneously, higher consumption amenities or an increase in overall productivity would imply a lower nominal wage. This is because, under the spatial equilibrium framework, workers are willing to accept lower nominal wages in exchange for a higher level of amenities. Further, for housing market equilibrium, taken Eqn. 1, the relative housing supply is a function of the relative population between the two cities given by $\log \hat{r} = h \log \hat{L}$, which implies that in equilibrium housing rents are determined by

$$\log \hat{r} = \rho\tau h\bigg(\log \hat{X}_n + (1 + \eta) \log \hat{L}_n \bigg) + \gamma\tau h \log \hat{S} + \tau h \log \hat{B}. \tag{9}$$

Eq. 27, analogous to Allcott and Keniston (2018), shows that a resource boom would increase wages and that relative equilibrium wages are defined by the relative size and total revenue productivity of the final good sector. However, relative equilibrium wages are mitigated by the revenue productivity of the non-tradable sector and relative amenities. Therefore, if the resource sector (or equivalently the tradable sector) is not inducing a crowding-out effect in the non-tradable sector or increasing the demand for intermediate goods, then it would induce a decrease in nominal wages. A major implication of this is that the productivity increments in the tradable sector can offset this negative effect of movement of labor, while productivity increments in the resource sector cannot offset this effect. Notwithstanding, both of these effects are mediated by the level of local amenities and migration.

2.3.2 Social Welfare

The cumulative indirect utility of people who live in city c across all periods is $\log U_c = \sum_t \log U_{ct} = \sum_t \zeta^t \left(\log w_{ct} - \gamma \log p_{lct} - \varphi \log r_{ct} + \log B_{ct}\right)$, where ζ is a discount factor. The underlying assumption is that the social planner only focuses on permanent residents, as in Allcott and Keniston (2018). This is because eliminates the need to keep track of migrants' idiosyncratic taste shocks ε_{ic}.[57] Additionally, producer surplus is ignored assumed that firms are owned by absentee shareholders. Therefore, the relative cumulative social welfare effect between the two cities can be rewritten as a function of the relative population

$$\log \hat{U} = \sum_t \zeta^t \xi \log \hat{L}_t. \tag{10}$$

Which establishes a direct mapping between relative population and welfare under the standard assumption that people vote with their feet. Replacing the relative population from Eqn. 28 yields the effect of the resource sector on social welfare.

2.4 Predictions

2.4.0.1 The Resource Boom and Bust Following Allcott and Keniston (2018), the predictions of a resource boom and bust are derived from a comparison of three static equilibrium points in which the resource boom is modeled as an exogenous shock to revenue productivity of the resource sector in one of the periods and cities each. The boom increases revenue productivity through an exogenous increase in prices P_{rc} (e.g., an increase in world demand) or due to an exogenous increase in physical productivity A_{rc} (e.g., a new discovery of natural resources). The two cities start at an initial symmetric equilibrium in $t = 0$ with no natural resources—$X_{ra,t=0} = X_{rb,t=0} = 0$. Further, in $t = 1$, city a experiences a resource boom as a shock that exogenously affects the revenue productivity in the resource sector—$X_{ra,t=1} > 0$. However, city b does not have natural resources, and therefore, $X_{rb,t=1} = 0$ in every period. The resource boom ends in $t = 2$, and cities go back to the initial symmetric equilibrium, $X_{ra,t=2} = X_{rb,t=2} = 0$, as displayed in the following timeline.

$$\begin{array}{ccc} t = 0 & t = 1 & t = 2 \\ X_{ra} = X_{rb} = 0 & X_{ra} > 0 \text{ and } X_{rb} = 0 & X_{ra} = X_{rb} = 0 \end{array}$$

2.4.0.2 Effects on Population/Employment, Wages, and Rents The first prediction is related to the contemporaneous relative effects on cities. In $t = 1$, assuming $X_{jat} = X_{jbt}$ for $j \in \{l, m\}$, and $B_{at} = B_{bt}$, the resource boom implies $X_{rat} - X_{rbt} > 0$. Thus, the relative effects of population and wages are partially obtained by differentiating Eqn. 28 with respect to $\hat{X}_r$,

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[57] This implies that the social welfare is computed over infra-marginal individuals, as represented in Fig. 2.3 (see Kline and Moretti, 2014b for a further discussion).

and equivalently for Eqn. 27 and 9, which yield

$$\frac{\partial \hat{L}_{t=1}}{\partial \hat{X}_{n,t=1}} = \rho\tau > 0 \qquad \frac{\partial \hat{w}_{t=1}}{\partial \hat{X}_{n,t=1}} = (1 - \rho\tau) > 0 \qquad \frac{\partial \hat{r}_{t=1}}{\partial \hat{X}_{n,t=1}} = \rho\tau h > 0,$$

where $\tau \equiv \frac{1}{1+\varphi h+\xi}$. This effect on the price of non-tradables is analogous to the spending effect given in Corden and Neary (1982), which states, as in Allcott and Keniston (2018), that the price of non-tradables rises faster than the increase in wages.

2.4.0.3 Effects on the Size and Productivity of the Manufacturing Sector The resource boom increases the demand for labor in the local goods (non-tradable) sector at the same rate as population $\rho\tau$. In the case of the tradable sector m, analogous to the resource movement effect from Corden and Neary (1982) and Allcott and Keniston (2018), a resource boom would crowd-out employment in the tradable sector. However, this crowding-out effect is mitigated by the productive linkages. More precisely, the relative effect of the resource boom on the size and productivity of the tradable —manufacturing— sector is given by

$$\frac{\partial \hat{L}_{mt}}{\partial \hat{X}_{nt}} = -\frac{1}{(1+\eta)} \qquad \frac{\partial \hat{A}_{m,t+1}}{\partial \hat{X}_{nt}} = \rho\tau\Lambda - \frac{\phi_m}{(1+\eta)}.$$

Contrary to Allcott and Keniston (2018), these derivatives show that the negative total effect of the resource sector on the local tradable sector (manufacturing employment) is mitigated by the positive indirect effect of the resource boom caused by the creation of productive linkages in upstream industries, captured in the parameter η. Therefore, the total effect, although is always negative, can be considerably small. As larger the *love-for-inputs effect*, smaller the crowding-out induced by the resource boom. This has important implications regarding the potential of the resource sector to induce local economic development via linkage creation, as increased offshoring directly decreases this potential to mitigate the crowding-out of other industries. This provides a reasonable argument against one of the key mechanisms of the *Dutch disease* and provides a plausible explanation to explain the lack of a crowding-out effect of the resource boom in the manufacturing sector, as in Allcott and Keniston (2018) for the US oil and gas sector and Aragon and Rud (2013) for the Peruvian gold mining industry, among others.

The resource boom increases the productivity of the local good sector in $t + 1$ due to the accumulation of sectoral and aggregate labor in the previous period t—*learning-by-doing* and agglomeration effects. The effect of the resource boom in the productivity of the non-tradable sector is always positive and more than proportional to the effect experienced by this sector in the previous period, which has been reinforced through agglomeration and *learning-by-doing*. This effect can be magnified if the resource boom also increases the demand for intermediate goods. δ plays a key role in magnifying the *learning-by-doing* effect. Thus, considering the assumption that domestic firms rely more on labor than MNCs—$\delta_{DOM} > \delta_{MNC}$, this implies that this magnification effect would be higher for domestic firms than for MNCs. Taking these results together we can establish the following proposition,

Proposition 1. *Consider a resource boom and bust as an exogenous increase and subsequent decrease in the revenue productivity of the resource sector in a given location X_{ra}, due to a price shock P_{ra} or/and a resource discovery A_{ra}. When the productivity gains from local input variety are sufficiently large, i.e. $\eta \rightarrow \infty$. Then, demand linkages from the resource sector to upstream suppliers:*

1.1 *Offset the crowding-out effects induced by the resource boom on local —manufacturing— tradable employment during the booming period $\frac{\partial \hat{L}_{m,t}}{\partial \hat{X}_{r,t}} \rightarrow 0$, and*

1.2 *Mitigate subsequent productivity losses due to foregone learning-by-doing during the bust period. In which case the productivity gains from spillovers from the resource boom to manufacturing firms approximate to a weighted agglomeration elasticity $\frac{\partial \hat{A}_{m,t+1}}{\partial \hat{X}_{r,t}} \rightarrow \rho\tau\Lambda$.*

This proposition establishes the condition for local *Dutch disease*. To the extent that sectoral externalities of the manufacturing firms in the form of localization economies are too large in relation to overall agglomeration effects $\frac{\phi_m}{\Lambda}$, then the condition is more likely to be violated. I.e., this term will be higher than the local multiplier and location preferences. Then is key to know the size of these externalities.

Proposition 2. *As long as MNCs are more intensive than domestic firms in the use of intermediate inputs, i.e. $\eta_{MNC} > \eta_{DOM}$. MNCs induce larger productivity spillover than domestic firms per unit of labor hired. However, to the extent that MNCs offshore a larger amount of intermediate inputs than domestic firms, i.e. $\lambda_{MNC} < \lambda_{DOM}$, backward productive linkages from the resource sector are less likely to offset productivity losses from crowding-out effects.*

2.4.0.4 Effects on Social Welfare Note that relative welfare will increase as a direct consequence of the resource boom. Therefore, aggregating over all periods and focusing on the impact of a resource boom in $t = 1$, keeping everything else constant, yield the following expression

$$\frac{\partial \hat{U}}{\partial \hat{X}_{nt}} = \frac{\xi(1-\gamma\delta)}{1+\tau\delta} > 0.$$

Assuming that the resource boom only happens in $t = 1$ (i.e., $L_{ra} = 0$ in $t = 0$ and $t = 2$), then social welfare in city a increases as a direct consequence of the resource boom *ceteris paribus*. Notwithstanding, this would vary across MNCs and domestic firms, given that $\delta_{MNC} < \delta_{DOM}$.

2.4.0.5 Equilibrium with Endogenous Amenities As is largely documented in the literature on resource economics, the booming sector generates negative consumption externalities in the form of dis-amenities, such as environmental hazards. To understand the implications for the previous equilibrium in such situations, I derive the effects assuming that the booming sector generates a dis-amenity effect in proximity to a resource extraction site. Specifically, suppose that the resource sector operates s extraction sites located at a distance τ from the booming city. Then the total amenity effect will now be an endogenous measure that follows $B^k_{ct} = b_{ct}\left(L^k_{rct}/L^k_{ct}\right)^{-\omega_k}$. Which states that local amenities increase with local population L_{ct} like in consumer cities, but these amenity effects are limited by the size of the resource sector L_{rct}, capturing the negative externalities from the resource sector. Moreover, the final amenity effect hinges on the magnitude of these components and is captured by ω. This implies that the effect of the resource boom in relative population, wages, and housing rents is

$$\frac{\partial \hat{L}_{t=1}}{\partial \hat{X}_{n,t=1}} = \rho\tau\mu > 0 \qquad \frac{\partial \hat{w}_{t=1}}{\partial \hat{X}_{n,t=1}} = (1-\rho\tau)\mu > 0 \qquad \frac{\partial \hat{r}_{t=1}}{\partial \hat{X}_{n,t=1}} = \rho\tau h\mu > 0,$$

where $\mu \equiv \frac{1}{1-\omega\tau}$. Compared to the case without the dis-amenity effect generated by the resource sector, the effect on wages is always positive by the magnitude $(\tau+\gamma)/(1+\tau\delta)$. Here, the positive effect on wages is heavily discounted by the factor $\omega(2+\delta\iota-2\gamma\delta)$. Despite the effect being positive, this dis-amenity effect is the result of the resource sector having important implications for the relative welfare effects of the resource sector. These effects also differ between the MNCs and domestic firms case in δ. Finally, the effect of housing rents is obtained by substituting the equilibrium relative population and partially differentiating with respect to $\hat{X}_{n,t=1}$. This yields the same effect as in the previous case.

$$\frac{\partial \hat{L}_{mt}}{\partial \hat{X}_{nt}} = -\frac{1}{(1+\eta)} \qquad \frac{\partial \hat{A}_{m,t+1}}{\partial \hat{X}_{nt}} = \rho\tau\Lambda\mu - \frac{\phi_m}{(1+\eta)}.$$

All these effects, considering the dis-amenity effect, yield the following theorem.

Proposition 3. *When amenities are negatively correlated with the resource boom these externalities limit the productivity and social welfare gains from the resource boom.*

2.4.0.6 Summary and Implications for the Empirics One important feature of this model is that allows us to formalize the conditions by which a resource boom might favor an *enclave* or an industrial agglomeration, which is consistent with the literature in economic geography. A taxonomy that define these two opposite extremes scenarios. In summary, we can characterize a modern *enclave* equilibrium considering the following conditions.

Definition. *A modern enclave equilibrium induced by the booming sector is characterized by:*

1.1 *Large productivity losses due to foregone scale economies: the crowding-out of the tradable sector induced by a local resource movement and spending effect that implies productivity losses in the long term (local Dutch disease). This is reinforced by limited linkage creation that does not offset the crowding-out of tradable —manufacturing— industries.*

1.2 *Social welfare losses due to local spending effect: the higher wages paid by the resource sector that induces higher local rents that induces a decrease in real wages. This is reinforced by the negative externalities of production in the form of dis-amenities.*

The existence of linkage creation by resource sectors rules out the possibility of local *Dutch disease* due to the absence of a crowding-out effect of the resource sector. Given that these effects nullify each other, limited linkage creation by MNCs can empirically imply that these linkages cannot offset the crowding-out of firms in the tradable sector. This situation will be consistent with the previous literature based on case studies but not with more quantitative large-scale evidence. If the existence of spillover effects is related to that of crowding-out effects, it is difficult to expect negative spillovers. Further, the final effect on wages and rents is more likely to determine the long-term equilibrium of the booming city. The dis-amenity effect induced by the resource sector might lead to limited real wage gains and, consequently, limited population gains in the long-term. These effects are more sensitive to the assumptions characterizing the behavior of MNCs and domestic firms in the resource sector. These effects are illustrated in Figure 2.3.

In Figure 2.3, the blue-shaded area under the yellow curve and above the red curve represents the social welfare gains from the booming period. From the symmetric equilibrium of the pre-booming economy, the fraction of workers is equal to 0.5 in both cities. However, the resource boom city A increases its population to 0.6 relative to total population in both cities. This change in the population of city A between $t = 0$ and $t = 1$, is denoted in the figure by $\Delta\hat{L}_1$. However, the dis-amenity effects of the resource sector are persistent and will affect the relative welfare in the bust period $t = 2$. In particular, two scenarios are described in the figure. Under the first scenario, for which the marginal relative utility is represented by the

Table 2.1: Qualitative Relative Predictions of a Resource Boom and Bust

	Overall Effects	Comparison MNCs/Domestic
Booming Period (short-term)		
Population/Employment	↑	↓
Wages/Prices (non-tradables)	↑	↑
Manufacturing Employment (tradable)	↓	↓
Bust Period (long-term)		
Manufacturing Productivity (tradable)	↓	↑
Social Welfare	↓	↑

Notes: Social welfare effects assumes amenities negatively correlated with the boom.

orange curve, the welfare losses induced by the dis-amenity effect are lower than the welfare gains during the booming period. Therefore, the total welfare gains from the booming and bust periods are positive, and the population change in relation to the pre-booming period is 0.05. Under the second scenario, the welfare losses induced by the dis-amenity effect are larger than the welfare gains from the booming period.[58] Consequently, the overall welfare effect from the booming and bust period is negative, and the booming city loses population in the long-term.

2.4.0.7 Theorem. *Consider that the resource sector is dominated by MNCs such that* $\lambda_{ra} \rightarrow 0$ *and* $\delta \rightarrow 0$*. Then a resource boom* $X_{ra,t} \equiv P_{ra,t}A_{ra,t} > 0$ *is more likely to induce an equilibrium with enclave features.*

2.5 Data

To provide empirical evidence on the mechanisms described previously, this study builds a dataset for Chile by combining information on mining activity and performance of local firms and workers' conditions in local labor markets.

2.5.1 Mining

To capture yearly and spatial variation in mining activity, I construct a measure of the intensity of mining operation at the plant-level for more than two decades by combining daytime and night-time satellite images based on recent advances in the field of remote sensing (Connette et al., 2016; Werner et al., 2020). Intuitively, imitating the restoration of an old picture, I use

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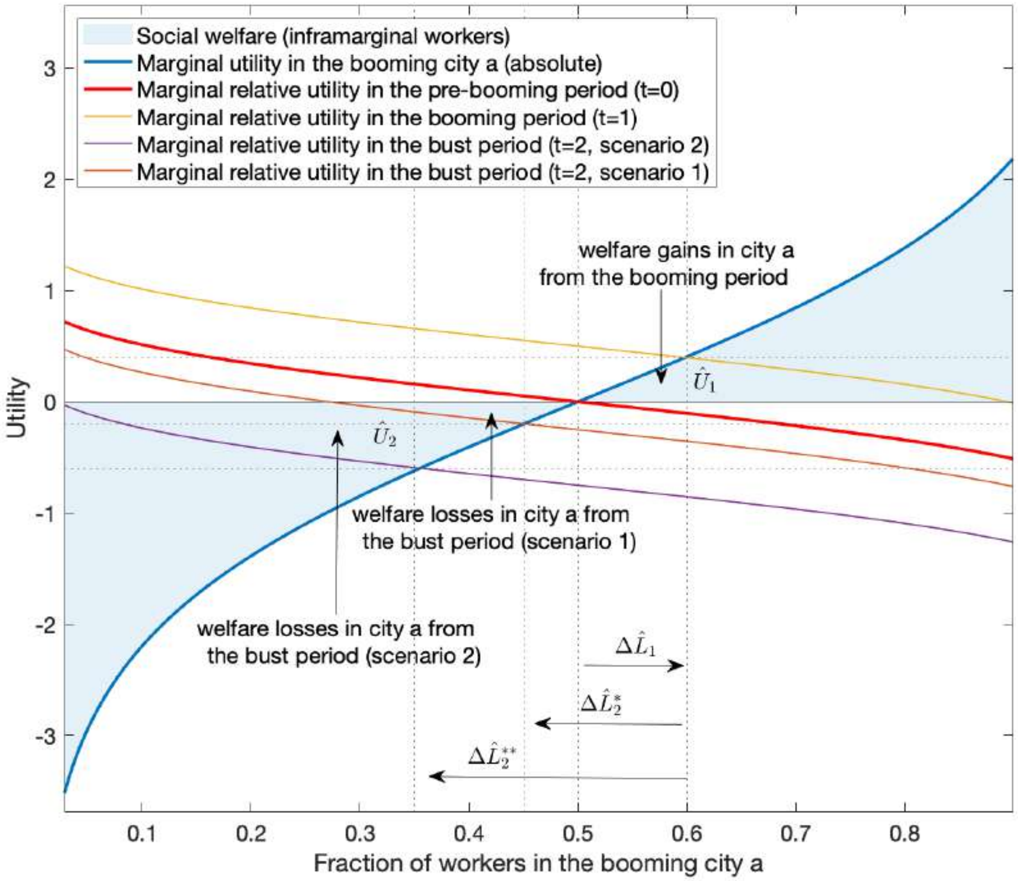
[58] Note that this is possible because the amenity measure accumulates over time.



Notes: The figure illustrates a numerical example over the model to compare the relative welfare gains and losses from a resource boom and bust in city a (booming city). The figure depicts two post-booming scenarios. One with low disamenity effects caused by the resource sector, and another with large disamenity effects. The last one can lead to population losses in the booming city in the long-term. *Source:* Own elaboration based on Kline and Moretti (2014b).

Figure 2.3: Relative Welfare Effects from the Resource Sector

the latest available LandSat high-resolution satellite images along with official geo-referenced data from the USGS and Chilean Ministry of Mines to identify the location and actual area of operation of the mining active and inactive sites. Further, for these areas, I compute statistics of night-time lights for each year between 1992 and 2017 as a proxy of the intensity of activity, as in Hodler and Raschky (2014). This idea relies on the documented fact that large mining sites operate on a 24-7 basis, which implies that night-time lights data are arguably a potential good source of information to proxy the intensity of activity of each plant.

To complement and validate the satellite information, for each mine identified and available, I compile administrative records about the following criteria: the type of extracted mineral, years of operation, owners of the plant, and production level. Regrettably, yearly production reported for each plant is only available for a sample of the largest mines and certain years. Moreover, this information is used to complement and validate the indicator of the intensity of activity of each plant, constructed using satellite images. A detailed description of the remote-sensing methodology used and results of the validation exercise are provided in the Online Appendix. Additionally, as described in Section 2.6.2.1, novel insights are based on Faber and Gaubert (2019) and by relying on a large amount literature on mineral geology (see e.g., Segal, 1982; Drury, 1987; Wolf, 2012). I use spectral bands—non-visible range—of the satellite images to construct an instrumental variable that captures the spatio-temporal variation in the concentration of heavy minerals in the soil of mining sites as a predictor of the yearly profitability of each mine.

2.5.2 Firms

To study the cross-sectoral and firm-specific spillover effects from the resource boom, I use manufacturing surveys and aggregated sector-municipality level tax records. Longitudinal data from manufacturing surveys are available from 1995 to 2014, provided by the Chilean National Institute of Statistics (INE). The Chilean manufacturing survey (ENIA) collects information about all Chilean manufacturing firms with more than ten employees. It has information on the location of production, number of employees, wages, workers' skill level, capital, and inputs used for production. This information is internally contrasted by the Chilean statistical office with the financial balance of each firm reported in their annual tax records (INE, 2006). Given that economic censuses that compile information about all the economic sectors are considerably recent in Chile, and the manufacturing surveys only report localization at the regional level, I complement this information with publicly available aggregate data for all economic sectors at the municipality level based on the tax records from 2005 to 2015.

2.5.3 Workers

The previous information is complemented with more detailed data from the supply-side of the labor market. A pool of household surveys from 2000 onward is used. The analysis is based on Chilean socioeconomic household Survey (CASEN). CASEN is constructed by the Office of National Statistics. This includes information on wages and workers' characteristics, such as age, gender, education, occupation, and sector. A repeated cross-section of six waves of the CASEN is used—the 2000, 2003, 2006, 2009, 2011, and 2013 waves. The pool contains a total of 1,927,822 observations, from which 703,512 report wages. Wages have been deflated using the Chilean Consumer Price Index (100=2008). Additionally, the sample is restricted to cities with a population of more than 25,000 inhabitants.

2.6 Empirics

The empirical evidence is divided in three parts. First, I test the predictions of the within-country version of the *Dutch disease* considering the heterogeneous effects between MNCs and domestic firms in the resource sector. This is done to understand if there is evidence to support the hypothesis that the mining sector is inducing unsustainable long-term local economic development by reducing workers' welfare and decreasing the gains from industrial agglomeration caused by crowding-out effects. Second, I document the existence of spillovers from local productive linkages of the mining sector to quantify its potential as a source to offset the negative effects of the *Dutch disease*. Finally, I present evidence on the role played by MNCs in the mining sector for forming these local productive linkages to better understand how the organization and production of the resource sector interact with the local agglomeration to induce an *enclave* equilibrium.

2.6.1 Relative Effects in Local Labor Markets

Previous empirical literature identifying the local economic impacts of resource-based activities has usually based its research strategy on an indicator of natural resource endowments in a given area that determine the exposure of local workers and firms to shocks in the resource sector, using a quasi-experimental shift-share design. It uses the arguably exogenous spatial variation induced by geological factors and/or the temporal variation in global commodity prices (e.g., Aragon and Rud, 2013; Caselli and Michaels, 2015; Allcott and Keniston, 2018). In this study, the impacts of mining on local economic outputs are mainly observed using an exposure variable that follows a similar strategy but varies between the exposures of MNCs and domestic firms in the mining sector. Specifically, the empirical strategy compares the cities more exposed to mining activity against cities less exposed, in which the general equation to be estimated, as a first-order approximation of Eqns. 28, 27 and 9, takes the following form:

$$\Delta \log Y_{ct} = \beta^k \log \left(Exposure^k_{ct-1} \right) + \mathbf{X'}_{ct_0}\gamma + \delta_t + \epsilon_{ct}, \tag{11}$$

where Y_{ct} = are the different economic outcomes in city c, year t: (1) population and employment, (2) wages and rents, (3) number and aggregate sales and revenue of firms, and (4) total factor productivity. $k = \{domestic, multinational\}$, $\mathbf{X'}_{ct_0}$ = control variables at the initial year, δ_t = year fixed effect.

2.6.1.1 Local Exposure to Mining Shocks The exposure to a mining shock for city c, located at a distance $d_{c,s}$ from a mining plant s of property $k = \{domestic, multinational\}$, with Q^k_{st} level of production, is defined by the following:

$$Exposure^k_{ct} = \sum_s Q^k_{st} \left(d^k_{c,s} \right)^{-1} \tag{12}$$

where Q^k_{st} is proxied by the sum of night-time lights within the area of a given mining plant. Here, the exposure is defined over a continuous space, which is more realistic than standard approaches where the exposure variable varies across a discrete space of regions, natural resource endowments, or the production of commodities. All these criteria equally affect the agents within the region and have a discontinuity given by the administrative borders. Instead, the exposure variable in Eqn. 12 captures geographical spillovers to more distant locations that are also being affected by mining activity due to long-distance commuters or increases in local investments due to national fiscal windfalls.[59] Under the plausible assumption that these effects falls with the distance to mining plants.

The endogeneity of this variable is determined by the extent to which local conditions affect the activity of mining companies, for example, local workers' strikes common in the sector for both domestic firms and MNCs (see e.g., The Economist, 2006; Financial Times, 2010; BBC, 2011; Durán-Palma, 2011). Their production levels are not mainly driven by geological conditions for mining exploitation. Identification is based on the following factors: exogenous geological factors influencing mining production and exogenous variations in mineral prices. As explained later, this is arguably the case, as is revealed in the small correction of the IV strategy in most estimates.[60]

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[59] Long-distance commuting or fly-in/fly-out commuting is a common phenomenon in mineral economies (Aroca, 2001; Aroca and Atienza, 2011; Paredes, Soto, and Fleming, 2018).

[60] Owing to the time span of the data and nature of hard minerals production described previously in the life cycle of large-scale mines, I do not study the cyclicality of the phenomenon, as in Allcott and Keniston (2018).The cyclicality of the booms and busts of the mineral sector is likely to be different than it is evidenced in the oil and

2.6.1.2 Population and Employment The first set of hypotheses is contradictory to the fact that the resource sector causes short-term positive impacts on population and employment. These effects are estimated in Eqn. 35, where the outcomes $Y_{ct} =$ are population and employment (dis-aggregated by sector). These effects are informative of the different mechanisms that affect location patterns of workers and firms. Although these effects are expected to be positive, the final result depends on the magnitude of the different mechanisms at play. For example, the effects on population would be positive if the increase in local wages is more than proportional to the increase in local rents and if the dis-amenity effect caused by proximity to mines is negligible. However, the total effects on employment would be positive if the mining sector is important in relation to other sectors, and the labor directly and indirectly created by the resource boom is significantly higher than potential crowding-out effects.

2.6.1.3 Wages and Rents The key mechanisms underlying the average relative impacts of mining on local population and employment are the effects in local wages and rents. Eqn. 35 is estimated with $Y_{ct} =$ log of residualized wages and rents in city c. These residuals are obtained from a standard wage and rent equation. These effects are expected to be positive according to the chain of events of the local *Dutch disease*. Specifically, a positive shock in the mining sector generates more demand for labor, which raises wages in the resource sector. If the mining sector is locally important, the excess of demand for labor would induce higher local wages in other sectors as well, as these sectors will compete for the same pool of labor. The increase in local wages raises the prices of non-tradables, which results in higher living costs. These costs would be captured by higher rents. These productivity effects can be masked by amenity effects on wages and rents, which might differ in their direction, depending on how workers and firms perceive mining activity.

The positive effects on wages and rents are predicted under the assumption that the resource boom is treated as a productive local amenity in the spatial equilibrium setting. However, this might not be the case if mining activity generates negative externalities, such as environmental impacts that affect workers' and firms' decisions. In that case, these effects are captured by wages and rents and move in opposite directions (negative). Nevertheless, if the environmental effects of mining on cities are negligible, and mining activity induces higher wages and rents, the extent to which the magnitude of the rise in rents might offset the wage increase would depend on a different set of factors. If the demand of labor increases signif-

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gas sector of the US. This is because the exploration and developing phases take more time, and when the mine is in the extraction phase, it incurs large exit costs. Additionally, they tend to negotiate future contracts of production at fixed prices. However, I provide robust evidence on the contemporaneous and long-run local economic impacts of mining to argue that the estimates are robust to time-trends and confounders that might occur during the boom.

icantly, and local areas cannot meet the supply of labor required for the new equilibrium, a high proportion of workers might end up living far away from mining cities. This might be reinforced by two main elements—the lack of local amenities affecting location incentives of workers and convenient working shifts offered by mining companies to its workers.[61]

2.6.1.4 Industrial Agglomeration As previously described, an important set of evidence to understand the long-term impacts of mining activity are the effects that this sector induces in other sectors. A specific case is if mining decreases the size and profitability of more tradable non-linked sectors. Eqn. 35, to be estimated for evidence on these mechanisms, considers $Y_{ct} =$ log of number of firms and aggregate sales and revenue in city c and year t, distinguishing between manufacturing and services sectors. According to the Dutch-Disease channel, the resource boom should induce a crowding-out effect in the manufacturing (or more tradable) sector. The crowding-out effect does not necessarily induce a long-term decline in overall growth, unless it is accompanied by a productivity loss in these non-linked tradable sectors. However, the higher local demand for non-tradables may be caused by an increase in wages and might provoke an increase in the size and profitability of these sectors. The demand for intermediate goods and services directly or indirectly required by the mining sector may generate an increase in the number of firms in linked tradable sectors as well. In this case, the net result would depend on the relative size of those effects and size of the shock in the resource sector (Lufin and Soto-Díaz, 2022). Empirically, it is not clear which of these effects would dominate, but a high degree of sectoral heterogeneity is expected in these impacts.

2.6.1.5 Productivity Spillovers The last mechanisms of the local Dutch Disease and key for the identification if the resource sector is inducing a decrease in long-term growth are productivity spillovers. The crowding-out effect of the resource sector in the manufacturing (tradable) sector should lead to a loss of positive externalities such as localization economies and/or *learning-by-doing*, which could induce a decrease in manufacturing productivity. This last negative effect is the key mechanism in the *Dutch disease* story and is the factor that induces a decline in economic growth in the long term. Therefore, it causes unsustainable economic development in the mining sector. In this case, the identification is done at the firm level. Specifically, Eqn. 35 takes the following form

$$\Delta \log Y_{jrt} = \alpha + \beta^k \log\left(Exposure^k_{rt-1}\right) + \mathbf{X'}_{jrt_0}\gamma + \delta_j + \delta_r + \epsilon_{jrt}, \tag{13}$$

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[61] For example, seven days working in the mine and seven days off, 15x10, etc.

where the long-run difference over Y_{jrt} = the total factor productivity of the firm j in region r and year t (distinguishing between linked and non-linked activities) is regressed against the exposure variable aggregated at the regional level, $\mathbf{X'}_{jrt_0}$ = is a vector of firm-level control variables at the initial year, δ_j = is a plant fixed effect, and δ_r = is a region fixed effect.

Note that the increase in the demand for intermediate goods and services offered by local suppliers to mining companies may induce a reduction in the average cost. Subsequently, this improvement in efficiency would imply a higher productivity. This may be generated by direct knowledge transfer, higher requirements for product quality and on-time supply, or economies of scale (Javorcik, 2004). If mining companies do not internalize this average cost reduction by bargaining for a lower price on their intermediate inputs, these spillover effects of mining companies would arise for the supplier. However, mining companies are likely to have high bargaining power and good information on these externalities induced on suppliers (because they are inducing some of them and are significantly large in terms of size and importance to the local economy). Hence, it is expected that these spillovers would be small. Additionally, some of these spillovers might be offset by the competition effects (Aitken and Harrison, 1999). This is because the reduction in the average costs induced by the spillover effects can also be captured by new entrants and, consequently, the number of competitors in the market, which would spread the reduction in the average costs over a larger number of competitors.

Although it is expected that technological improvements in the mining sector spill over in the domestic firms belonging to other sectors and increase their productivity, these productivity effects offset the potential loss of productivity induced by the crowding-out effects in non-linked sectors. It is also expected that spillovers within the mining sector are limited to activities that are not necessarily knowledge-intensive or profitable in the long-term. Moreover, MNCs offer incentives in the resource sector to delocalize these types of activities to more competitive locations. Furthermore, the lack of urbanization and localization in economies characterize the cities that are more specialized in resource-based activities.

MNCs might be highly reliable on imported intermediates and source parts of their activities to foreign suppliers, weakening the capacity of the resource sector to generate productivity spillover effects. However, domestic firms are more likely to develop linkages with domestic suppliers. For example, public-private partnership for mining projects have been developed to mitigate these effects. Further, a priory, the effects are uncertain and are likely to be dependent on the degree of foreign ownership for each project.[62] Spillovers are weakened by *enclave*

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[62] One example of this is the Gabi mining project, in which the state-owned company CODELCO own 51% of the shares.

features of the resource sector in resource-oriented cities, but MNCs might overcome these limitations that generate spillovers due to the following factors: (1) direct knowledge transfer to local suppliers, (2) higher requirements for product quality and on-time delivery, and (3) increasing demand for intermediate products inducing the formation of scale economies (Javorcik, 2004).[63] MNCs can introduce new to better technologically advanced inputs from foreign markets in the domestic industry, which also might offset the losses caused by the delocalization of knowledge-intensive activities.

2.6.2 Identification Strategy

The main empirical challenge is to disentangle the within and cross-sector spillovers generated by the mining activity from natural location advantages or location fundamentals. Authors usually rely on exogenous natural events or law enforcement. In this study, to identify the plausible causal effects of mining on local economic development, I use two sources of exogenous variation. The instruments that I present try to capture both of these factors. First, exploiting the exogenous geological conditions that explain the location decision of mining plants would help identify the spatial variation in the distance variable. Second, exogenous time-variant component is given by the following two considerations: (1) the demand-driven shock of mineral prices induced by the super-cycle of mineral prices and (2) exogenous variations in plants that might predict variation in supply requirements.

2.6.2.1 Mining Planning, Mineral Production, and Heavy Metal Indices Open-pit mines are characterized by spatial variation or greater concentrations of heavy metals and temporal variation or changes in heavy metal indices on the time and changes in elevation. These changes in heavy metal indices might explain the profit ratio of each open-pit mine and explain future patterns of production. This is stated more precisely in the following quote that describes the uncertainty in open-pit mining and planning: *"the mine plan has to be developed with uncertain information such as the characteristics of the ore body and the economic drivers (prices and costs) of the mining project..."* (Arteaga et al., 2014). Therefore, the identification strategy follows three routes, depending on the parameters to be identified within the theoretical framework. First, I use exogenous geological variables to determine the location and intensity of production of mining plants, in addition to exogenous variation in mineral prices. The key identifying assumption is that residuals are uncorrelated with exogenous changes in mineral

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[63] Numerous case studies document these effects in mineral economies: (Auty, 2001a,b; Atienza, Lufin, and Soto, 2019; Arias, Atienza, and Cademartori, 2014), inter alia. These factors demonstrate the capacity of MNCs to generate productive linkages that induce productivity spillovers. One concrete example of this is the requirement of mining companies for suppliers to obtain the International Standard Organization (ISO) quality certification on products and behaviors.

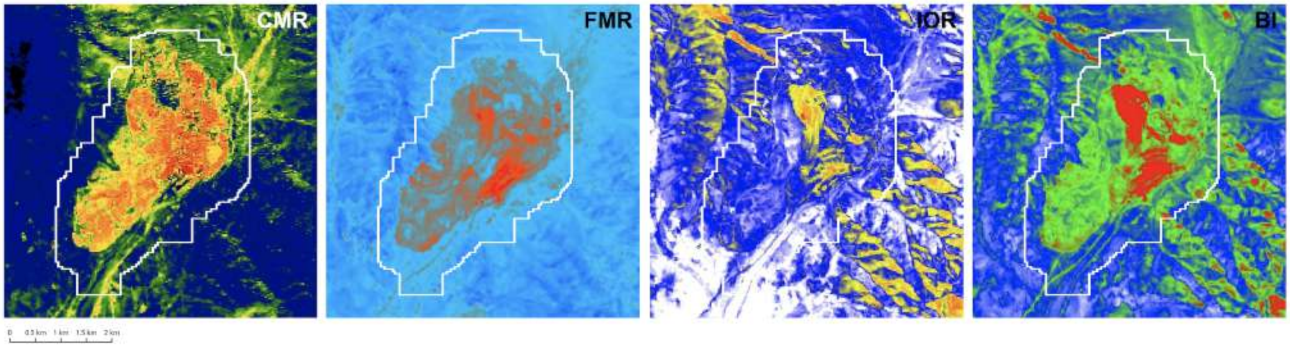
prices and geological factors underlying mining production in plants. For price variation, mining companies should not have sufficient market power to move global mineral prices.

2.6.2.1.1 Variation in Heavy Metals in Soil within Mines After the exploration phase, the development and extraction phases of a mining site are the longest phases. The extraction phase of a mining plant can range from 5 to 50 or more years, depending on the estimated amount of minerals underground. Every phase of the process is uncertain, based on the exogenous factors. The extraction is particularly characterized by exogenous elements that can be tracked using satellite data. Specifically, using the infrared sensors of satellite, one can track temporal variations in concentration of minerals in soil, during the extraction.

This variation in soil minerals determines the profit ratio of each mine, which is the main variable behind the organization and production of each mine. Specifically, this measure is affected by the ratio between the mineral extracted and waste material. In the mining and planning process, engineers are oriented to maximize this profit ratio. A priori, they only rely on initial estimates based on soil samples to compute the expected profits of a mine, until they start operations in the developing phase. During the firsts years of this phase, most of the material removed is waste rock. However, as soon as they start to observe an increase in the profit ratio, they change the method of extraction, specifically, the altitude and slope of each bench. All these variations in the soil mineral concentration can be proxied using the invisible spectral bands of satellite data, as shown in Figure 2.4.

This contributes an important source of exogenous spatial and temporal variation, which are likely to meet the exclusion restriction in the IV design. This is because it is correlated with local economic outcomes only through its effects on the profit and production of each mining plant. Therefore, for each mine and year, I compute a series of indices that capture mineral characteristics of the soil. However, they have low variation without human intervention, especially when a mine is open due to the removal of soil and mineral deposits that present important variation. These indices are computed using non-visible spectral bands of satellites. This predicts the effect of the intensity of the mining activity for each plant and is likely to fit the exclusion restriction for each mine, given the different city-level economic outcomes.

These indices also have temporal variation, together with the elevation of the terrain. The temporal variation of these indices explain the profit ratio of the exploitation or, in other terms, the amount of minerals being extracted in comparison to waste material. They also help predict future production. This is a proxy because the information used for mining and planning also relies on geological studies, which are unavailable. To show that remote sensing indices of heavy metals on soil are a good predictor of mineral production, I describe



Notes: The figure describes concentration of heavy metals within the boundaries of the Chuquicamata copper mine. These indexes were computed using the non-visible spectral bands of the LandSat images. *Source:* Own elaboration.

Figure 2.4: Concentration of Heavy Metals in Mining Sites

the correlation between these indices and actual production of minerals for a sample of mines.

2.6.2.1.2 Mineral Concentration

One of the main problems of identification, as the case of identifying infrastructure impacts the local economy, is to show that these estimates are independent of local economic conditions. For this purpose, I introduce a measure of mining potential that predicts the potential of a mine based on observed geological factors, given the concentration of heavy metals in the soil. This exogenous measure can help identify the effects different from local conditions. Specifically, this measure is as follows:

$$MineralConcentration^{k}_{ct} = \sum_{s} M^{k}_{cst} \tag{14}$$

with M_{cst} = the intensity of mineral indices on plant s in year t (within 500km from a city c), and $k = \{MNC, DOM\}$. Intensity of minerals in soil is measured as the median of the product of Clay Minerals Ratio (CMR), Ferrous Minerals Ratio (FMR), Iron Oxide Ratio (IOR), and Bare Soil Index (BI). The shock of prices on mining production is plant-specific. For each plant, the main mineral produced is identified, and then the production in this plant is multiplied by the price of that specific mineral.[64] Figure A2.5 describes the evolution of the aggregate index in minerals during the sample years. [65]

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[64] One of the limitations is that the instrument is not specific to local firms in the manufacturing sector.

[65] Most mining plants are specialized in the production of a specific mineral, and usually, other minerals are classified as subproducts. Despite the importance of their absolute value, they tend to represent a small share of annual production. For example, the annual production of subproducts of Escondida, one of the largest copper producers in Chile and the world, was sufficient to cover all the initial investments of the developing phase.

2.6.2.1.3 Identification of Productivity Spillovers Additional concerns are raised in the identification of causal effects of the boom in the mining sector on the productivity of manufacturing firms. These considerations derive from the following three main stylized facts explaining firms' behavior: (1) firms tend to be highly heterogeneous in productivity, within and between sectors; (2) this productivity tends to be highly persistent; (3) there is an important turnover of firms exiting and entering the market (Bartelsman and Doms, 2000). All these facts might induce the following three main sources of endogeneity: (1) there is a simultaneity bias in the selection of inputs and productivity; (2) there is a selection bias toward high productive firms in the sample; (3) there is a measurement error bias on inputs and output prices. To deal with the problem of endogenous inputs and selection bias of firms entering and exiting the market, a semi-parametric estimation strategy based on Olley and Pakes (1996) is implemented. Additionally, firms' productivity estimates are corrected following Levinsohn and Petrin (2013) to account for the simultaneity of inputs and productivity. Total factor productivity is computed by following these approaches. Moreover, the variable measuring local exposure to mining shocks is separately regressed on these corrected measures of productivity of each plant.

2.6.3 Estimates

2.6.3.1 Relative Effects in the Labor Market According to theory, it is expected that an increase in mining activity would lead to contemporaneous positive effects on the local population and employment in the non-tradable sector. Notwithstanding, the total effect of increased mining activity on employment and, consequently, population depends on the relative importance of the non-tradable sector in relation to more tradable sectors and to what extent the mining sector induces a crowding-out effect on the tradable sector, suggested by the mechanisms of the *Dutch disease*. Given that non-tradables account for a large proportion of the workforce and usually comprise high employment multipliers of the mining sector (Fleming and Measham, 2014), the effect on total employment would likely be positive, as suggested by the empirical evidence in other contexts (Aragon and Rud, 2013). Even if there is a decline in employment in the manufacturing sector, this would be probably offset by the positive effects in the local non-tradable sector. The top panel in Table 2.2 shows the estimations of the exposure to mining shocks on population and employment in local labor markets. Results seems to be consistent with this argument when exploring the heterogeneous effects. They show a weaker effect for MNCs in comparison to domestic firms in local population, but no differences for overall employment.

Theory also predicts that the resource boom would induce higher local wages, which, to some extent, would be offset by higher local rents. This is because under a spatial equilibrium framework *à la Roback*, it is expected that differences in wages and rents capitalize the differences in workers' utility and firms' costs generated by spatial variations in local amenities. Specifically, within the Allcott and Keniston (2018) model, the resource boom is formalized as an exogenous shock that increase the revenue productivity in the resource sector. However, even if the resource boom increases the level of local wages due to this productivity shock, it implies a growth in the size of the sector. This should be accompanied, in some moment, by higher local prices induced by the spending effect in the local *Dutch disease* framework.

Table 2.2: Relative Effects in the Labor Market

	Change in Log Population						Change in Log Employment					
	Overall		Domestic		Multinationals		Overall		Domestic		Multinationals	
	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS	(9) OLS	(10) 2SLS	(11) OLS	(12) 2SLS
Log Exposure	0.007	0.011	0.015	0.016	0.013	0.003	0.006	0.008	0.006	0.009	0.008	0.009
	(0.004)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.006)
Year FE + Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjusted R^2	0.093		0.140		0.102		0.145		0.144		0.144	
Observations	365	365	365	365	365	365	365	365	365	365	365	365
First-Stage:												
K-P F-stat		39.427		77.681		218.893		39.427		77.681		218.893
Mineral Intensity		0.792		0.628		0.514		0.792		0.628		0.514
		(0.126)		(0.071)		(0.035)		(0.126)		(0.071)		(0.035)

	Change in Log Wages						Change in Log Rents					
	Overall		Domestic		Multinationals		Overall		Domestic		Multinationals	
	(13) OLS	(14) 2SLS	(15) OLS	(16) 2SLS	(17) OLS	(18) 2SLS	(19) OLS	(20) 2SLS	(21) OLS	(22) 2SLS	(23) OLS	(24) 2SLS
Log Exposure	0.004	0.008	0.004	0.010	0.005	0.014	0.021	0.022	0.010	0.022	0.031	0.067
	(0.003)	(0.004)	(0.003)	(0.007)	(0.004)	(0.005)	(0.007)	(0.009)	(0.009)	(0.016)	(0.014)	(0.012)
Year FE + Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjusted R^2	0.785		0.785		0.785		0.757		0.900		0.901	
Observations	365	365	365	365	365	365	365	365	365	365	365	365
First-Stage:												
K-P F-stat		44.995		80.227		328.827		44.995		80.227		328.827
Mineral Intensity		0.791		0.627		0.510		0.791		0.627		0.510
		(0.118)		(0.070)		(0.028)		(0.118)		(0.070)		(0.028)

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95% confidence intervals in square brackets. Standard errors are clustered at the regional level. First-stage results are reported in the Appendix. Control variables, which varies with time and location, include: wages, population, quality of education, fiscal dependency on national government, per capita fiscal income.

The bottom panel of Table 2.2 shows the average and heterogeneous effects of the exposure to mining shocks on local wages and rents. Both elasticities, on wages and rents, are positively significant. The magnitude of the elasticities of rents tends to be much higher than that of wages. This is expected under a spatial equilibrium scenario, given that households tend to spend a high proportion of their income in rents. Therefore, rents offset higher wages, and if this difference is sufficiently large, it can explain the observed pattern of long-distance commuters that characterizes mining regions (Paredes, Soto, and Fleming, 2018). The effects on wages consider all sectors. It is predicted as an increase in the average wage across all sectors, which is explained by the fact that despite the lack of an increment in the productivity of workers' or improvements in firms' efficiency in other sectors, local firms not linked to the resource sector have to compete for the local labor with mining companies that offer higher wages. This increases the average local wage for non-linked tradable and non-tradable sectors.

Note that the amenity effect associated with proximity to mining activity might confound the spending and/or resource movement effect of the *Dutch disease*. For instance, negative environmental externalities of mines can induce a decrease in the productivity of firms located near extraction sites. These effects might nullify possible positive spillovers due to productive linkages, *learning-by-doing* or localization economies. However, if workers are also affected by these environmental externalities, they may bargain higher wages as an incentive to work in those areas with environmental problems or lack of natural amenities, as is suggested in the spatial equilibrium framework. This might further amplify the increase in local wages due to the resource boom. Housing rents also capitalize on these negative amenity effects, as the evidence for Chile suggests (Rivera, 2020). It might outweigh the increase in local prices induced by the spending effect in the within-country *Dutch disease* model.[66]

These amenity effects are important in mining regions, which is consistent with the large number of long-distance commuters in those regions. These long-distance commuters represent nearly 35% of the workforce in the mining sector and 12% of the total workforce in all sectors within regions specialized in mining activities. The economic incentives for long-distance-commuting is partially given by the negative externalities associated to proximity to mining-extraction sites (Paredes, Soto, and Fleming, 2018). It is common that these sites are located in places with lack of natural amenities. Consequently, these negative environmental externalities correlate with the lack of natural amenities and remoteness of mining regions (Soto and Paredes, 2016). Therefore, local controls include amenity controls at the city level,

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[66] Despite the importance of these amenity effects in the resource-oriented regions, these are overlooked in the Allcott and Keniston (2018) setting.

such as local crime, education quality, share of highly skilled workforce, and local per capita fiscal resources. These might affect location incentives of workers and firms by providing a different set of local public goods.

2.6.3.2 Social Welfare The plausible causal evidence identified previously inform the social welfare measure by relying on the mapping between these elasticities and primitives of the model. In particular, the effects on population, wages, and rents, determine the social welfare in the model, assuming that local prices of the tradable and non-tradable sectors are captured in housing rents (Hornbeck and Moretti, 2022). Therefore, these elasticities are sufficient statistics of the welfare consequences of a resource boom and bust. Further, adapted from Allcott and Keniston (2018), in the cumulative indirect utility function in Equation 10, social welfare estimates for a city c are given by the following formulation:

$$\hat{W} = \frac{1}{14} \sum_{t=2000}^{T=2013} \left[\Delta \log X_{r,t} \left(T - t + 1 \right) \left(\hat{\beta}_{wage} - 0.3\hat{\beta}_{rent} - \hat{\beta}_{amenity} \right) \right].$$

The social welfare estimates are reported in Table 2.3. The main difference from Allcott and Keniston (2018) is that, here, the local exposure to mining shocks variable already captures the spillovers. Therefore, it is measure of absolute effects. These estimates reveal a negative long-term effect of the mining boom in the real wage and population gain. This is consistent with the hypothesis of *immiserizing growth* related to the original *Dutch disease* theory by Corden and Neary (1982), but in a within-country framework. Specifically, the contemporaneous increments in local wages and employment caused by the resource boom are insufficient to offset the increase in local rents. In this case, they are insufficient to outweigh the negative variations in mining activity experienced during the period. This is because, even though $wage - 0.3(rent)$ is positive but small (0.082), the annual average real wage and population gains are negative.

2.6.4 Mechanisms

2.6.4.1 Heterogeneous Effects in Sectoral Employment and Revenue Another level of evidence for the local economic impacts of mining activity, and an important mechanism of the *Dutch disease* (both in the within- and between-country version), is the shrink in the manufacturing non-linked sector. This is because local manufacturing firms in non-related sectors have to compete for local labor against the higher wages offered by the resource sector, due to the positive shock of productivity caused by the resource boom (resource movement effect). Moreover, the increase in local prices, increases the average cost of production (spending ef-

Table 2.3: Relative Welfare Effects

	Relative Welfare					
	Overall		Domestic Firms		Multinationals	
	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS
Wage elasticity	0.004	0.008	0.004	0.010	0.005	0.014
	(0.003)	(0.004)	(0.003)	(0.007)	(0.004)	(0.005)
Rent elasticity	0.021	0.022	0.010	0.022	0.031	0.067
	(0.007)	(0.009)	(0.009)	(0.016)	(0.014)	(0.012)
$\hat{\beta}_{wage} - 0.3\hat{\beta}_{rent}$	-0.002	0.002	0.000	0.004	-0.004	-0.006
Annual average real wage (log points)	-0.002	0.002	0.000	0.002	-0.005	-0.007
Population elasticity	0.007	0.011	0.015	0.016	0.013	0.003
	(0.004)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)
Annual average population gain (log points)	0.003	0.005	0.001	0.001	0.008	0.002

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis. Period 2000-2013. Cities 73.

fect). However, manufacturing firms can implement different strategies to tackle with the higher cost of production, without necessarily implying a reduction in the number of firms at the local level. Therefore, different outcomes for firms at the local level are used in the following regressions to study the effects on the overall size and profitability of the sector.

The effect on aggregate employment, although positive and significant, is masking the heterogeneity of the impact of employment on tradable and non-tradable sectors, predicted in theory. Table 2.4 distinguishes between employment in manufacturing and services sectors. The effects of mining and services employment are positive and significant across all estimations. As predicted, increments in mining activity lead to proportional increments in mining employment (elasticity close to 1). However, the proportional increments in employment in the services sector are comparatively smaller (elasticity of approximately 0.2). The difference in the effects of employment between these sectors is statistically significant.

However, the effects on manufacturing employment are non-significant. The manufacturing sector is related to different levels of tradability of manufacturing goods. Further, the effects of employment may be insignificant because the classification might be too aggregated and mask the negative effects caused by the resource movement and crowding-out of manufacturing non-linked firms. As found by Allcott and Keniston (2018), in the oil and gas sector in the US, it is more likely for the negative effects of a boom in the resource sector to be highly localized for manufacturing firms producing goods that are highly tradable and non-linked to the mining sector. Considering this, exporting firms are more likely to be exposed to the crowding-out effects, given the high levels of tradability and the fact that those firms are subject to within-country *Dutch disease* effects and classical between-country effects of currency appreciation.

Table 2.4: Relative Heterogeneous Effects in Employment and Revenue by Sector

	Change in Log Employment											
	Manufacturing						Services					
	Overall		Domestic		Multinationals		Overall		Domestic		Multinationals	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Log Exposure	-0.011	-0.039	-0.027	-0.038	-0.020	-0.053	0.010	0.012	0.016	0.013	0.017	0.003
	(0.010)	(0.020)	(0.017)	(0.022)	(0.014)	(0.022)	(0.006)	(0.009)	(0.009)	(0.014)	(0.010)	(0.011)
Year FE + Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjusted R^2	0.198		0.200		0.198		0.108		0.109		0.108	
Observations	365	365	365	365	365	365	365	365	365	365	365	365
First-Stage:												
K-P F-stat		39.427		77.681		218.893		39.427		77.681		218.893
Mineral Intensity		0.792		0.628		0.514		0.792		0.628		0.514
		(0.126)		(0.071)		(0.035)		(0.126)		(0.071)		(0.035)

	Change in Log Revenue											
	Manufacturing						Services					
	Overall		Domestic		Multinationals		Overall		Domestic		Multinationals	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Log Exposure	0.052	0.055	0.078	0.023	0.097	0.095	0.139	0.166	0.183	0.192	0.217	0.157
	(0.030)	(0.046)	(0.055)	(0.061)	(0.052)	(0.048)	(0.047)	(0.058)	(0.040)	(0.058)	(0.055)	(0.061)
Year FE + Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjusted R^2	0.133		0.139		0.137		0.203		0.230		0.209	
Observations	365	365	365	365	365	365	365	365	365	365	365	365
First-Stage:												
K-P F-stat		39.875		53.598		119.803		39.875		53.598		119.803
Mineral Intensity		0.751		0.584		0.548		0.751		0.584		0.548
		(0.119)		(0.080)		(0.050)		(0.119)		(0.080)		(0.050)

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95% confidence intervals in square brackets. Standard errors are clustered at the regional level. First-stage results are reported in the Appendix. Control variables, which varies with time and location, include: wages, population, quality of education, fiscal dependency on national government, per capita fiscal income.

The estimates of the exposure to mining shocks on the size and profitability of the mining, manufacturing, and services sectors in each city, are presented in Table 2.4. Results are positive for mining, services and manufacturing sectors, which suggests that there are no crowding-out effects of the mining sector on the number of manufacturing firms and city-level aggregate sales and revenue. This evidence is consistent with the results founded by Allcott and Keniston (2018). However, these estimates have to be interpreted with caution, given that this data are derived from tax declaration aggregated at the city level, and only considers firms in the formal sector. This is despite the fact that the formal sector accounts for approximately 75% of total non-agricultural employment in Chile. The IV estimates imply that a 10% increase in mining activity would lead to more than proportional increments in the services sector. These increments would be about 5% for the number of local firms, and about 10% for the average sales and profits.

Given that the manufacturing sector is mainly producing goods locally or with low tradability, it is also comprehensible that an increase in mining activity would lead to an increase in the size and profitability of local manufacturing firms, as observed in the data. Further, high elasticities are expected because the mining sector is capital intensive but indirectly requires a high number of employees from other sectors, such as transport and communications, construction, and other services. Moreover, higher wages increase the local consumption of non-tradables. This is the first strong evidence against local *Dutch disease*. However, this is an average aggregate effect, and it is expected that this effect would be heterogeneous according to the level of tradability of goods and services produced by these firms, and the extent to which these activities are directly or indirectly linked to the resource sector.

2.6.4.2 Productivity Spillovers Firms can implement different strategies to tackle economic shocks, and therefore, aggregate local indicators such as the number and total revenue of firms, which might not identify the negative impacts related to the local *Dutch disease*.[67] In fact, the key mechanism that distinguishes a *Dutch disease* scenario from a local specialization case in the resource sector is induced by comparative advantages such as those predicted by the Rybczynski theorem. These are the negative effects in the productivity of the manufacturing sector that, *ceteris paribus*, might induce a decline in long-term economic growth. However, the average effects of mining activity on the agglomeration of firms are positive and robust (Table 2.4), indicating that there is no evidence of crowding-out effects. Further, there are no reasons to expect that the effect on the productivity of firms would be negative. As the crowding-out effect is a necessary but not a sufficient condition for the *Dutch disease*.

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[67] Given the relationship between profits and productivity, we can formulate a empirical test in relation to both of these variables.

Table 2.5: Effects on the Productivity of Manufacturing Firms

	Change in Log TFP											
							Olley-Pakes method					
	Overall		Domestic		Multinationals		Overall		Domestic		Multinationals	
	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS	(7) OLS	(8) 2SLS	(9) OLS	(10) 2SLS	(11) OLS	(12) 2SLS
Log Exposure	0.060	0.088	0.078	0.023	0.097	0.095	0.048	0.051	0.025	0.017	0.075	0.067
	(0.028)	(0.033)	(0.055)	(0.061)	(0.052)	(0.048)	(0.027)	(0.031)	(0.020)	(0.022)	(0.030)	(0.036)
Year FE + Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adjusted R^2	0.037		0.139		0.137		0.030		0.029		0.029	
Observations	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215	2,215
First-Stage:												
K-P F-stat		17.762		112.169		112.169		17.762		112.169		112.169
Mineral Intensity		0.333		0.525		0.525		0.333		0.525		0.525
		(0.079)		(0.050)		(0.050)		(0.079)		(0.050)		(0.050)

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Extended results and Levinsohn-Petrin estimates of the TFP are reported in the Appendix. Standard errors (in parentheses) are clustered at the regional level. 95% confidence intervals in square brackets. 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. The Olley-Pakes estimation includes the value of investments as a proxy variable of the probability of exit. The correlation between the logarithm of exposure to mining shocks and the logarithm of backward linkages is 0.962.

Additionally, the high heterogeneity of firm performance is an important insight in considering the productivity spillovers from exposure to mining activities that are also highly heterogeneous. These heterogeneous effects on firms are also to be expected in terms of the size of the firm. Large firms with more capital can resist negative shocks on productivity whereas small firms cannot, inducing positive selection. Therefore, older firms are expected to be more productive than new firms entering the industry (Olley and Pakes, 1996). This is in addition to the fact that, according to the *Dutch disease* framework, the crowding-out effects of the resource boom are expected to be concentrated on firms that produce more tradable goods and services. Notwithstanding, plant fixed-effects and firm-level-time-varying controls should capture part of those differences in the size of firms, or more generally, any idiosyncratic factor influencing productivity.

A controversial hypothesis of this study is that the existence of local positive spillovers from the resource sector are not enough to induce long-term productivity gains, given the offshoring of MNCs in the resource sector. If this is true, a first insight to be observed, is a difference in the spillover effects between MNCs in the mining sector and domestic firms. Specifically, the effect induced by MNCs should be significantly lower than that for domestic firms. Table 2.5 shows the average and heterogeneous productivity spillover effects from the exposure to mining shocks. The effects are positive but the effects induced by domestic mining firms are slightly lower than the effects of foreign MNCs. The power of the IV in the first stage is particularly high for MNCs. Notwithstanding, coefficients are not very distinct from the OLS with plant- and industry-fixed effects and time-varying firm controls. However, it is more likely that the production of foreign mining companies is driven by other external factors instead of the profit ratio of each mine, that is, the amount of minerals extracted in relation to waste material.

2.7 Conclusions and Policy Implications

Within the existing economic literature, the evidence of positive effects of the resource sector in the local economy is usually theoretically grounded in environments where productivity spillovers spontaneously arise from an increase in productive linkages. These linkages are induced by a resource boom, which ultimately foster local *agglomeration effects* and *learning–by–doing*. In other words, the formation of within- and between-sectors increasing returns to scale induced by the resource sector, is understood as a direct consequence of a resource boom. This overstates the potential of the resource sector to offset negative externalities or future productivity losses caused by crowding-out effects. Specifically, in this study, I show that the observed large concentration of MNCs in the resource sector and the incentives of these companies to offshore activities, implies that a resource boom might foster an *enclave* equilibrium. This is despite the presence of contemporaneous local positive spillovers from productive linkages.

In doing so, this study exploits within-country spatial variation by integrating the mechanisms of the local *Dutch disease* accounting for the heterogeneous impacts between MNCs and domestic firms in the generation of local productive linkages and externalities. This is based on an expansive literature related to economic geography and the relationship between natural resources, MNCs, and *enclave* formation. This is crucial in understanding the ability of the resource sector to mitigate the potential de-industrialization caused by the *Dutch disease* and its long-term welfare implications. Considering the incentives of MNCs in the resource sector to generate local productive linkages, improves our understanding of the capacity of the resource sector to induce a more sustainable long-term local economic development.

The existence of potential social welfare losses and externalities in production from the resource boom and bust, reveal that local policy interventions relating the resource sector are therefore necessary. This argument of the importance of local economic conditions is not by any means specific to the resource sector, as is also implicit in the design of place-based policies. In particular, establishing a set of local economic conditions that define those long-term welfare implications, and therefore, the expected returns of local investments, is critical for policy purposes. This paper, therefore, enriches the existing literature with economic theory, a rich data setting and methodologies that allows to understand better the within-country geography mechanisms of economic development in resource-oriented economies. Specifically, a contemporaneous understanding of such phenomenon implies a good description of the nature and behaviour of MNCs involved in the global production network of minerals.

By relating the capacity of the resource sector to generate productivity spillovers with the local economy through the formation of local productive linkages, the analysis presented in this paper gives insights on the potential of different policy tools for contemporaneous and long-term local economic development based on the resource sector. Particularly, the results question the relative effectiveness of policies that increase location incentives of workers and firms toward particular resource-endowed locations, such as investments in local public goods and amenities. Conversely, policies with a focus on the production side foster the creation of local productive linkages that might generate productivity spillovers such as subsidizing local services suppliers. The distinction between these two kinds of policies is not straightforward. Governments and private companies usually invest large amounts of money in reinforcing the competitiveness of local suppliers of the resource sector. However, at the same time, governments in resource-oriented regions in the developing world spend little effort to invest in local amenities and resource-rich locations which could attract workers and firms, and are more likely to have positive long-term effects.

More specifically, the evidence in this paper points towards a complemented strategy between fostering local productive linkages and developing local amenities. This is because, even if important efforts are being made to improve the productivity of local suppliers of the resource sector. The lack of local conditions that favour location incentives towards those areas, would have a detriment effect on such policies. Given that firms would continue delocalizing these upstream activities towards areas that are more competitive and with a thick labor market. If these linkages are not being developed in activities that would have more value added and would generate within- and between-sectors productivity spillovers, then the expected long-term effects of such policies might be limited. Moreover considering the cyclical nature of booms and busts and the level of offshoring in the resource sector. This is because local planners have to deal with the negative amenity effects such as environmental externalities associated with mining extraction and the local increase in prices that offset the increase in local wages. These effects are pushing workers and firms towards other locations with better provision of public goods and agglomeration economies. Creating incentives for long-distance commuting and low population growth.

On the other hand, a precise knowledge on the expected local and aggregate economic impacts of new mining projects is very important for policy purposes. For example, establishing the economic setting for an ex-ante evaluation is necessary to clarify the local incentives that allow policy makers to take decisions based on the requirements that mining companies should meet to open a new mining plant. This decision is usually partially informed, and the consideration of general equilibrium effects, such as the spillovers to the local economy, are not usually carefully considered. This paper also contributes to this issue by proposing a model and an empirical strategy for the estimation of such effects with a more appropriate consideration of the role of MNCs in the formation of these spillovers. However, this article is limited on the extent to consider the fully extension of general equilibrium effects.

Given the extent of the topics explored in this dissertation, insightful general equilibrium channels through which the resource boom and bust can affect the local economy with heterogeneous effects among MNCs and domestic firms are left to be explored in further research. In particular, exploring the productivity spillovers and the pro-competitive effects from trade in intermediate inputs. This is the incentives of firms to exploit economies of scale and access to cheaper inputs. To fully capture the role of *learning-by-importing* and *learning-by-exporting* for intermediate suppliers, the decision to offshore have to be endogenous, and explored with further data. Notwithstanding, to the extent that these spillovers exists, the productivity effects reported in this paper represent a lower bound of the potential productivity gains from the resource sector, and therefore, more likely to offset the negative effects induced by the crowding-out of manufacturing industries. With expected higher productivity spillovers from MNCs in comparison to domestic firms. However, to properly capture the full impacts of MNCs, the import channel should be incorporated in the theory and empirics. In order to capture the productivity gains from access to intermediate varieties abroad. To account for this in the empirics, a measure of the inputs required by MNCs and domestic firms should be included. This article, however, offers a robust approximation of the implications that the given heterogeneous level of offshoring between MNCs and domestic firms have in local labor markets, in the context of a resource boom and bust.

2.8 Appendix

2.8.1 Mathematical Appendix

2.8.1.1 Housing and Local Goods Market Equilibrium The equilibrium price in the local non-tradable goods is obtained equalizing local demand which is individual demand for non-tradables times the number of workers in the city L_c, with local supply. Then, considering free mobility of workers across sectors within a city, i.e. $w_{lc} = w_{zlc} = w_c$ and substituting the number of local varieties Ω_{lc} yields

$$L_c(\gamma w_c) = p_{lc}Q_{lc} = p_{lc}(\upsilon A_{lc}\Omega_{lc}^{\eta}L_{lc}^{\delta}L_{zlc}^{1-\delta}) = p_{lc}\upsilon A_{lc}\Omega_{lc}^{\eta}L_{lc}^{\delta}\left[\alpha\left(\frac{1-\delta}{\delta}\right)\frac{w_{lc}L_{lc}}{w_{zlc}}\right]^{1-\delta}$$

$$\iff p_{lc} = \left(\frac{\gamma\delta}{\alpha^{1-\delta}}\right)\frac{w_cL_c}{A_{lc}\Omega_{lc}^{\eta}L_{lc}} \iff p_{lc} = \left(\frac{\gamma\delta^{1+\eta}}{\alpha^{1-\delta}(1-\alpha)^{\eta}(1-\delta)^{\eta}}\right)\frac{w_c^{1-\eta}L_c}{\lambda_c^{\eta}A_{lc}L_{lc}^{1+\eta}} \tag{15}$$

Taking the logs yields

$$\log p_{lc} = (1-\eta)\log w_c + \log L_c - \eta\log\lambda_c - \log A_{lc} - (1+\eta)\log L_{lc} + k_p \tag{16}$$

where $\kappa_p = \log\left(\frac{\gamma\delta}{\alpha^{1-\delta}}\right)$. Taking the log of the ratio (equivalent notation to the difference in logs in Allcott and Keniston, 2018) between the two cities $c = \{a, b\}$, we can represent the relative prices for the local non-tradable sector as

$$\log\hat{p}_l = (1-\eta)\log\hat{w} + \log\hat{L} - \eta\log\hat{\lambda} - \log\hat{A}_l - (1+\eta)\log\hat{L}_l \tag{17}$$

where $\hat{p}_l \equiv \left(\frac{p_{la}}{p_{lb}}\right)$, $\hat{w} \equiv \left(\frac{w_a}{w_b}\right)$, $\hat{L} \equiv \left(\frac{L_a}{L_b}\right)$, $\hat{A}_l \equiv \left(\frac{A_{la}}{A_{lb}}\right)$, $\hat{\Omega}_l \equiv \left(\frac{\Omega_{la}}{\Omega_{lb}}\right)$, and $\hat{L}_l \equiv \left(\frac{L_{la}}{L_{lb}}\right)$. In the case of housing, given the constant elasticity supply functions in Eqn. 1 $r_c = H_0L_c^h$, we can express the relative housing supply as

$$\log\hat{r}_c = h\log\hat{L} \tag{18}$$

where $\hat{r}_h \equiv \left(\frac{r_{ha}}{r_{hb}}\right)$, and $\hat{L} \equiv \left(\frac{L_a}{L_b}\right)$. The price in the resource sector p_{rc} is exogenously set in international markets, while the price in the tradable sector is defined as the numeraire $p_{mc} = 1$.

2.8.1.2 Labor Market Equilibrium

2.8.1.2.1 Aggregate Labor Demand Aggregate labor demand equals the labor in the final good and intermediate sectors. We can express the aggregate labor in city c in terms of labor in the final good sector as

$$\begin{aligned} L_c &= \sum_j L_{jc} + \sum_j L_{zjc} \\ L_c &= \sum_j L_{jc} + \left(\frac{1-\delta}{\delta}\right) \sum_j L_{jc} \\ L_c &= \left(\frac{1}{\delta}\right) \sum_j L_{jc} \end{aligned}$$

where $\left(\frac{1}{\delta}\right)$ is the multiplier effect. Given the assumption that wages equalize across sectors within a city and given that firms pay minimum cost wages, then $w_c = w_{jc} = \alpha^{\frac{1-\delta}{\delta}} (p_{jc} A_{jc} \Omega^{\eta}_{jc})^{\frac{1}{\delta}} / w_{zjc}^{\frac{1-\delta}{\delta}}$. Using the cost-minimizing wages, rearranging terms and substituting the equilibrium price in the non-tradable sector, yields

$$\begin{aligned} \alpha^{1-\delta} \left(\frac{1}{\delta}\right) \sum_j p_{jc} A_{jc} \Omega^{\eta}_{jc} L_{jc} &= \alpha^{1-\delta} \left(\frac{1}{\delta}\right) \sum_j p_{jc} A_{jc} \Omega^{\eta}_{jc} L_{jc} \\ \sum_j w_{jc} L_{jc} &= \alpha^{1-\delta} \left(\frac{1}{\delta}\right) \sum_j p_{jc} A_{jc} \Omega^{\eta}_{jc} L_{jc} \\ \left(\frac{1}{\alpha^{1-\delta}}\right) w_c \sum_j L_{jc} - p_{lc} A_{lc} \Omega^{\eta}_{lc} L_{lc} &= p_{mc} A_{mc} \Omega^{\eta}_{mc} L_{mc} + p_{rc} A_{rc} \Omega^{\eta}_{rc} L_{rc} \\ \left(\frac{\delta}{\alpha^{1-\delta}}\right) w_c L_c - \left(\frac{\gamma\delta}{\alpha^{1-\delta}}\right) \frac{w_c L_c}{A_{lc} \Omega^{\eta}_{lc} L_{lc}} A_{lc} \Omega^{\eta}_{lc} L_{lc} &= X_{mc} \Omega^{\eta}_{mc} L_{mc} + X_{rc} \Omega^{\eta}_{rc} L_{rc} \\ (1-\gamma)\delta w_c L_c &= \alpha^{1-\delta} \sum_{j=m,r} X_{jc} \Omega^{\eta}_{jc} L_{jc} \end{aligned}$$

We can simplify more this expression by taking advantage of the total number of local varieties in equilibrium Ω_{jc},

$$\begin{aligned} (1-\gamma)\delta w_c L_c &= \alpha^{1-\delta} \sum_{j=m,r} X_{jc} \left((1-\alpha) \left(\frac{1-\delta}{\delta}\right) \lambda_{jc} w_{jc} L_{jc} \right)^{\eta} L_{jc} \\ (1-\gamma)\delta w_c^{1-\eta} L_c &= \alpha^{1-\delta} \left[(1-\alpha) \left(\frac{1-\delta}{\delta}\right) \right]^{\eta} \lambda_c^{\eta} \sum_{j=m,r} X_{jc} L_{jc}^{1+\eta} \\ w_c &= \left(\kappa_w \lambda_c^{\eta} \sum_{j=m,r} \frac{X_{jc} L_{jc}^{1+\eta}}{L_c} \right)^{\frac{1}{1-\eta}} \end{aligned} \tag{19}$$

where $\kappa_w \equiv \left(\frac{\alpha^{1-\delta}}{(1-\gamma)\delta}\right)^{\frac{1}{1-\eta}} \left[(1-\alpha)\left(\frac{1-\delta}{\delta}\right)\right]^{\frac{\eta}{1-\eta}}$. Then aggregate inverse labor demand taking logarithms gives

$$(1-\eta)\log w_c = \eta \log \lambda_c + \log \sum_{j=m,r} X_{jc} + (1+\eta)\log \sum_{j=m,r} L_{jc} - \log L_c + \kappa_w \tag{20}$$

In consequence, for the case of two cities $c = \{a, b\}$, the relative inverse labor demand can be written as

$$(1-\eta)\log \hat{w} = \eta \log \hat{\lambda} + \log \sum_{j=m,r} \hat{X}_j + (1+\eta)\log \sum_{j=m,r} \hat{L}_j - \log \hat{L} \tag{21}$$

where $\hat{w} \equiv \left(\frac{w_a}{w_b}\right)$, $\hat{\lambda} \equiv \left(\frac{\lambda_a}{\lambda_b}\right)$, $\hat{L}_j \equiv \left(\frac{L_{ja}}{L_{jb}}\right)$, and $\hat{L} \equiv \left(\frac{L_a}{L_b}\right)$.

2.8.1.2.2 Aggregate Labor Supply In terms of aggregate labor supply. Assuming spatial equilibrium $U_{ic} = \overline{u}$, and that $\log \epsilon_{ic}$ is distributed type I extreme value with scale parameter ξ^2 with $\xi \in (0, \infty)$, and considering that the tradable good m is the numeraire, then the inverse labor supply can be written as

$$\log w_c = \log \overline{U} + \gamma \log p_{lc} + \varphi \log r_c - \log B_c + \xi \log L_c - \kappa_u \tag{22}$$

and in relation to both cities $c = \{a, b\}$,

$$\log \hat{w} = \gamma \log \hat{p}_l + \varphi \log \hat{r} - \log \hat{B} + \xi \log \hat{L} \tag{23}$$

where $\hat{w} \equiv \left(\frac{w_a}{w_b}\right)$, $\hat{p}_l \equiv \left(\frac{p_{la}}{p_{lb}}\right)$, $\hat{r} \equiv \left(\frac{r_a}{r_b}\right)$, $\hat{B} \equiv \left(\frac{B_a}{B_b}\right)$, and $\hat{L} \equiv \left(\frac{L_a}{L_b}\right)$.

2.8.1.3 Relative Effects in Local Labor Markets Substituting in the aggregate inverse labor supply (Eqn. 23), the equilibrium relative local goods prices from Eqn. 17 and the relative equilibrium housing prices from Eqn. 18 yields

$$\log \hat{w} = \gamma\Big((1-\eta)\log \hat{w} + \log \hat{L} - \eta \log \hat{\lambda} - \log \hat{A}_l - (1+\eta)\log \hat{L}_l\Big) + \varphi h \log \hat{L} - \log \hat{B} + \xi \log \hat{L}$$

$$\iff [1-\gamma(1-\eta)]\log \hat{w} = (\gamma + \varphi h + \xi)\log \hat{L} - \gamma \log \hat{A}_l - \gamma(1+\eta)\log \hat{L}_l - \log \hat{B}$$

Substituting the relative inverse labor demand (Eqn. 21) and solving for the relative population difference gives

$$\begin{aligned}(\gamma+\varphi h+\xi)\log\hat{L}-\gamma\log\hat{A}_l-\gamma(1+\eta)\log\hat{L}_l-\log\hat{B}&\\ =\rho\Big(\eta\log\hat{\lambda}+\log\sum_{j=m,r}\hat{X}_j+(1+\eta)\log\sum_{j=m,r}\hat{L}_j-\log\hat{L}\Big)&\\ \iff[\gamma+\varphi h+\xi+\rho]\log\hat{L}=\rho\eta\log\hat{\lambda}+\rho\log\sum_{j=m,r}\hat{X}_j+\rho(1+\eta)\log\sum_{j=m,r}\hat{L}_j&\\ +\gamma\log\hat{A}_l+\gamma(1+\eta)\log\hat{L}_l+\log\hat{B}&\end{aligned}\tag{24}$$

where $\rho\equiv\frac{[1-\gamma(1-\eta)]}{(1-\eta)}=1-\gamma$. Defining $\tau\equiv\frac{1}{\gamma+\varphi h+\xi+\rho}=\frac{1}{1+\varphi h+\xi}$, we can express the equilibrium relative population equation (or migration equation) as

$$\log\hat{L}=\rho\tau\eta\log\hat{\lambda}+\rho\tau\log\sum_{j=m,r}\hat{X}_j+\rho\tau(1+\eta)\log\sum_{j=m,r}\hat{L}_j+\gamma\tau\log\hat{A}_l+\gamma\tau(1+\eta)\log\hat{L}_l+\tau\log\hat{B}\tag{25}$$

Then, substituting this population difference again in the relative inverse labor demand Eqn. 21, yields the equilibrium relative wages

$$\begin{aligned}(1-\eta)\log\hat{w}=\eta\log\hat{\lambda}+\log\sum_{j=m,r}\hat{X}_j+(1+\eta)\log\sum_{j=m,r}\hat{L}_j&\\ -\Big(\rho\tau\eta\log\hat{\lambda}+\rho\tau\log\sum_{j=m,r}\hat{X}_j+\rho\tau(1+\eta)\log\sum_{j=m,r}\hat{L}_j+\gamma\tau\log\hat{A}_l+\gamma\tau(1+\eta)\log\hat{L}_l+\tau\log\hat{B}\Big)&\\ \iff(1-\eta)\log\hat{w}=\eta(1-\rho\tau)\log\hat{\lambda}+(1-\rho\tau)\log\sum_{j=m,r}\hat{X}_j+(1+\eta)(1-\rho\tau)\log\sum_{j=m,r}\hat{L}_j&\\ -\gamma\tau\log\hat{A}_l-\gamma\tau(1+\eta)\log\hat{L}_l-\tau\log\hat{B}&\end{aligned}$$

then, let define

$$\hat{X}_n\equiv\hat{\lambda}^{\eta}\sum_{j=m,r}\hat{p}_j\hat{A}_j\tag{26}$$

the relative equilibrium wages are

$$\log\hat{w}=(1-\rho\tau)\Big(\log\hat{X}_n+(1+\eta)\log\hat{L}_n\Big)-\gamma\tau\Big(\log\hat{A}_l+(1+\eta)\log\hat{L}_l\Big)-\tau\log\hat{B}\tag{27}$$

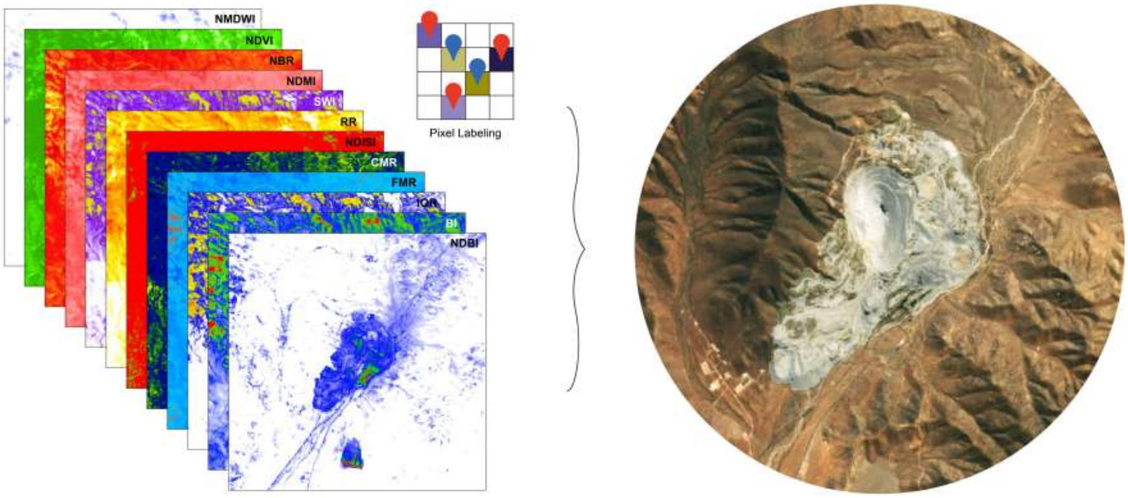
and the migration equation can be expressed as

$$\log \hat{L} = \rho\tau\left(\log \hat{X}_n + (1+\eta) \log \hat{L}_n \right) + \gamma\tau\left(\log \hat{A}_l + (1+\eta) \log \hat{L}_l \right) + \tau \log \hat{B}. \tag{28}$$

The effects on the productivity of the manufacturing sector can be obtained substituting equilibrium conditions in the productivity evolution for the tradable sector, and solving for

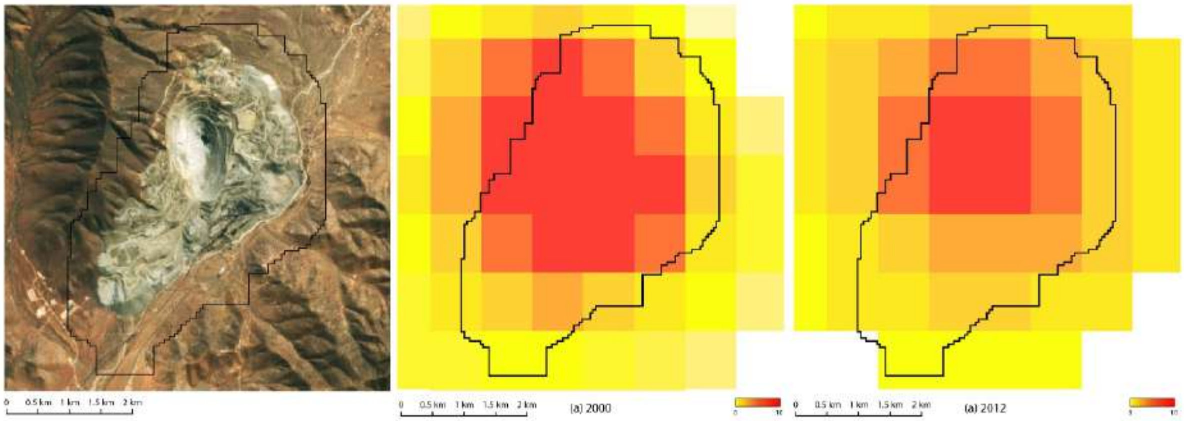
$$\begin{aligned} &\log \hat{A}_{m,t+1} = \psi_m \log \hat{A}_{m,t} + \phi_m \log \hat{L}_{m,t} + \Lambda \log \hat{L}_t \\ &\quad \Longleftrightarrow \log \hat{A}_{m,t+1} = \psi_m \log \hat{A}_{m,t} + \phi_m \log \hat{L}_{m,t} + \Lambda \Big[\rho\tau\left(\log \hat{X}_n + (1+\eta) \log \hat{L}_n \right) \\ &\qquad\qquad + \gamma\tau\left(\log \hat{A}_l + (1+\eta) \log \hat{L}_l \right) + \tau \log \hat{B} \Big]. \end{aligned}$$

2.8.2 Additional Figures

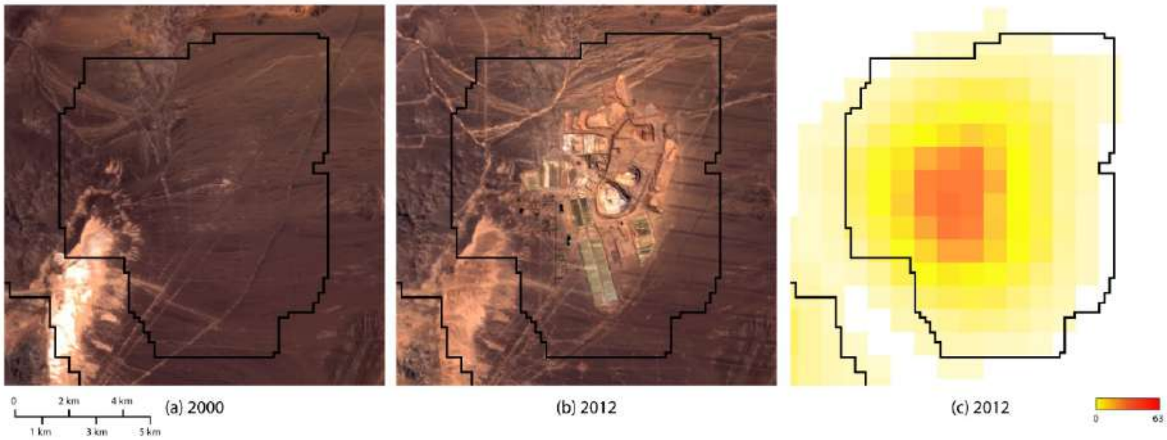


The figure summarizes the methodology used to identify the area of each mining site. This methodology roughly follows Connette et al. (2016) and Werner et al. (2020). The method consist of a seven-step procedure. (1) In the first place, the following spectral indexes are computed using the visible and invisible range of the Sentinel and LandSat satellites. These indexes are NMDWI, NDVI, NBR, NDMI, SWI, RR, NDISI, CMR, FMR, IOR, BI, and NDBI, and summarize information on Water, Vegetation. In addition NTL is used. (2) In the second step a Support Vector Machine (SVM) classification algorithm is used to classify images (10x10m), using the most recent satellite information. A mask of vegetation, water, and dark areas is used to diminish the amount of pixels to classify for mines. (3) With the remaining pixels, a random forest algorithm is used to define which pixels are mine and the others that are not. (4) A focal statistical with a kernel of 5 (50m) is used to make easy build polygons of mines. (5) Classified pixels averaged by the max to a 5m resolutions are grouped and transformed to vectors (polygons). (6) For each polygon built in the previous step, the quantity of pixels that are classified as part of mines are computed and a filter of at least 100 mine pixels is applied to reduce the number of classified polygons from 489 with at least 1 pixel identified as mine to 89. (7) centroid coordinates of mines, area used for production (pixels classified as mines), and the light intensity on each pixel classified as mines is computed.

Figure A2.1: Identification of the Area of Mining Sites



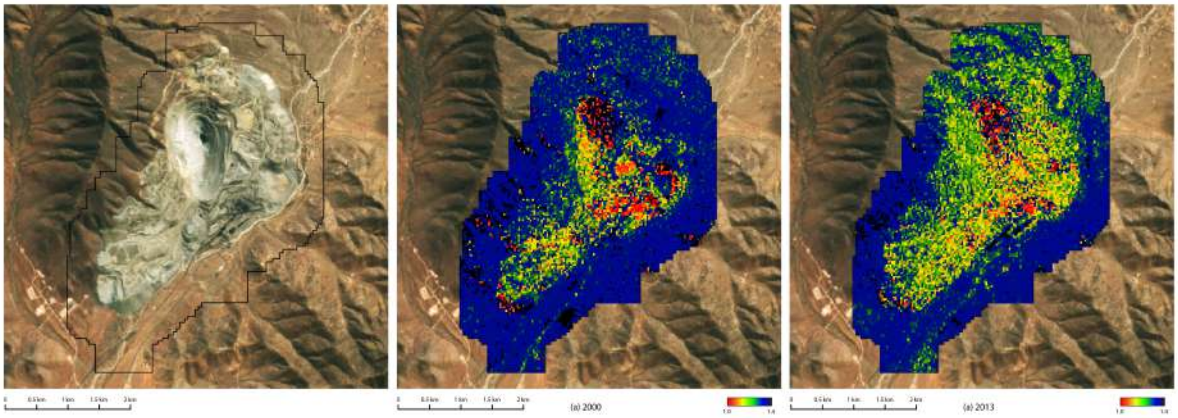
(a) El Romeral Mine



(b) BHP Spence Mine

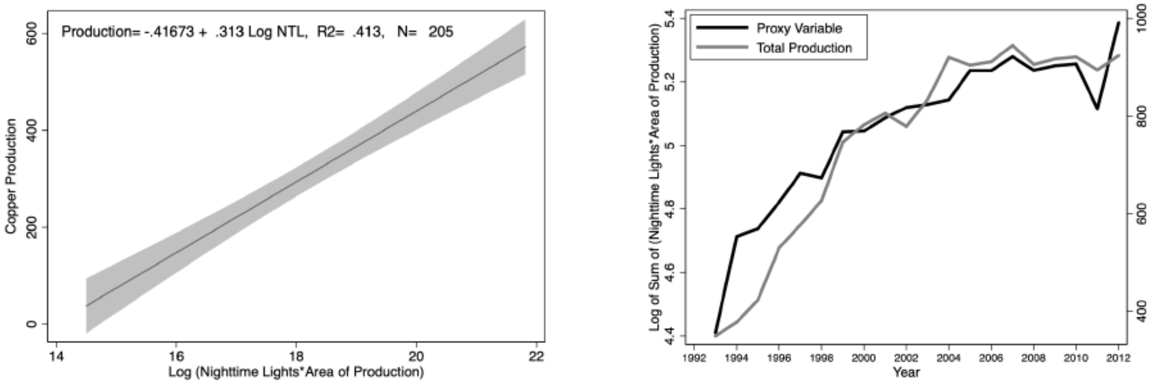
The figure compares the aggregate production of minerals against the aggregate nighttime lights on mining plants between 1992 and 2012. Data for validation was obtained from (Baker et al., 2017). Which contains recent geospatial data from the UGSG on explorations, mines, and ports that exports mineral commodities in Latin America.

Figure A2.2: Examples of Area and Nighttime Lights Identified

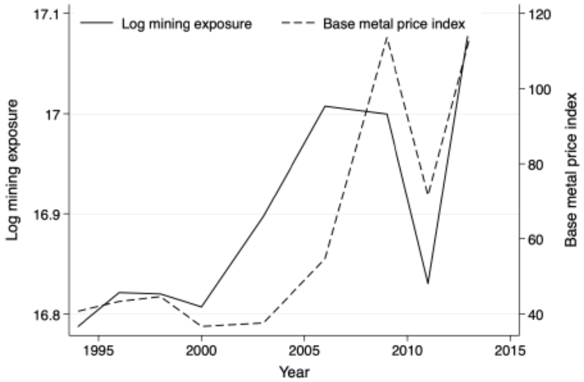


Following the intuition of Faber and Gaubert (2019) to identify the intrinsic characteristics of a place (quality of beaches in their case), and a wide literature in mineral geology such as: Segal (1982), Drury (1987), and Wolf (2012). I use different multispectral satellite mineral-related indices as a proxy measure of the quality of the mineral extracted and therefore as predictor of the profit ratio of each mine. These indices use the visible and infrared information capture by satellites. Visible light capture by cameras cover the Blue (450-495, μm), Green (495-570, μm), and Red (620-750, μm) bands of the satellite. While the infrared are divided in: Near Infrared (NIR, 750-900, μm), Short Wave Infrared (SWIR, 900-3000, μm), and Thermal Infrared (TIR, 3000-14000, μm). Specifically, the concentration of particular minerals are identified using the spectral range of the satellite (i.e. that are non-visible to the human eye) that can be measure with LandSat-7, which are: the clay minerals ratio (CMR), the ferrous minerals ratio (FMR), the iron oxide ratio (IOR), the WorldView New Iron Index (WV-II) and the WorldView Soil Index (WV-SI). In addition, the Bare Soil Index (BI) is used to improve the accuracy of other indices. The clay minerals ratio is computed as the quotient between the shortwave infrared (SWIR) that lie between 1.55 to 1.75 μm (LandSat7 satellite band 5) over shortwave infrared in the range 2.08 to 2.35 μm (LanSat7 satellite band 7). $CMR = \frac{SWIR1}{SWIR2}$. The ferrous minerals ratio (FMR) is the quotient between the shortwave-infrared in the range 1.55 to 1.75 μm over the near infrared in the range 0.76 to 0.8 μm (LandSat7 satellite band 4). $FMR = \frac{SWIR}{NIR}$ The iron oxide ratio (IOR) is computed as the quotient between the red (0.63-0.69 μm, LandSat-7 satellite band 3) and blue bands (0.45-0.52 μm, LandSat-7 satellite band 1) of the satellite. $IOR = \frac{Red}{Blue}$ The bare soil index is computed as $BI = \frac{B4+B2-B3}{B4+B2+B3}$.

Figure A2.3: Illustration of the Instrumental Variable



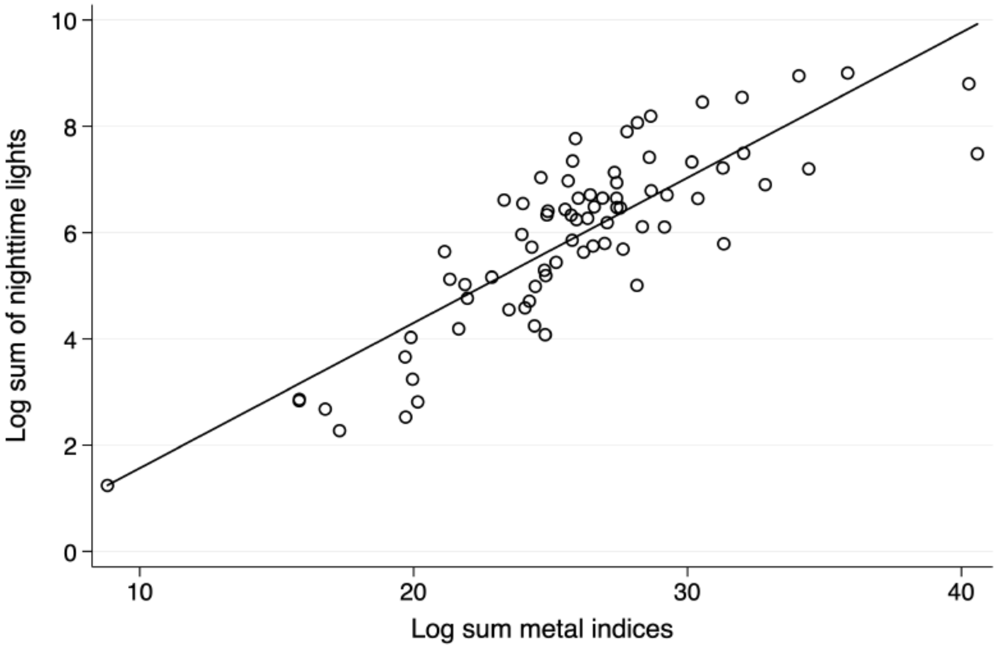
(a) Validation with Individual Plant Production **(b)** Validation with Aggregate Total Production



(c) Validation with Price Trends

The figure compares the aggregate production of minerals against the aggregate nighttime lights on mining plants between 1992 and 2012. Data for validation was obtained from (Baker et al., 2017). Which contains recent geospatial data from the UGSG on explorations, mines, and ports that exports mineral commodities in Latin America.

Figure A2.4: Validation of Satellite Measures of Mining Activity



Notes: The figure compares logarithm of the sum of the concentration of heavy metals in soil within the boundaries of the mining plants, against the logarithm of the sum of nighttime lights on mining plants between 1992 and 2012. *Source:* Own elaboration.

Figure A2.5: Prediction of Total Annual Production of Each Mining Plant

Global Value Chains and Industrial Upgrading in Local Labor Markets

> *"...It is time to give the open hand of copper to every human being. [...] From the steep hills, from the green height, will come the copper of Chile, the hardest harvest of my town..."*
>
> Pablo Neruda, *Ode to Copper (1954)*

Abstract

Moving from the production of low-processed commodities to downstream basic manufacturing activities within a value chain is a popular strategy in emerging countries. However, the welfare and productivity gains from this process of sectoral industrial upgrading, and its distributional impacts in local labor markets are not clear. This study examines the expansion of the copper industry in Chile, the world's largest copper producer. The empirical strategy exploits the variation in upgrading from low-processed mine copper to smelting and refined copper exports with two main objectives: 1) measuring the role of resource endowments and export competition in inducing industrial upgrading at the sectoral level 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 this process of 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. This evidence supports the promotion of policies that foster alternative forms of upgrading in the lower segments of the value chain in resource-rich economies.

3.1 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, a process usually categorized as industrial upgrading.[68]

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 may decline due to the reallocation of knowledge-intensive activities (Soto-Díaz, 2022). These features may be particularly troublesome for resource-rich 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). Consequently, while these economies 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.

A central issue in the success of industrial policies for economic development in the context of growing GVC participation is a better understanding of the aggregate and distributional economic impacts of policies that promote sectoral industrial upgrading. That is, policies favoring higher downstream segments of a value chain in relation to primary upstream activities in a given location. To address this dilemma, this study examines the economic impact of industrial upgrading in local labor markets. I ask how the aggregate growth of higher downstream activities relative to lower segments of a value chain in local labor markets affects local

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

economic development. Furthermore, I provide evidence on how resource endowments and export competition in GVCs influence this process of sectoral industrial upgrading in local labor markets. In order to inform this dilemma, this paper studies the economic impacts of industrial upgrading in local labor markets. More precisely, how the aggregate growth of higher downstream activities relative to lower segments of a value chain in local labor markets, impacts local economic development. And provides evidence on how local comparative advantages and export competition in GVCs influence this process of sectoral industrial upgrading in local labor markets.

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 variations 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.[69] 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 real gains for the local economy from this process of industrial upgrading. These two objectives can be informative about the potential effect of industrial policies targeting different segments of a value chain on economic development.

In the empirical analysis, I focus on three distinct things. First, by relying on the spatial variation in industrial upgrading at the sectoral level in local labor markets, I identify the plausible causal role of resource endowments and export competition in inducing this process of industrial upgrading. This exercise provides a measure of the extent to which industrial upgrading in local labor markets responds differently to exogenous local and global shocks. On the one hand, the local shock is induced by variations in resource endowments and is informative about the role of comparative advantages. On the other hand, a global shock is the result of competition in GVCs. 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 in the copper sector 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

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[69] 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 (Gereffi, 1999; Gereffi et al., 2001; Cattaneo et al., 2013; Gereffi, 2019; Verhoogen, 2021).

relative social welfare. As is standard in spatial equilibrium models with idiosyncratic restrictions on the mobility of workers, this is proxied by the changes in the local population and real wages (Moretti, 2010a; Allcott and Keniston, 2018). I then explore the impacts of industrial upgrading on local employment and nominal wages, a proxy for labor productivity. Finally, the heterogeneous impacts of these effects are explored in the manufacturing and non-manufacturing sectors.

Third, I provide evidence of how industrial upgrading in local labor markets affects the competitiveness of firms 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 key extractive sector as an alternative to traditional industrial upgrading.

However, the expansion of production in different segments of a value chain is likely correlated, sharing similar trends and impacts in the local economy. This may affect the empirical analysis. 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 in the local economy in a value chain. 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.[70] 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 doing so is an important part of the strategy of development in Chile as well as many emerging economies where primary activities play an important role (Addison and Roe, 2018).

From a theoretical perspective, this study contributes to the growing literature on the relationship between GVCs and local labor markets (Antràs and Chor, 2021). Specifically, I provide a better understanding on how local economies respond when some segments within the same

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

sector in a value chain lose comparative advantages while others gain.[71] 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 mean 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, 2010a).[72]

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.

3.2 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, Chile. Furthermore, the specific role of China in reallocating part of these activities is discussed, as is very important for Chile 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.

3.2.1 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

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

[72] 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, 2014a; Bartelme et al., 2019), how local labor markets adjust to large trade shocks (Author, Dorn, and Hanson, 2013; Autor, Dorn, and Hanson, 2013; Autor et al., 2015; Autor, Dorn, and Hanson, 2016; Dix-Carneiro, 2014; Artuç, Chaudhuri, and McLaren, 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).

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 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. 3.1: 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.[73] 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).[74] 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.[75] Essentially, the minerals from any of these second stage activities can be exported. The development of

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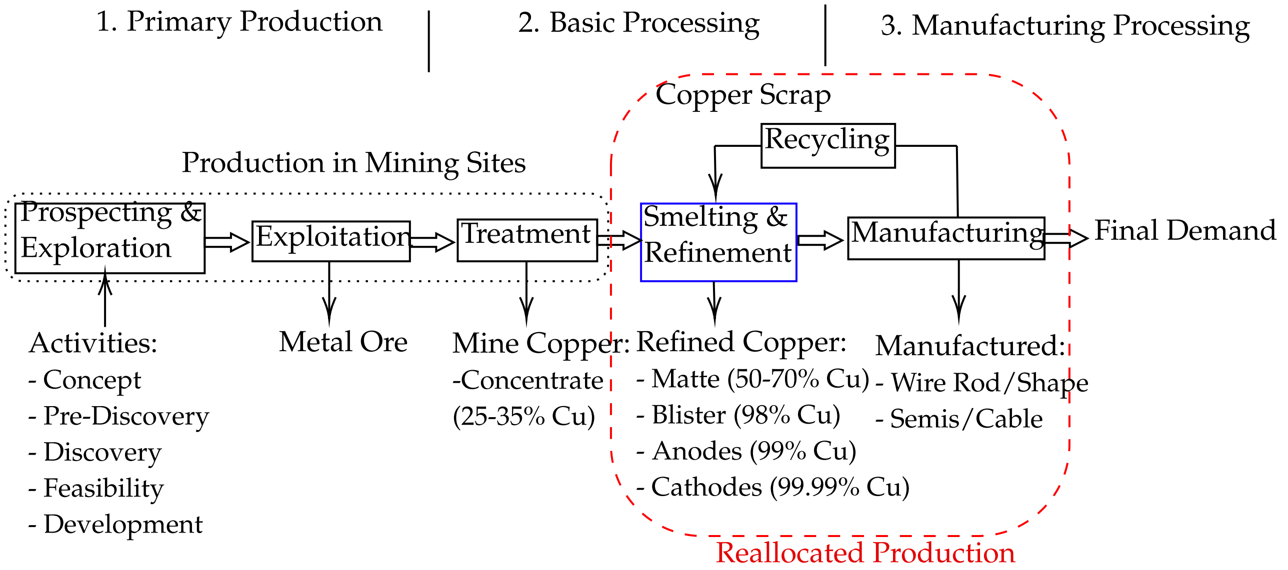
[73] During the early activities of prospecting and exploration, there are funding risks associated to financial speculators, and technical and discovery risks. Meanwhile, more institutional and strategic investment is made during the phase of development and exploitation.

[74] 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.

[75] 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.



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 3.1: Value Chain of the Copper Industry

these activities depends on a series of factors, such as labor and transport costs, environmental regulations (Pérez et al., 2021; Sturla-Zerene, Figueroa, and Sturla, 2020; Sturla, 2020), and institutional conditions (Leiva, 2020). Due to the large sunk costs involved in primary production and the long-term nature of mining projects, mining companies usually have high 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; that is, industrial upgrading from the first to the second stage of the copper value chain. 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.

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.

3.2.2 Comparative Advantages and the Geography of 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. 3.1) 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.[76] Further, although the prices of mine and refined copper tend to 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.[77]

As shown in Figure 3.2, Chile has been the major exporter of mine copper for many decades.

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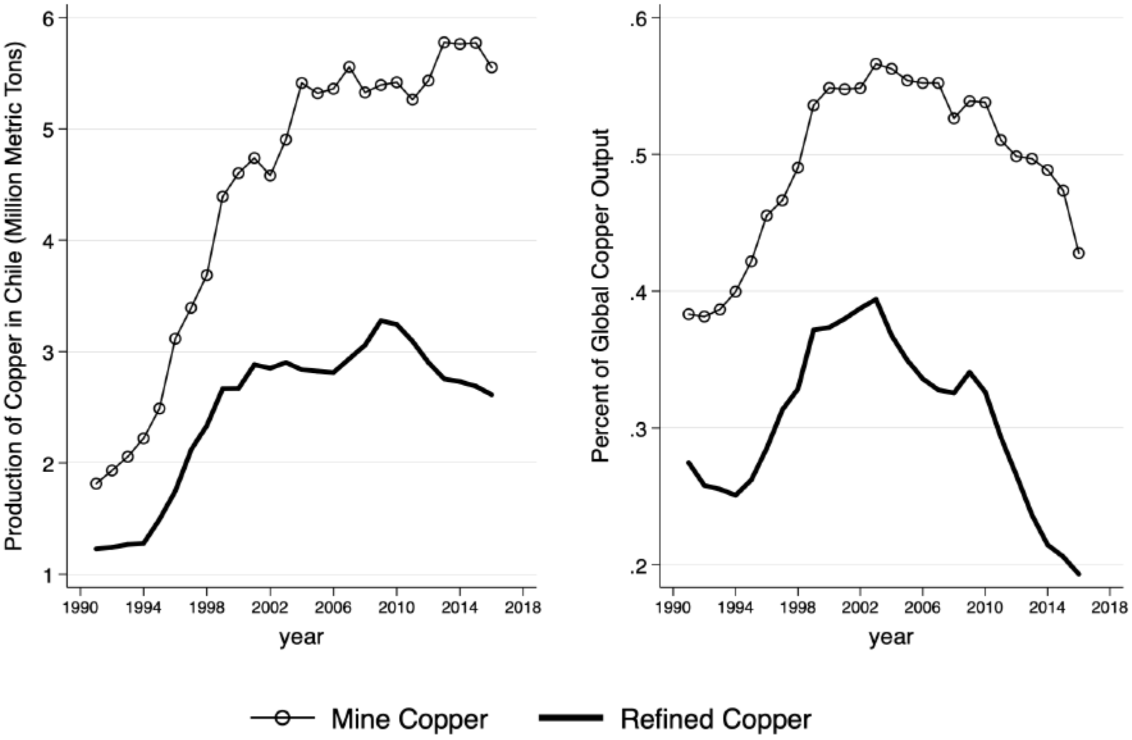
[76] The massive reallocation of world manufacturing industries to China has affected the organization of production of many sectors. The copper industry is illustrative of this. As Appendix Fig. A3.1 shows, in the past few decades, China became the main consumer of copper with over 40% of global demand as well as the major refiner, despite having limited extraction sites.

[77] 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.



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 3.2: Production of Copper in Chile

Moreover, 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, Lufin, and Soto, 2019). These services include geological, engineering, design, construction, energy, and water management; environmental studies; communication and transport; and leasing, maintenance, and repair of equipment.[78]

I characterize the spatial attributes of the process of sectoral industrial upgrading to downstream stages of a value chain in local labor markets and how this responds to resource endowments –a proxy for natural local comparative advantages– and export competition in these segments of the copper value chain. Fig. 3.3 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 low-value-added activities fail to move up in the value chain and industrialize, and grow through related activities that supply the low

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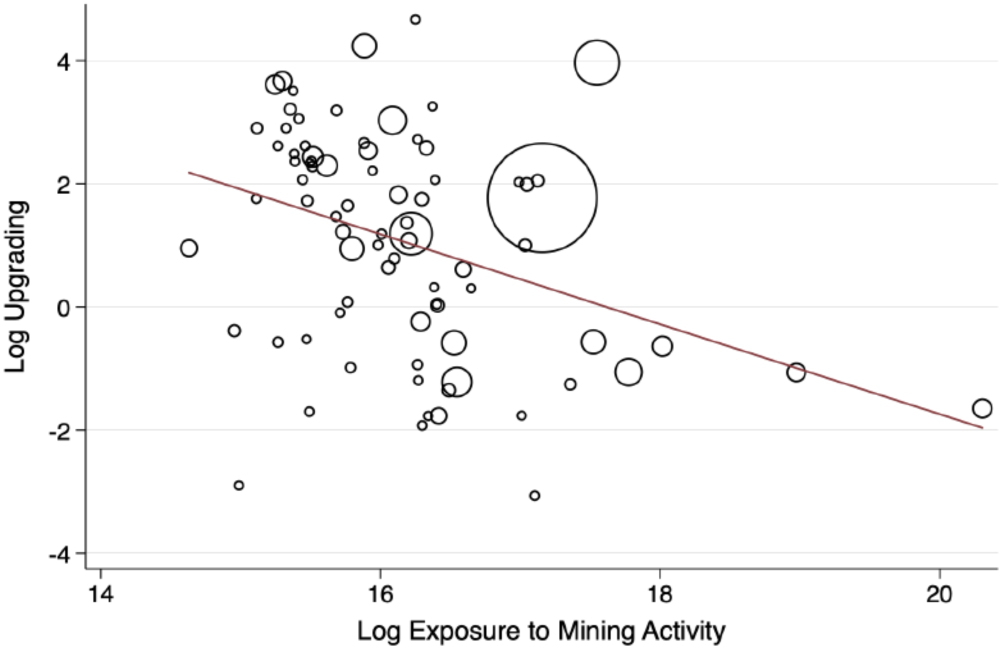
[78] Recently, with the growth in automation and remote work, the demand for data and software management and design has increased as a proportion of activities in some mines is being done from remote locations. This may further reduce incentives for the formation of local productive linkages even in services provided in the low value-added segments of the value chain.

value-added sector. Indeed, the current policy approach suggests this (Korinek, 2020).



Notes: The figure illustrates the relationship between industrial upgrading to downstream activities of refinement and smelting of copper 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 3.3: Resource Endowment and Industrial Upgrading in Local Labor Markets

The high dispersion for low values of exposure to mining activity may be because smelting and refinement activities are not skill- or knowledge-intensive. 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 incentivize locating smelting and refinement activities in places with high unemployment to foster local economic activity.

3.2.3 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, Kaplinsky, and Kaplan, 2012; Farooki and Kaplinsky, 2014; Figueiredo and Piana, 2016; Katz and Pietrobelli, 2018; Pietrobelli, Marin, and Olivari, 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 growth are questionable (Atienza, Lufin, and Soto, 2019; Atienza and Modrego, 2019).[79] 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).

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[79] 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).

3.3 Global Value Chains 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 the 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.

3.3.1 Industrial Upgrading and Global Value Chains

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 and specializing in lower segments of the value chain may be preferable due to comparative advantages. 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. 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. 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 component among the different stages of a value chain is interdependent.

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 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 us 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. 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.

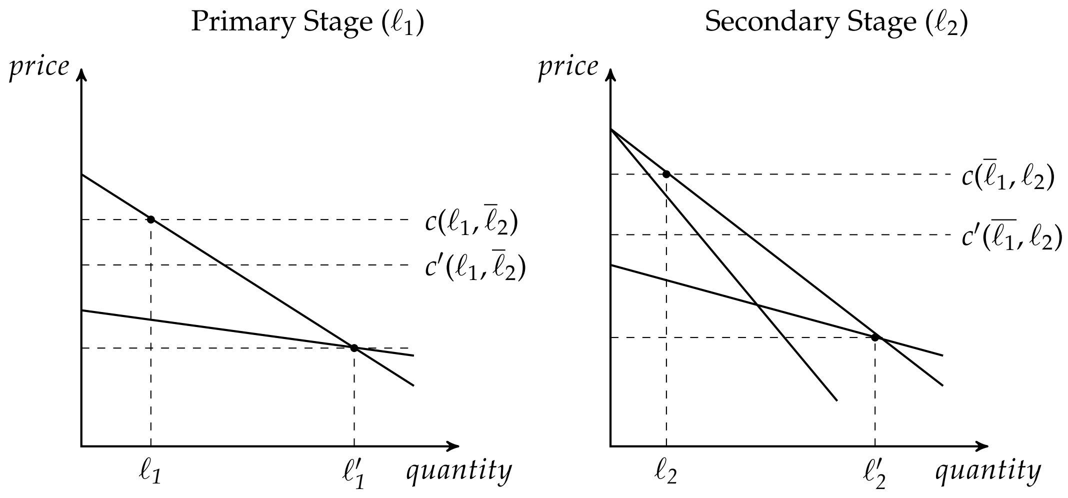
In this context, given the high comparative advantages in the primary export sector and that trade costs tend to decrease with further downstream activities within the value chain, Antràs and de Gortari (2020) predicts that the specialization on a specific activity in the value chain, and thus, industrial 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). 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.

3.3.2 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–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 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 3.4 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.


Primary Stage (ℓ_1)

Secondary Stage (ℓ_2)

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 higher value-added segment is less than that of the lower value-added segment, there are no incentives to implement industrial upgrading. This because investments in the lower added segment would lead to higher welfare gains. Moreover, subsidizing the primary stage would decrease marginal costs in the secondary stage, which may also foster the industry. *Source:* Adapted from Bartelme et al. (2019).

Figure 3.4: The Incentives for Industrial Policies and Value Chains

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.[80]

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). Moreover, 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

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[80] This simple framework is expanded and tested empirically in Bartelme et al. (2019). As these authors explain and Kucheryavyy, Lyn, and Rodríguez-Clare (2022) 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, 1991b).

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.

3.4 Local Labor Market Exposure to Global Value Chains

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 Author, Dorn, and Hanson (2013) and subsequent works that have explored the impacts of international trade shocks on local labor markets.[81] One of the key contributions of Author, Dorn, and Hanson (2013) 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, Lu, and Shen (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

$$EPW_{jc} = \frac{L_{jc}}{L_c}\frac{X_j}{L_j} \tag{29}$$

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. 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

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

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.[82] 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.

3.5 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.[83]

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[82] 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.

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

3.6 Empirical Evidence

3.6.1 Baseline Reduced-Form Specification

3.6.1.1 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, Lu, and Shen (2019) adapted from Author, Dorn, and Hanson (2013) 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:

$$\Delta EPW_{jct} = \frac{L_{jct}}{L_{ct}} \frac{\Delta X_{jt}}{L_{jt}} \tag{30}$$

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 $j = \{\text{mine copper}\}$,

$$Upgrading_{ct} = \Delta EPW_{j=refined,ct} / \Delta EPW_{j=mine,ct}. \tag{31}$$

The $Upgrading_{ct}$ variable in Equation 31, 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.

3.6.1.2 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:

$$MiningExposure_{ct} = \sum_{k} Q_{kt} \left(d_{kc}\right)^{-1}, \tag{32}$$

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:

$$ExportCompetition_{ct} = MiningExposure_{ct} \left(\frac{\Delta X^{ROW}_{j=refined,t}}{\Delta X^{ROW}_{j=mine,t}} \right) \tag{33}$$

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

$$\log Upgrading_{ct} = \beta \log ExportCompetition_{ct-1} + \mathbf{X'}_{ft-1}\gamma + \delta_f + \epsilon_{ct}. \tag{34}$$

3.6.1.3 Industrial Upgrading, Employment, Wages, and Firms' Agglomeration The upgrading variable in Equation 31, 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:

$$\Delta \log Y_{ct} = \beta \log Upgrading_{ct-1} + \mathbf{X'}_{ct-1}\gamma + \delta_t + \epsilon_{ct}, \tag{35}$$

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 (4) 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 35, the upgrading variable, previously defined in Equation 31, 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.[84]

3.6.2 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 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

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[84] This data has been first used in Atienza, Lufin, and Soto (2019) and Atienza and Modrego (2019).

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 considering 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. A3.1, 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:

$$\log Upgrading_{ct} = \alpha \log MineralConcentration_{ct-1} + \delta_t + \mu_{ct}. \tag{36}$$

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.

3.7 Results

3.7.1 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 3.1 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. A3.1. 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 Author, Dorn, and Hanson (2013) and Autor, Dorn, and Hanson (2020). This is in line with the argument of Amior and Manning (2018) that the existence of large employment effects and small population ad-

Table 3.1: Resource Endowment, Mineral Prices, Export Competition, and Industrial Upgrading in Local Labor Markets

	Log Industrial Upgrading								
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) 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.

justments 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.

Table 3.2: 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) OLS	(2) OLS	(3) OLS	(4) 2SLS	(5) OLS	(6) OLS	(7) OLS	(8) 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				-1.501***				-1.455***
*(Log Export Competition)				(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.

3.7.2 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 (2010a), 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 3.2 describes the impacts of industrial upgrading on changes in the local population and real wages. As in Author, Dorn, and Hanson (2013), 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.[85] 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 3.3 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 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 3.2.

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 3.3 is consistent with the heterogeneous impacts suggested by the theory. The positive impacts of industrial upgrading are concentrated in the man-

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

Table 3.3: Industrial Upgrading and Employment and Wages in Local Labor Markets

	Change in Log Employment								
	Overall			Manufacturing			Non-Manufacturing		
	(1) OLS	(2) OLS	(3) 2SLS	(4) OLS	(5) OLS	(6) 2SLS	(7) OLS	(8) OLS	(9) 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) OLS	(11) OLS	(12) 2SLS	(13) OLS	(14) OLS	(15) 2SLS	(16) OLS	(17) OLS	(18) 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.

ufacturing 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 3.3 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.

3.7.3 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 3.3 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 3.4 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 3.4 considers only sectors at the CIIU-4 digit level, which are classified as primarily extractive (Panel a) and smelting and refinement (Panel b).[86]

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

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

Table 3.4: 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).

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 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 3.1: the growing participation of China in the refined mineral market (see Figure 3.2), 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 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, Marin, and Olivari, 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 3.5 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.

Table 3.5: Industrial Upgrading and the Size and Profitability of Services Suppliers

	Change in Log Employment			Change in Log Sales			Change in Log Revenue		
	(1) OLS	(2) OLS	(3) 2SLS	(4) OLS	(5) OLS	(6) 2SLS	(7) OLS	(8) OLS	(9) 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.

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, Lufin, and Soto (2019) 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 A3.1).

3.8 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 low value-added 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 value-added segments in a value chain relative to the lower value-added 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. Notwithstanding, industrial policy in the resource sector can be justified in light of other valid reasons that are not explored in this paper but are left to be explored in further research, such as activities that induced more learning and innovation, and/or larger innovation spillovers.

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.

Within these services suppliers policies, is particularly important to mention that firms that supply mining companies in the primary stage of production, do not necessarily provides same services to the secondary stage in the copper value chain. As estimates shows that the effects of industrial upgrading in the growth of the size and profitability of mining services suppliers firms in local labor markets are positive albeit small in magnitude. This is likely because of the heterogenous nature of the different services that are provided by these firms, and its substitutability among the two segments in the copper value chain involved in industrial upgrading. Descriptives shows that as more specialized the type of services offered, more negative is the effect. Supplier effects have to rely on import substitution. This deals directly with product market effects, i.e. the substitution of manufacturing inputs used by mining companies by local produced intermediate goods or services. These supplier firms can also be multinationals, or exporting firms. In fact, one of the main objectives of the public policy trying to strength local suppliers in the mining sector, has been reinforce capabilities, in order to make them exporters, in what the policy call "world class mining services suppliers".

The results also might imply that the process of industrial upgrading in this case, required much more time to develop in order that complementarities in inputs between both segments of the value chain emerge, so that would be a source of increasing returns, due to the lower cost of inputs. However, the channel of the productivity spillovers related with trade in intemediate inputs constitute a topic for further research. In particular, the effect on quality upgrading and *learning-by-doing* that suppliers of firms at different stages of the value chain can face due to to import competition. However, it is expected that this channel might induce higher productivity spillovers in suppliers of the lower segment of the value chain of copper, given that is more capital intensive than downstream activities in the value chain. In addition, the heterogeneous effects of this channel among supplier firms can give important lessons to inform industrial policy in resource-oriented emerging economies.

3.9 Appendix

3.9.1 Value Chain Related Activities (CIIU-4)

3.9.1.1 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. 3.1). 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.[87] 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 separated in two categories. A direct copper and related mineral transformation, and is conformed by the following activities

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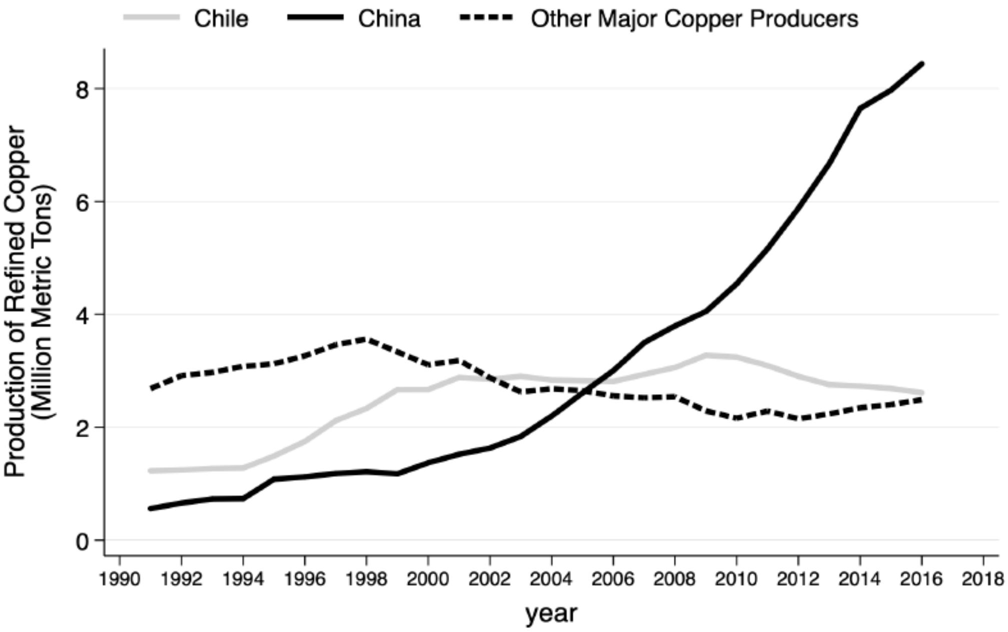
[87] For Chile, copper corresponds to 97% of the total mineral exports.

- 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.



Notes: The figure illustrates a simplified description of the copper industry value chain. Other major producers include Australia, Peru, and the U.S., among other.

Figure A3.1: World Production of Refined Copper

Table A3.1: Effects on the TFP of Manufacturing Firms

	Change in Log TFP					
				Olley-Pakes Method		
	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5) OLS	(6) 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 plant size, type of property of the plant, percentage of domestic owned shares, firm type, and the value of exported goods. 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.

When Does Illegal Mining Pay?
Evidence from the Gold Rush in the Peruvian Amazon

> *"...from the point of view of the world economy nothing is more beneficial than that those parts of the earth best suited to the production of raw materials be devoted to that purpose...*
>
> Knut Wicksell (1919)

Abstract

How do mineral price booms influence illegal mining in sourcing developing countries? This study examines the case of small-scale gold mining in the Peruvian Amazon to understand how informal and illegal supply chains of raw materials respond to global demand shocks. For this purpose, the study estimated the heterogeneous responses of small-scale gold mining to variations in the international gold prices. Using a combination of medium-resolution satellite images and official geographical information on mining sites, this study presents evidence that differences in mining activity between illegal and non-illegal producers disappear in the wake of high prices. The results suggest that price booms induce a more than proportional proliferation of illegal mining activity in comparison with that of non-illegal gold mining, which might be associated with an increase in the relative profitability of such producers. This might lead to a reconsideration of the current policy approach that underestimates the importance of price shocks, to limit the profitability of illegal gold producers in the study area.

4.1 Introduction

Unintended consequences of participation in international trade may arise when sourcing economies have precarious local institutional conditions, poor labor markets, and informal or illegal production networks to supply global markets (Mehlum, Moene, and Ragnar, 2006b; Angrist and Kugler, 2008; Brückner and Ciccone, 2010; Van der Ploeg, 2011; Dube and Vargas, 2013; Berman et al., 2017; Saavedra and Romero, 2021). Data limitations arising from the nature of informal and illegal activities imply that this dimension has been much less studied in the academic literature. In particular, trade from illegal sources tends to be hidden through formal intermediaries, making it difficult to trace and measure the extent of these activities and analyze how they respond to foreign demand shocks.[88]

Within illicit trade, one of the most environmentally destructive and dangerous but highly profitable illegal activities in developing countries is the illegal mining of precious minerals (SPDA, 2015; UNEP-INTERPOL, 2016; OECD, 2016; Berman et al., 2017). In 2015, it was estimated that trade in illegal mining was an industry worth annually between US$12–48 billion, equivalent to 1–4% of the total mining industry trade (UNEP-INTERPOL, 2016; Global Financial Integrity, 2017).[89] Because the profitability of these activities is directly linked to a surge in global demand (OECD, 2016), it is necessary to better understand the extent to which price booms affect the expansion of these informal and illicit forms of mining compared with the extent of their effect on formal mining. These are the marginal responses to foreign demand shocks, which can have important consequences for economic development, in particular, considering that the price of these commodities has experienced a significant rise during the last two decades and is expected to continue rising in the following years.

Within the illegal precious mineral mining industry, gold mining is the most profitable. This activity is highly concentrated in Latin America, particularly in the Amazon region.[90] An estimated annual worth of US$7 billion was produced in the region in 2016, equivalent to more than twice the total annual worth of global illicit trade of diamonds (Global Financial Integrity, 2017).[91] The industry has gained worldwide notoriety because of its large visible

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[88] Currently, measuring these costs is a major concern for policy makers and scholars, especially when disruptions in global supply chains make it more difficult to enforce responsible sourcing.

[89] This is at least six times the annual worth of illicit diamond trade that, in 2015, was worth approximately US$2.74 billion (Global Financial Integrity, 2017). There is evidence that the profitability of this activity has surpassed that of coca production (SPDA, 2015). Despite the existing evidence on how these activities foster conflicts (Berman et al., 2017) and their environmental consequences (Romero and Saavedra, 2019), there is a lack of evidence on how illegal activities respond to global demand shocks compared with how alternative legal activities do.

[90] This is in part explained because alluvial gold mining is less costly and more difficult to control in comparison to underground gold mining given the remoteness of mining sites in the Amazon region (SPDA, 2015).

[91] In the empirical literature, illegal mining of diamonds has received the most attention.

environmental impacts caused by deforestation, precarious working conditions, and negative consequences induced by the intensive use of mercury in production (Bebbington and Bury, 2009; Swenson et al., 2011; Ashe, 2012; Blackman et al., 2017; Romero and Saavedra, 2019; Tollefson, 2021).[92] It is estimated that illegal gold mining has contaminated over 30 rivers in the Amazon region, and in Peru alone, approximately 40 tons of mercury is dumped each day in the Amazon rivers owing to artisanal and small-scale gold mining activities (SPDA, 2015).

During the past decade, governments have invested enormous efforts in discouraging illegal gold mining in the Amazon region to mitigate these negative effects, but have seen no success (e.g., Saavedra and Romero, 2021).[93] A remarkable case within Latin America is that of a vast expansion of illegal gold mining in the Peruvian Amazon over the last two decades. Peru is the largest illegal (and non-illegal) gold producer in Latin America. In 2016, Peru was estimated to account for approximately 37% of the illegal gold production in the region (Global Financial Integrity, 2017). Given its relevance, this study investigates the case of the Peruvian Amazon gold rush to shed light on the differences in mining activity between formal, informal, and illegal small-scale gold producers, and on how these differences respond to shocks to the international prices of gold.[94]

The empirical strategy in the study was divided into two parts. First, the differences in the intensity of mining activities between formal, informal, and illegal gold mining producers were explored. Second, given the considerable differences in mining activity between illegal and non-illegal producers, the price elasticities and their heterogeneous effects distinguishing between these types of producers were reported. Evidence shows that the difference between formal and informal artisanal and small-scale gold mining was negligible and not statistically significant. This could be explained by the diffuse institutional boundaries that distinguish between these two groups. However, the difference in activity between illegal and non-illegal mining sites (including both formal and informal sites) was substantial, statistically significant, and robust. This suggests a much clearer contrast between the two types of producers, which is further explored in the estimates.

Consistent with the existing empirical literature, the price elasticity of the activity in mining sites is high (about 0.5 to 0.8) and robust to the inclusion of various fixed effects and controls. Naturally, this is indicative of an important dependence of activity in artisanal and small-scale

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[92] Alluvial gold mining is a type of mining with characteristics of small-scale and artisanal gold producers in the Amazon region. It uses water at high pressure to remove and filter the soil from gold particles.

[93] Literature differentiates between artisanal and small-scale producers in that artisanal producers may be much less organized, and may have a highly precarious technology of production.

[94] Gold mining in the Amazon region is dominated by artisanal and small-scale mining because the type of mining developed in the area—alluvial gold mining—is not profitable on a large scale.

gold mines on variations in the international prices of gold. More importantly, the interaction between the price of gold and type of mine (illegal vs. non-illegal) reveals an important difference associated with the price effect between these producers that disappears for high values of gold price. In other words, evidence suggests that a particularly large price boom can lead to a more than proportional increase in the intensity of illegal gold mining activity compared with that in the intensity of non-illegal mining, potentially explained by an increase in the relative profitability of illegal versus non-illegal gold mining activities. These results show the relevance of price shocks for the proliferation and intensity of illegal mining activities that might redirect future policy interventions.

The remainder of this paper is organized as follows. The context of the empirical case studied is explained in section 2. Section 3 describes the data along with theoretical mechanisms and predictions to be identified and tested. Section 4 presents the methodology followed by results. Conclusion and policy implications are presented in Section 5.

4.2 Background

4.2.1 Overall Context

Peru is one of the world's largest producers of gold, along with other minerals such as silver and copper.[95] This is because of the particularly rich concentration of ore deposits in the area surrounding the Andean Mountains and the Amazon region, accompanied by a long-lasting tradition in mining activity (e.g., Dell, 2010). The overall mining sector in Peru represents approximately 62% of its total exports, 12% of the GDP, and 30% of the state revenue. In recent decades, gold production has reached a peak of 20% of the world market. More recently, gold has become the second largest export commodity after copper, with the main destination markets being Canada, the USA, Switzerland, India, and the UAE. Of particular interest are the size and persistence of informal and illegal gold mining in these exports, which are predominantly carried out by artisanal and small-scale producers. These producers tend to be highly dependent on international gold prices (see Fig. 4.1).

Despite the difficulties in measuring informal and illegal mining, official estimates suggest that informal and illegal gold mining reached more than 60% of total Peruvian gold exports in the early 90s, and currently represents approximately one-third of the total exports (Global Financial Integrity, 2017). Even though there has been a reduction in informal and illegal gold mining in comparison with formal gold mining, the informal and illegal gold mining production capacity has increased over the last few decades. As displayed in Fig. 4.1, the

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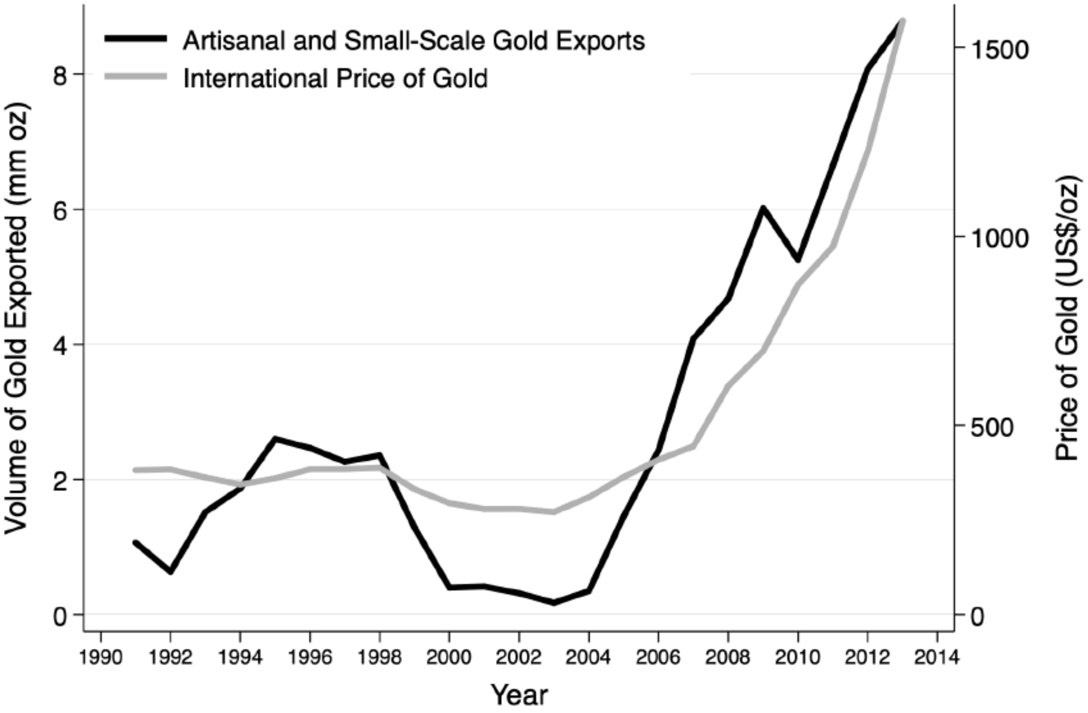
[95] The country accounts for 18% of copper production and 27% of silver production globally.

volume of Peruvian gold exports has grown by more than eight times since 1990. In fact, during the 2000s alone, the area associated with artisanal and small-scale gold mining activity in the Peruvian Amazon grew by approximately 400%, as estimated using satellite images (Asner et al., 2013; Asner and Tupayachi, 2017; Espejo et al., 2018). This is equivalent to more than 50,000 hectares of Amazon forest loss Asner et al. (2013).



Notes: The figure describes the evolution in gold prices and artisanal and small-scale gold production (formal, informal, and illegal) in Peru. The estimated exported produce associated with small-scale producers considers formal, informal, and illegal gold mining. Despite the decrease in the participation of informal mining in total gold production from 60% to approximately 30% over the last decades, the absolute size of the informal sector has increased substantially during the same period.

Figure 4.1: Artisanal and Small-Scale Gold Production and the Price Boom

While formal mining tends to be concentrated in northern Peru in close proximity to the urban areas, informal and illegal gold mining is usually located in remote areas in the southern Peruvian and Amazon regions (see Fig. A4.1) where small-scale gold mining is more common and challenging to control because of the difficulty in accessing the mining sites. Approximately 70% of small-scale gold producers are located in the Amazon region of Madre de Dios (SPDA, 2015). Artisanal and small-scale gold mining are labor intensive, need low levels of production technology, and are an important source of income for local workers who lack profitable alternatives. It is suggested that a worker at an artisanal and small-scale gold mining site can earn about five times the earnings of an agricultural worker in the study area (Global

Financial Integrity, 2017). Recent estimates indicate that approximately 10,000 workers are employed in the informal and illegal gold mining sectors in Madre de Dios, and nearly 20,000 indirect workers offer services for these activities in the area (USAID, 2021). This is alongside the population of departments involved in this region growing over the national average.

4.2.2 The Process of Alluvial Gold Mining

Alluvial gold mining is the predominant form of artisanal and small-scale gold mining in the Amazon Region. This type of mining activity encompasses formal, informal, and illegal gold mining, and is spatially concentrated in the Peruvian region of Madre de Dios. The overall mining process is simple, labor and land intensive, and has low technological requirements. First, this process involves forest clearance. This is followed by a hydraulicking stage where the soil is loosened and fractured, then filtered in a sluice box, and then washed. The third stage consists of separating the gold particles, which involves further filtering and washing with water and mercury. Finally, once the gold particles are separated, the waste residues are amalgamated and dumped. The entire process can lead to a few grams of gold per day for a small-scale gold mine in the study area. Workers move extensively over the area over a few months to search for more gold.[96] The process is environmentally demanding, with long-term consequences like deforestation, loss of biodiversity, and water poisoning by mercury.

4.2.3 Formal, Informal, and Illegal Gold Mining

In contrast with formal artisanal and small-scale gold mining, both informal and illegal gold mining lack official authorization to operate; however, informal gold mining takes place in non-protected areas, whereas illegal gold mining operates in protected areas. Practically, this implies that workers at illegal gold mining sites are more likely to be arrested, and their equipment, destroyed by the police and military officers. By contrast, workers at informal gold mining sites do not face this problem. However, informal gold producers might still have to pay a fine, and receive a lower price for their produce than what formal artisanal and small-scale gold producers would. This is because trade in informally or illegally produced gold is prohibited by law, and formal producers tend to participate more in cooperatives that have agreements with large intermediaries of gold as part of their responsible sourcing initiatives. In some cases, this implies that formal mining sites might have a better production technology with lower environmental impacts and fewer negative consequences for the health of their workers than those for informal and illegal artisanal and small-scale gold mining workers.

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[96] For a mining site of about 30 meters, the site is exhausted in less than a year.

The process of formalization of a mining site usually takes several months. This process does not necessarily follow previous registries of land used for other purposes in the area such as agriculture or forestry, potentially leading to conflicts about land use rights. Furthermore, anecdotal evidence suggests that some mining concessions may be used to declare the gold produced at illegal mining sites (SPDA, 2015). This is because a formal concession to a mining site implies that the site has to be exploited and a minimum amount of production must be declared; otherwise, a penalty proportional to the hectares under the concession is applied to the owner of the concession under the Peruvian General Law of Mining.[97] If the penalty is not paid in the two years following, the concession is revoked. Once a concession is granted, however, the producers are required to report at least a minimum amount of gold produced in the years following, to keep the concession. These factors imply that the distinction between formal and informal gold mining in the region is diffuse or blurred, as the laws that regulate informal activity are diffuse and came into effect more recently.

Hypothesis 1. *There are differences in the intensity of activities between informal, formal, and illegal gold mining sites. However, this difference between formal and informal mining sites tends to be more diffuse.*

The distinction between illegal and non-illegal mining, including both formal and informal mining, is more evident. This is in part because the protected natural areas were defined earlier in the sample and are geographically more easily distinguishable (see Fig. A4.2 for the official boundaries of mining concessions and protected areas in the Peruvian Amazon). According to qualitative surveys, the organization of artisanal and small-scale gold mining workers in the region tends to be decentralized (SPDA, 2015). A worker from a group of workers at an artisanal or small-scale mining site usually explores new areas to develop, while also moving in response to inspections by the police and military authorities. This is in contrast with non-illegal-including formal and informal-gold mining, where workers tend to stay more at the sites, and move to other places only when they exhaust the land in the area. Workers usually move to small camps and follow the gold tracks found by other miners. In the case of formal and informal mining, this occurs within the geographical boundaries of the so-called *"corredor minero"* (mining corridor). The area delimited by the government is authorized for exploitation. However, most illegal gold mining falls within protected natural areas and the *"zona de amortiguamiento"* (buffer zone), a geographical belt between the mining corridor and natural reserves.

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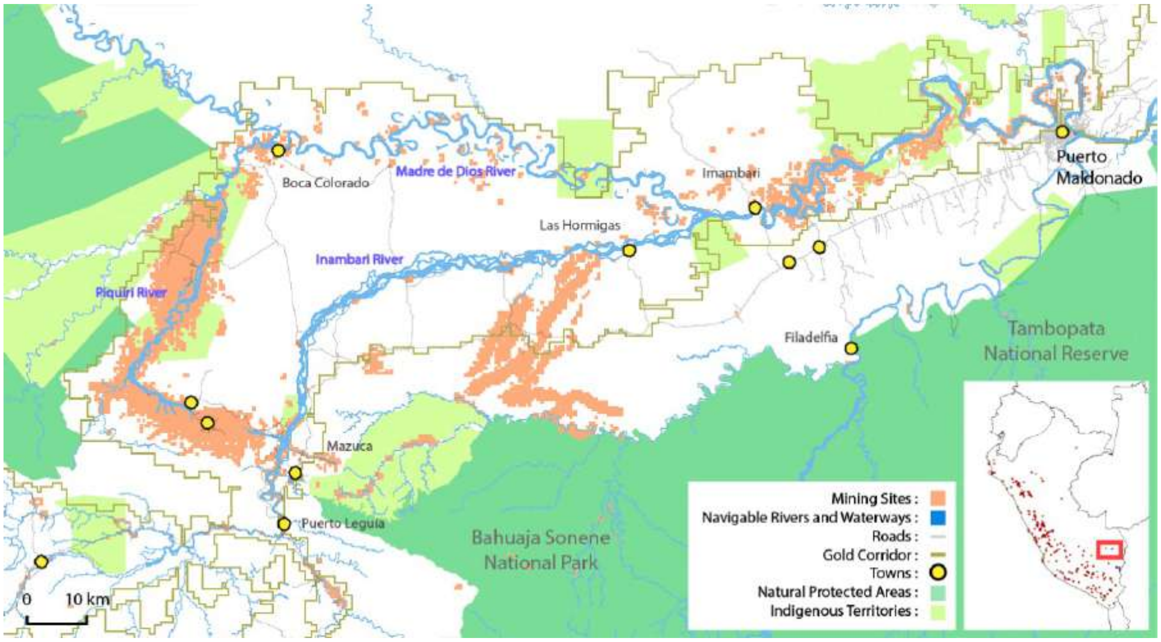
[97] These laws are stipulated in: DL No. 1320 and DS No. 011-2017-EM.



Notes: The figure shows the artisanal and small-scale gold mining sites (area in orange) in the Peruvian Amazon region of Madre de Dios, where an estimated 70% of the artisanal and small-scale gold Mining in Peru is produced. Unless specified in the data on mining concessions (see Fig. A4.2), non-illegal gold mining sites are generally defined as sites that fall within the boundaries of the Mining Corridor (polygon with golden borders). Almost all mining sites outside this polygon are defined as illegal mining sites. Illegal mining sites include sites that fall in the Buffer Zone, that is, the area between the Mining Corridor and protected natural parks, and sites within the boundaries of the protected natural areas and indigenous territories. For mining sites within the boundaries of the Mining Corridor, data on mining concessions from the Peruvian Ministry of Mines (see Fig. A4.2) allows the identification of these sites as formal (with a concession granted), and informal (without a mining concession).

Figure 4.2: Artisanal and Small-Scale Gold Mining in the Peruvian Amazon Region

4.2.4 Policy Making

Major policy efforts regarding the formalization and control of illegal gold mining activity in the Peruvian Amazon began in the 2000s, with a boom in commodity prices. These were, in part, motivated by the large visible impacts of the gold mining activity in the form of deforestation. Before these reforms, these activities were practically unregulated. Informal and illegal gold mining had developed without major restrictions, despite the geographical delimitation of the protected natural areas and the existence of mining concessions and rights for different land uses in the region dating back to 1977.[98] The first major reform to formalize the activity was implemented as late as in 2002, followed by a series of reforms that did not have a major impact on the activity, due to which gold mining continued to expand in the

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[98] Before 2000s, the Peruvian government did not have much incentive to discourage gold mining in the Amazon region given that this activity induced a significant growth in the population in the region, and there were geopolitical interests in preventing occupancy of these lands by Brazilian forces.

area.

A major reform toward the formalization of gold mining activities in the region was implemented in 2011. With this reform, miners could now request a concession over a certain area that automatically granted them the legal right to exploit a mining site within it. After the concession was requested, the miners had a period of three years to complete the process of formalization. Many concessions were requested in the years following this reform. However, this policy was heavily criticized because it was perceived that illegal gold producers could take advantage of these concessions to declare their exploitation from other sites as a form of money laundering. The process of formalization as per this reform was completed in 2014 after which any new request for concessions entails slightly more rigorous control. Under this new regulation, the existing and new mining concessions in the area face more stringent law enforcement and greater control of illegal gold mining activity. These controls involve police and military raids, destruction of illegal producersâ mining equipment, and clashes that occasionally result in casualties.[99]

Hypothesis 2. *Price elasticity of gold mining sites is high and tends to be higher in illegal mining sites, capturing the lower cost of being informal or illegal.*

4.3 Data

4.3.1 Identifying and Measuring Alluvial Gold Mining Activity

To measure the activity of each mine, I adopted a variation of the strategy pioneered by the work of Hodler and Raschky (2014), followed by Berman et al. (2017), Mamo, Bhattacharyya, and Moradi (2019), and Saavedra and Romero (2021), among others. Specifically, I used a composite measure of nightlight data (MODIS) and spectral information from medium-resolution satellite images ($\approx$500 m) to construct a proxy for the intensity of the mining activity at each site. This measure was validated by examining the correlation with formal gold mining production in the Amazon region of Madre de Dios, as reported by the Peruvian Ministry of Mines (MINEM). This strategy provided a large number of monthly data observations between January 2014 and December 2018 for approximately 4,000 mining sites identified in the Peruvian Amazon region.[100]

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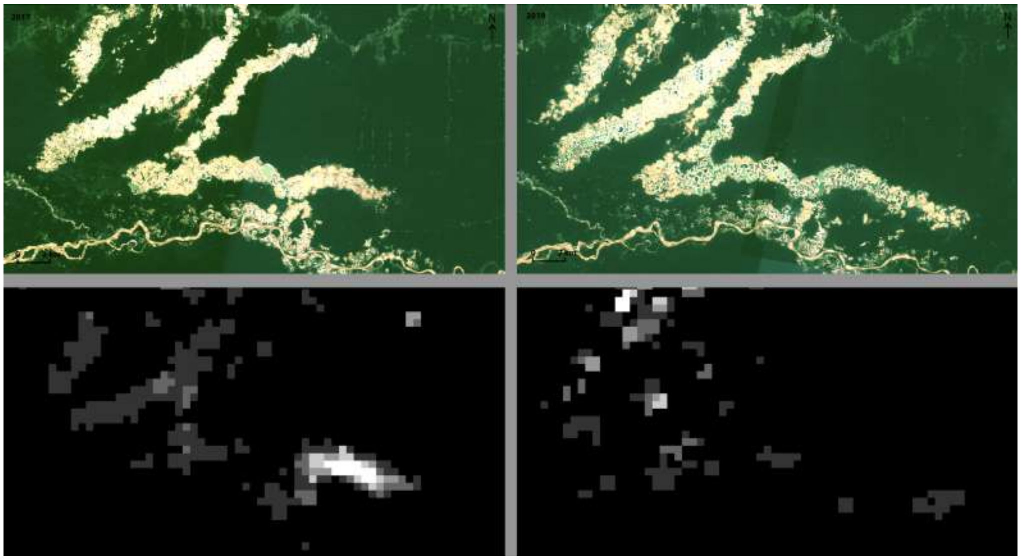
[99] Despite the existence and growth of conflicts caused by the mining activity in the Amazon region, these are small in magnitude and not comparable to those reported in the empirical literature on the African region (e.g., Berman et al., 2017) or other Latin American countries such as Colombia and Venezuela. Empirically, however,



Notes: The figure shows the distribution of night-time light values of mining sites according to the categories identified in the registry of mining concessions and protected areas for the period from 2014 (light colors) to 2018 (darker colors). Each mining site ($n = 369,017$) represents an area of approximately 30m2 for which the value of night-time lights from MODIS is presented. The mining site is considered active when a positive value of night-time light is reported. Vertical lines represent average values for each category. Formal mining sites ($n = 211,596$) are represented by pixels that are within areas with a registered valid concession. Informal mining sites ($n = 97,127$) are represented by pixels in areas without a registered valid concession but authorized for mining activity, denoted as the *"corredor minero"*. Illegal mining sites ($n = 60,294$) are represented by pixels within protected natural parks and indigenous land.

Figure 4.3: Intensity of Activity in Mining Sites

4.3.2 Defining Formal, Informal, and Illegal Mining Sites

Once mining sites were identified using satellite information, the layers of official data on mines from protected areas and the mining cadastral from the Peruvian Ministry of Mines were used to classify each pixel identified as a mine (see Fig. A4.2). Whenever a pixel was within a protected area, the mining site was classified as illegal. When a site fell within the boundaries of the cadastral areas registered as concessions, the information of this concession was added to the pixel. This information contained the date on which the concession was granted. In this context, an informal mine could become formal during the study period or a formal one could become informal if its concession expired. Finally, when a pixel was outside any of these areas, the mine was classified as informal. This definition and classification of

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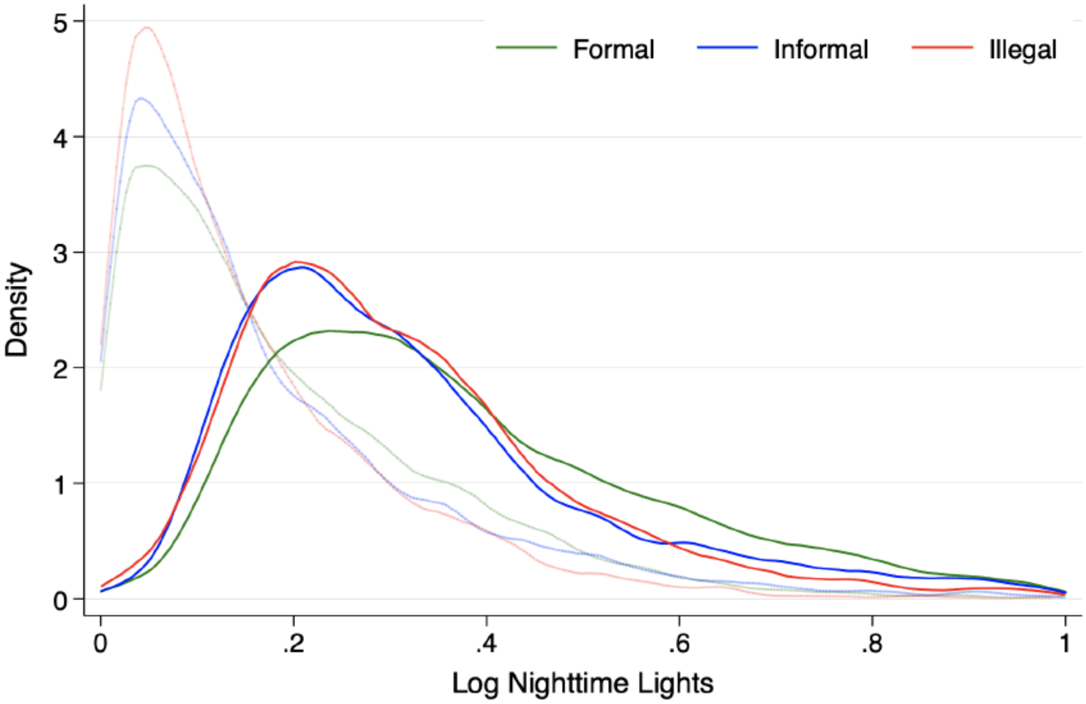
these concerns are addressed by proxying for the likelihood of such events at mining sites.

[100] The large number of observations is key to estimating the price channels because it provides sufficient room to identify the interactions between prices and a series of variables capturing these different channels of the supply chain. This method of using pixels as the unit of observation has also been used in Berman et al. (2017). Here, the claim is simpler because these pixels were already identified as part of mining sites by a machine learning classification algorithm, as in the work of Soto-Díaz (2022).

mines closely followed those used by the government authorities.[101]



Notes: The figure shows the distribution of night-time light values of mining sites according to the categories identified in the registry of mining concessions and protected areas for the period from 2014 (light colors) to 2018 (darker colors). Each mining site ($n = 369,017$) represents an area of approximately 30m2 for which the value of night-time lights from MODIS is presented. The mining site is considered active when a positive value of night-time light is reported. Vertical lines represent average values for each category. Formal mining sites ($n = 211,596$) are represented by pixels that are within areas with a registered valid concession. Informal mining sites ($n = 97,127$) are represented by pixels in areas without a registered valid concession but authorized for mining activity, denoted as the *"corredor minero"*. Illegal mining sites ($n = 60,294$) are represented by pixels within protected natural parks and indigenous land.

Figure 4.4: Differences in the Intensity of Activity in Mining Sites

4.4 Empirical Evidence

The empirical strategy was divided into two parts to provide comprehensive evidence of the case studied. First, the differences in activity between informal and formal, and illegal and non-illegal gold mining sites were analyzed. Second, given the significant differences found, the heterogeneous responses of illegal and non-illegal gold mining sites to the international

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[101] Nearly 15% of the cadastral registry surface overlaps other mining concessions. In addition, some of these concessions also overlap forest land use for production and forest concessions (see Fig. A4.2). A small number of mining concession areas overlap protected natural reserves or areas of indigenous land and an area called *"zona de amortiguamiento"* (buffer zone): a protected land area between protected natural areas and the mining corridor.

price of gold were further explored.

4.4.1 Estimation Strategy

4.4.1.1 Comparative Differences between Gold Producers To test for differences between formal, informal, and illegal gold mining activities, previously defined in Subsection 4.3.2, two sets of regressions were estimated. The first set compared informal gold producers with formal gold producers, whereas the second set compared illegal gold producers with non-illegal producers, including formal and informal gold mining. More precisely, we estimated these differences using the following specification:

$$\log y_{ot} = \alpha + \delta D_{ot} + \theta_d + \theta_t + \theta_{dt} + \mathbf{X}'_{ot}\Gamma + \eta_{ot}, \tag{37}$$

where D_{ot} is an indicator function that categorizes a mining site as informal (relative to formal) or illegal (relative to non-illegal). θ_d are district fixed effects; θ_t are month fixed effects; θ_{ot} are district-by-month fixed effects; $\mathbf{X}'_{ot}$ is a vector of geographic coordinates, and η_{ot} denotes an idiosyncratic error term. Given the set of fixed effects in Eq. 37, the identification of the differences between gold mining sites relies on the spatial variation within each district in each month, balancing the observations by their precise location. However, to gain a better understanding of the differences between formal and informal gold mining activities, it is possible to exploit more temporal variations in each mining site, more precisely, to exploit the fact that some mining sites operating in the sample became formal. Accordingly, an event study was implemented using this subsample of observations with the following staggered Diff-in-Diff specification:

$$y_{ot} = \alpha + \sum_{k=-m}^{-1} \delta_k D_{ot} + \sum_{k=0}^{m} \delta_k D_{ot} + \theta_o + \theta_t + \eta_{ot}, \tag{38}$$

where the event was determined by the month in which the formal mining concession was registered as granted. The reported results use the Sun and Abraham (2020) correction for the potential negative weights in the estimates driven by heterogeneous treatment effects. In Eqn. 38, the differences in the intensity of mining activity between informal and formal gold mining sites were identified from the variation in the timing of formalization. Given that mining sites tend to operate for usually no longer than a year, this exercise compared the differences between the five months before and after the formalization. This was done using the date on which the concession was registered according to the mining cadastral of the Peruvian Ministry of Mines.

4.4.1.2 Price Elasticities

As the differences between gold mining sites have been documented now, the following section discusses these differences in the context of the international monthly price of gold. This is the key component of the empirical evidence and motivation behind this study, which is to understand how illegal gold mining in comparison with non-illegal gold mining responds to the shocks to the international price of gold. Specifically, the existence of the heterogeneous effects of the price of gold on illegal and non-illegal mining sites was tested in the following specification.

$$\log y_{ot} = \alpha + \beta \log Price_t + \delta D_{ot} + \lambda(D_{ot} \times \log Price_t) + \theta_d + \theta_t + \theta_{dt} + \mathbf{X}'_{ot}\Gamma + \eta_{ot}, \tag{39}$$

where D_{ot} is an indicator function for illegal mines relative to non-illegal mines (including formal and informal sites). θ_d are district fixed effects; θ_t are three-month period fixed effects; θ_{dt} is the three-month period by district fixed effects; Γ is a vector of geographic coordinates, and η_{ot} is the error component. The identification of these heterogeneous effects relies on the exogeneity of the international price of gold and spatial differences in the intensity of activity across mining sites.[102]

To identify the degree of the price effect, given that this varies monthly, the time and time-by-district fixed effects considered a three-month window. Fig. A4.4 shows the variation in the international gold price and average night-time lights over these three-month period windows. A substantial variation of about 25% is seen over a few months in the gold price and intensity of activity at mining sites. In addition, it shows the absence of particular trends during the analysis period. The results with the full sets of fixed effects including month and pixel fixed effects are also reported.

4.4.2 Results

4.4.2.1 Comparative Differences between Gold Producers

Consistent with the previous descriptive evidence, the results in columns 1 to 3 of Table 4.1 show that informal mining sites tend to have lower night-time light intensity than formal mining sites do. However, this difference was not statistically significant. As described in subsection 4.2.3, this is likely explained by the diffuse institutional boundaries that distinguish between informal and formal small-scale gold mining activities. In other words, the lack of regulation of informal mining sites might induce a similar intensity of activity to that of formal mining sites. By contrast, when illegal mining sites are compared with non-illegal—including formal and informal—

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[102] Even though Peruâs gold exports are large, there is no evidence that they affect the international price of gold, especially considering that these observations represent artisanal and small-scale gold producers.

sites in columns 4 to 6 of Table 4.1, the difference is statistically significant and robust to the inclusion of fixed effects and geographic coordinates. These estimates suggest that illegal mining sites have approximately 4% lower night-time light intensity than non-illegal gold mining sites do.

Several reasons could be identified why these results show more differences between illegal and non-illegal gold mining sites than between informal and formal sites. The principal reason among these is that the institutional boundaries that define informal and formal gold mining are more diffuse than those that define illegal and non-illegal gold mining. Specifically, as mentioned previously in the case study, informal gold mining activities in the region are usually not prosecuted. They are considered illegal gold mining. Informal miners may continue to exploit their sites as long as they pay the fines if they are denounced to the authorities, or do not face opposition from landowners, those with other concessions, or the local population. By contrast, illegal gold miners may face imprisonment, and their equipment may be destroyed upon arrest. This implies that they must move quickly over the land as they mine to avoid the police, and smuggle their equipment and produce to avoid being caught in the rivers and roads. Trade in fuel and mining equipment is banned above a certain threshold in these areas.

Despite the seemingly insignificant differences between informal and formal gold mining sites in terms of the spatial variation, the event study on formalization in Fig. 4.5 reveals a clearer picture of the differences between these producers. Specifically, the estimates that rely on the variation in the timing of formalization of a subsample of the previously informal mining sites show that in the five months preceding the formalization, informal mining sites tended to have a lower night-time light intensity relative to what formal mining sites did. However, once formalization was completed, these differences disappeared and became insignificant in the five months after formalization.[103] This indicates that formalization of previously informal mining sites led to higher activity relative to the night-time lights revealed prior to the formalization. These results might be explained by informal miners adopting better technologies in their production, which were captured by night-time light intensity.

4.4.2.2 Price Elasticities The results on the effect of the gold price on the intensity of activity at mining sites and how the differences in the intensity of activity between illegal and non-illegal gold mining sites respond to variations in the price of gold are reported in Table 4.2. Price elasticity is positive, economically, and statistically significant, and robust to the

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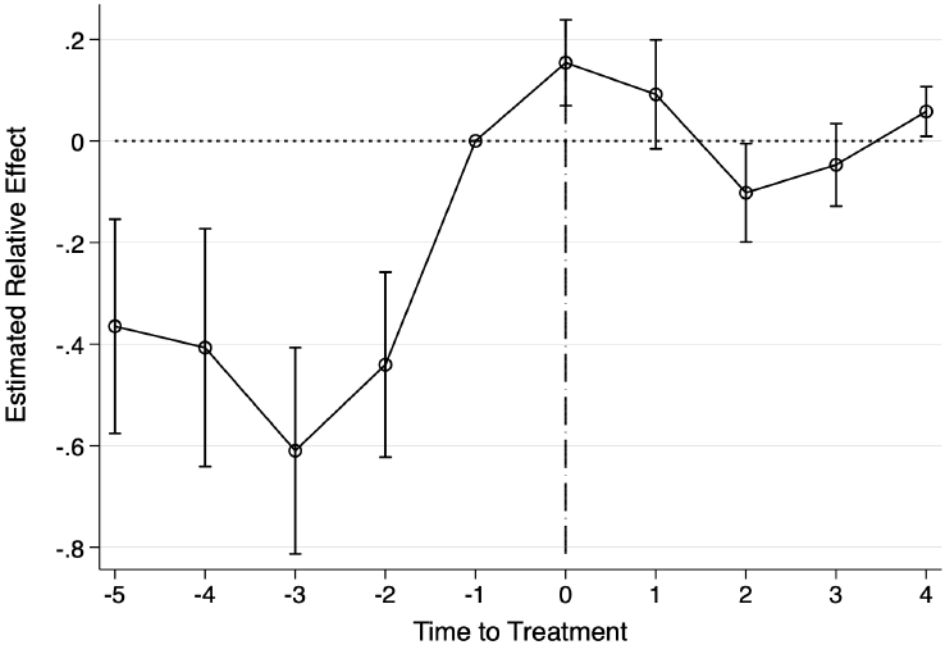
[103] The event study could not be carried out over a longer period due to a lack of a sufficient number of observations. In most cases, the mine started to operate once the concession was granted, and therefore, there were few pre-treatment observations like the observations used in Table 4.1.

Table 4.1: Differences between Gold Mining Sites

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Informal (=1)	-0.015	-0.020	0.002	0.003	0.006					
	(0.014)	(0.015)	(0.013)	(0.013)	(0.011)					
Illegal (=1)						-0.065*	-0.070*	-0.040**	-0.039**	-0.038***
						(0.034)	(0.038)	(0.016)	(0.015)	(0.012)
Month FE		✓	✓	✓	✓		✓	✓	✓	✓
District FE			✓	✓	✓			✓	✓	✓
Month × District FE				✓	✓				✓	✓
Geographic Coord.					✓					✓
Constant	0.299***	0.301***	0.294***	0.293***	32.088**	0.294***	0.295***	0.290***	0.290***	29.655***
	(0.035)	(0.038)	(0.004)	(0.004)	(13.674)	(0.032)	(0.035)	(0.003)	(0.002)	(10.023)
Adjusted R^2	0.001	0.152	0.229	0.264	0.275	0.010	0.172	0.241	0.275	0.285
Observations	421,447	421,447	421,447	421,384	421,384	505,070	505,070	505,070	505,009	505,009

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. The standard errors are in parentheses. Standard errors are clustered at the district level. Each observation corresponds to a 30m pixel identified as a mining site in a given month between January 2014 and December 2018. In columns (1) to (3), informal sites (=1) are compared with mining sites identified as formal only, and illegal mining sites are dropped from the sample. In columns (4) to (6), Illegal sites (=1) are compared with mining sites identified as non-illegal (including both formal and informal).



Notes: The figure displays the results of an event study using the mining sites before and after the mining concessions were granted. Night-time lights and the mining cadastral registry were used for the purpose. The time to treatment was measured in months from the date the mining concession was registered. The y-axis shows the estimated relative effect of the formalization of informal sites in comparison to mining sites that were formal during the period. Before the concession was registered, there were significant differences between informal and formal mining sites, but those differences in night-time lights disappeared once the concession was registered. Because the protected areas were defined prior to the sample period, an event study could not be undertaken on illegal mining sites.

Figure 4.5: Event Study on Formalization

specifications. The magnitude of this coefficient is approximately 0.5. These results are consistent with those shown in Fig. 4.1, suggesting that artisanal and small-scale gold mining are highly sensitive to the variations in the international price of gold. Specifically, a price boom, as shown in Fig. 4.1 that increased the gold price by approximately 3, is estimated to have increased the overall artisanal and small-scale gold mining by 1.5 times.

It is interesting to observe the heterogeneous effects of gold prices across illegal and non-illegal producers. As the previous descriptive evidence suggests, illegal gold mining sites have a significantly lower intensity of mining activity. However, this intensity increases with an increase in gold prices. This implies that for high values of gold prices, the difference in night-time light intensity between illegal and non-illegal producers disappears. This is clearly represented by the marginal effects of gold prices, as shown in Fig. 4.6.[104] As displayed in Fig.

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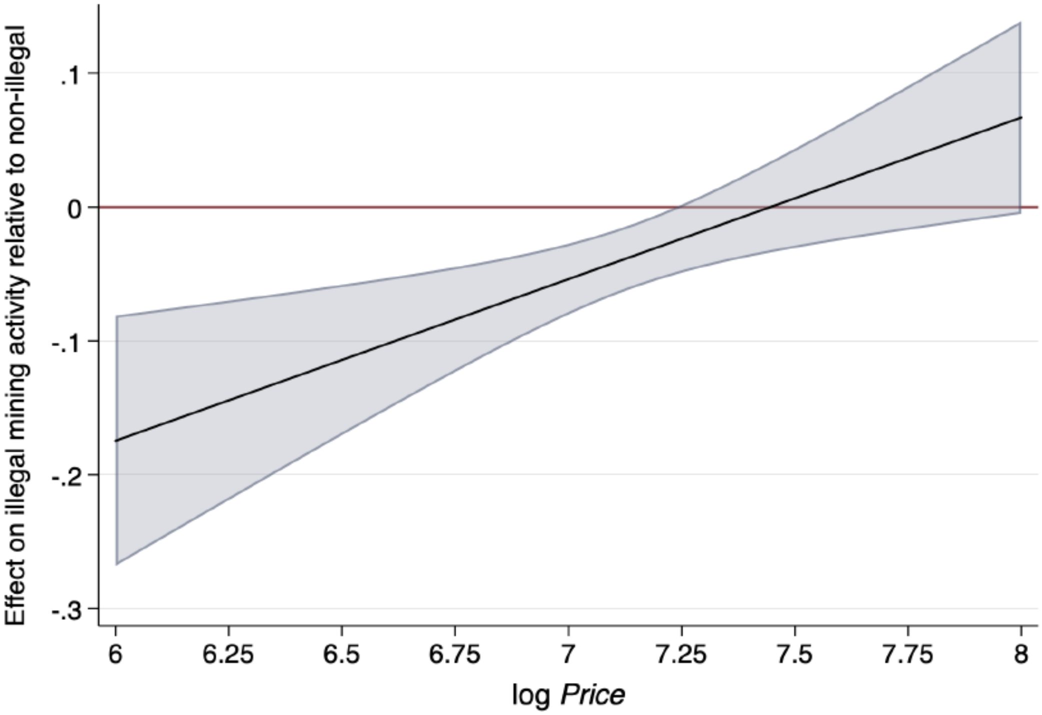
[104] Nonlinear effects were estimated, but were found to be insignificant.

Table 4.2: Price Elasticities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log *Price*	0.664***	0.671***	0.646***	0.432***	0.514***	0.516***	0.537***
	(0.032)	(0.034)	(0.036)	(0.146)	(0.120)	(0.128)	(0.135)
Illegal (=1)		-0.066*	-1.180***	-1.116***	-0.883**	-0.992***	-0.899***
		(0.035)	(0.240)	(0.235)	(0.323)	(0.283)	(0.289)
Illegal (=1) × log *Price*			0.156***	0.147***	0.118**	0.134***	0.121***
			(0.038)	(0.036)	(0.047)	(0.040)	(0.040)
Three-Month Period FE				✓	✓	✓	✓
District FE					✓	✓	✓
Three-Month Period × District FE						✓	✓
Geographic Coord.							✓
Constant	-4.452***	-4.488***	-4.310***	-2.781**	-3.375***	-3.390***	25.677**
	(0.221)	(0.231)	(0.236)	(1.072)	(0.860)	(0.913)	(9.500)
Adjusted R^2	0.021	0.032	0.032	0.134	0.202	0.217	0.227
Observations	505,070	505,070	505,070	505,070	505,070	505,067	505,067
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
log *Price*	0.646***				0.768***		
	(0.036)				(0.030)		
Illegal (=1)	-1.180***	-1.034***	-0.794**	-0.736*			
	(0.240)	(0.270)	(0.376)	(0.377)			
Illegal (=1) × log *Price*	0.156***	0.135***	0.106*	0.098*	0.089**	0.070	0.043
	(0.038)	(0.042)	(0.054)	(0.054)	(0.038)	(0.048)	(0.050)
Month FE		✓	✓	✓		✓	✓
District FE			✓	✓			
Month × District FE				✓			✓
Pixel FE					✓	✓	✓
Constant	-4.310***	0.295***	0.290***	0.290***	-5.298***	0.201***	0.232***
	(0.236)	(0.035)	(0.003)	(0.002)	(0.192)	(0.056)	(0.058)
Adjusted R^2	0.032	0.172	0.241	0.275	0.404	0.588	0.623
Observations	505,070	505,070	505,070	505,070	505,070	505,067	505,009

Notes:$^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parentheses. Standard errors are clustered at the district level. Period of observations is monthly. Each observation corresponds to a 30m pixel identified as a mining site in a given month between January 2014 and December 2018. Illegal (=1) is compared with mining sites identified as non-illegal (including both formal and informal).

4.1, the last price boom increased the price of gold by three times. In line with this, an increase in the price of gold of approximately 30% from the average in the sample would increase the intensity of illegal mining activity such that the activity level exceeds that of legal small-scale gold mining in the Amazon region. In further analysis, the non-linear effects of the price of gold on the intensity of activity at mining sites were explored but found not to be statistically significant.



Notes: The figure presents the marginal effects of gold price from Column (6) in Table 4.2. The y-axis shows the difference in the intensity of mining activity measured with night-time lights between illegal and non-illegal mining sites.

Figure 4.6: Marginal Effects of Gold Price

4.5 Conclusion and Policy Implications

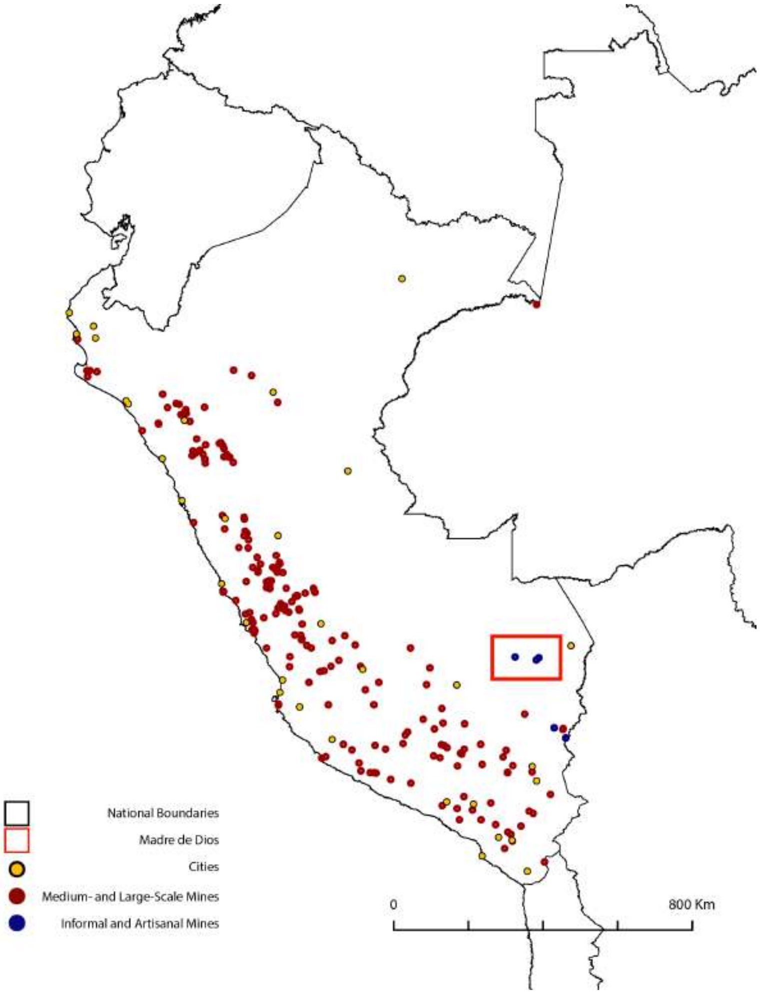
To shed light on the responses of informal and illegal mining in comparison with formal mining to large foreign demand shocks, this study estimates the differences in the intensity of mining activity between formal, informal, and illegal small-scale gold producers in the Peruvian Amazon and how these differences respond to variations in the international price of gold. First, the results show an important and robust difference in the intensity of mining activity between illegal and non-illegal gold mining producers, on average, of about 4%, but negligible differences between informal and formal producers. However, an event study using a sub-sample of previously informal mining sites that were formalized in the study period showed that in the months before the formalization of the site, informal mining displayed an average of 4% lower night-time light intensity than formal mining did. However, once the mining site was formalized, these differences disappeared in the months following the granting of the concession to the site.

Second, and more importantly, from a policy perspective, the evidence shows that the intensity of activity of artisanal and small-scale gold producers is highly sensitive to variations in the international price of gold, with a price elasticity of approximately 0.5 to 0.8, across the different estimates, and is robust to the inclusion of a wide set of fixed effects. Moreover, these effects are highly heterogeneous between illegal and non-illegal producers, suggesting that a price boom causing a price rise of about 25% in the average price level makes the differences disappear between illegal and non-illegal producers in night-time light intensity. Such price variations were observed in the sample within a short period of less than one year. More precisely, the results suggest that a significant price increase can lead to a more than proportional increase in illegal gold mining activity relative to non-illegal gold mining. This is arguably the result of an increase in the profitability of this activity.

These results have important policy implications. The current policy approach to discourage illegal gold mining activity in the Peruvian Amazon is based on artificially increasing their costs of production to reduce the profitability. For this purpose, authorities have banned the commercialization of mercury and fuel in illegal gold mining areas. However, this activity has continued to spread in recent years. Although the economic logic of this policy approach is correct and might lead to a decrease in profits from illicit mining activity, and thus, a decrease in illegal activity, the results of this study suggest that the incentives to engage in illegal gold mining are too high, and the activity is highly responsive to international demand shocks. In other words, the high price elasticities of the activity of small-scale gold producers suggest that they are more likely to respond to policies that target marginal income.

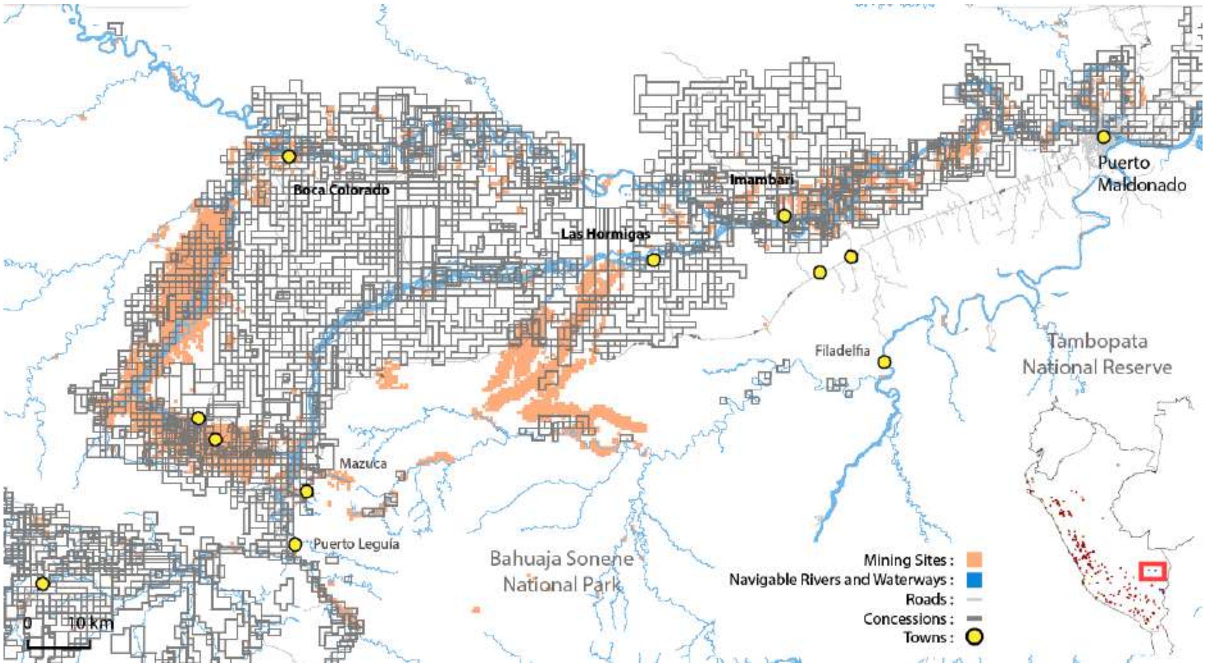
These results imply that authorities can, on the one hand, have a more significant impact by implementing policies that affect the local price of illegal gold relative to non-illegal gold, especially, policies that reduce the effect that unexpected shocks to the international price of gold might have in the form of raising the profitability of illegal gold mining. This type of policy might reduce the elasticity found in the estimates. To do this, the government might consider regulating gold market intermediaries, as they are the main buyers of this illicit gold. On the other hand, they can promote fair trade policies that increase the profitability of formal mining relative to informal and illegal mining. However, more research is required to quantify the impact of these policies, and in particular, on the role of intermediaries in the gold supply chain.

4.6 Appendix



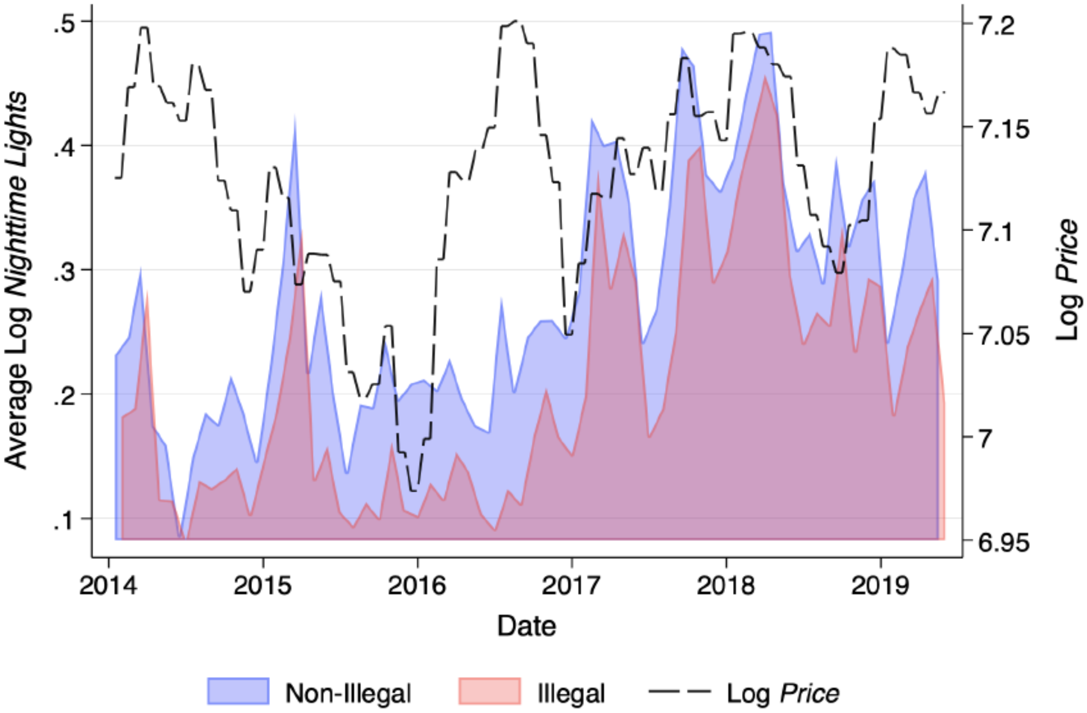
Notes: The figure shows the spatial distribution of cities represented by yellow dots (with a population greater than 25,000 inhabitants), and mines. Medium- and large-scale mines are represented by red dots, whereas small-scale informal and artisanal mines are represented by blue dots. The study area, "Madre de Dios" is highlighted by the red box. Small-scale informal and artisanal mining is concentrated in southern Peru and the Amazon region, and on gold mining. The region accounts for about 70% of small-scale and artisanal gold exports. Medium- and large-scale mining is scattered across the Andean region and is in close proximity to urban areas.

Figure A4.1: The Geography of Mining in Peru



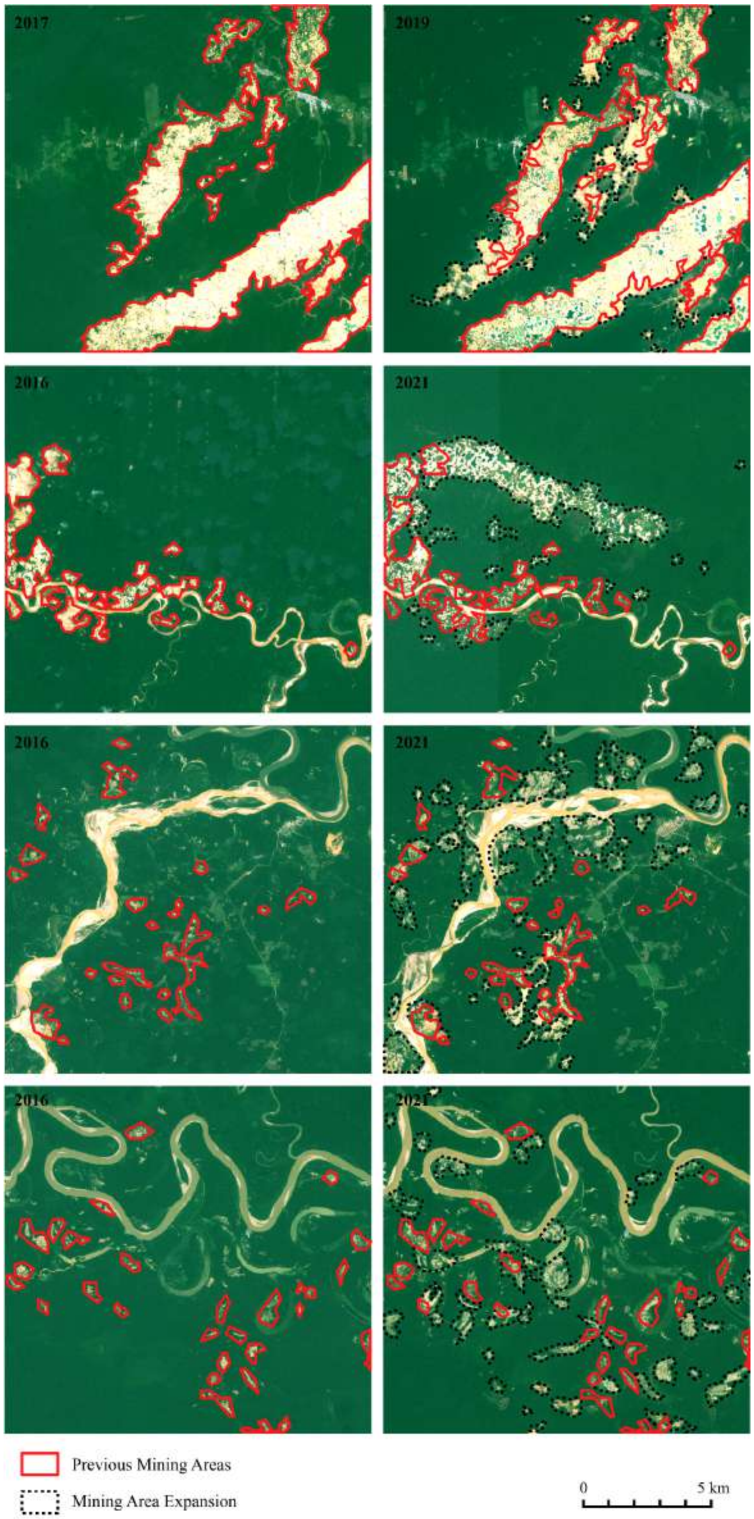
Notes: The figure displays the land concessions in the study area. Each polygon represents a land concession granted. Mining concessions that overlapped with mining sites identified with satellite images were classified as formal mining sites if the period during which the site was operational as measured by night-time lights coincided with the period during which the mining concession was active. If the concession was not active during the period of exploitation, the mining site was defined as informal. These concessions are spatially distributed in the area defined as the "Mining corridor." With a few exceptions, mining sites identified with satellite images that fall outside this mining corridor are illegal mining sites.

Figure A4.2: Mining Concessions and Protected Areas



Notes: The figure presents the average monthly temporal variation in activity at illegal and non-illegal mining sites, and the average monthly international price of gold during the study period. As a point of reference to a significant price variation within short periods of time, it can be seen that within only about six months in 2016, the price of gold increased by approximately 25%, whereas the same level of decrease was observed between 2014 and the end of 2015.

Figure A4.3: Variation in International Gold Price and Activity in Mining Sites



Notes: The figure shows the expansion of artisanal and small-scale gold mining in the Madre de Dios Region, Peru. The figure compares different periods and areas that are included in the sample and experienced large variation during the period analyzed.

Figure A4.4: Expansion of Artisanal and Small-Scale Gold Mining in Madre de Dios

Urbanization and the Optimal Routes to Structural Change Out of Agriculture

> *"...even the distribution of agricultural production is dictated as much by access to urban markets as by the underlying quality of the soil -a point made by von Thunen at the very beginning of location theory".*
>
> Paul Krugman, *Development, Geography, and Economic Theory* (1997)

Abstract

How urbanization shape structural change out of agriculture across space? Does growth in cities also generate growth and development in rural areas? This article estimates the effects of urbanization and road infrastructure development on the structural transformation of rural villages in Chile. Following a market access approach, these effects are analyzed by estimating the elasticities of urban market access on the population, and farm and non-farm employment of rural villages. Using population censuses and remote sensing data for a 25–year period, we find in our preferred estimations that a 10% increase in access to urban markets induced in average a 3% increase in the population of rural communities and a 7% in non-farm employment, but non-significant effects in farm employment. These results support the hypothesis of the diversification of the rural economy which also are consistent with the evidence of the intensification of agriculture. Moreover, the evidence suggests important heterogeneous effects across rural areas, that reveal that the farm sector took important advantages from market access in rural areas with better conditions for agricultural production.

5.1 Introduction

It is widely documented that modern economic growth has been largely explained by a move of workers from agriculture to more productive economic sectors (Herrendorf, Rogerson, and Valentinyi, 2014). Since the global spread of the industrial revolution, this process of structural change has been strongly correlated with urbanization rates, which increased living standards in urban areas (Bairoch, 1988). However, the opposite is not necessarily true, i.e., the extent to which urbanization induces growth and economic development in rural areas or foster agricultural activities. Features such as the economic nature of small rural economies, the exposure of farms to exogenous climatic productivity shocks, and the different stages of development across the geographical space, suggest the existence of important heterogeneity and nonlinearities. Nonetheless, based on this relationship between the urban and the rural economy, over the last decades an increasing number of policies in the developing world promote the creation of the so-called *urban-rural linkages*, to foster trade integration, agricultural intensification, and the growth of non-farm activities in rural areas.[105]

The notion that growth and development in urban areas shape growth and development in rural areas, which is underlying the process of structural transformation, has been on the mind of scholars for a long time. More pessimistic views on rural decline and peripheral development tend to predominate in the eyes of early high-development theorists (Hoselitz, 1955; Myrdal, 1957; Hirschman, 1958), whose arguments to some extent were captured by core-periphery models (Krugman, 1991b). However, the contemporaneous empirical evidence documenting growth and economic development in rural areas in developing countries challenge those predictions, and is more consistent with the idea that urbanization induces rural economic growth and development, as early hypothesized by Jacobs (1969).[106] Even with some evidence suggesting that this might have happened in early stages of the now-developed countries (Michaels, Rauch, and Redding, 2012b). For this argument of urbanization with rural development to work, however, this would imply that agricultural productivity is an increasing function of access to urban markets and apart from migration to urban areas, there is a movement towards the non-agricultural sector in rural areas in order to keep rural population growing, at least on average.[107]

The idea behind the promotion of *urban-rural linkages*, therefore, relies on this argument that

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[105] For example, six points of the UN Sustainable Development Goals (United Nations, 2015) are dedicated to this topic, and also developed in World Bank (2008) and World Bank (2009).

[106] This was mentioned by Jane Jacobs in her influential book on the economy of cities (Jacobs, 1969), explicitly in a chapter entitled: *"Cities First - Rural Development Later"*.

[107] Note that this growth in rural population is still seeing in the developing world. Despite growth rates, in both, urban and rural areas has been declining over the last two decades.

the net effect of growth in urban areas in the growth and development of rural areas is positive. In other words, that the consumption and production linkages in the form of positive and negative spillovers from urban growth, that drive the pattern of rural-to-urban migration, employment, and productivity in rural areas, are virtuous, on average.[108] The mechanisms that define the sign and magnitude of these geographical spillovers from urbanization, are key in the current and future design of rural development policies (World Bank, 2008, 2009; United Nations, 2015, 2017; FAO, 2017), and therefore, crucial to identify. Without a clear understanding of how urbanization and transport infrastructure development connecting rural areas to cities, are actually generating economic development in rural areas, seems problematic to foster policies that eventually would have negligible impacts (see for example, Asher and Novosad, 2020 evaluation of the 1 billion rural roads program in India).

To illustrate better the ambiguous nature between urbanization and rural economic development at small spatial scale on the data, Fig. 5.1 shows for our case study the relationship between the change in the share of non-farm employment in rural communities and the distance to the nearest city, a measure of access to urban markets for rural villages. Consistent with the arguments made by agricultural economists (Berdegué et al., 2001; Reardon, Berdegué, and Escobar, 2001; Reardon et al., 2009), this relationship seems to hold even at a small spatial scale. I.e, on average, as rural locations have more access to urban areas they tend to diversify by moving away of farm activities. However, the figure describes a negative weak correlation that is explained by the large heterogeneity in both, geographical location and specialization in the agricultural sector. Which have important implications for policy design on the arguments of transport infrastructure investment and rural development.

When describing the small spatial scale of rural economies, it is natural to think that as rural locations grow, on average, the agricultural sector will represent a lower size of their economies. This is consistent with the existing evidence showing that in rural areas there is also a process of structural transformation to off-farm activities (Reardon, Berdegué, and Escobar, 2001; Reardon et al., 2009), that is underlying increases in agricultural productivity. The question, is how and to what extent these issues are related to urbanization. Which requires a better understanding of the mechanisms that determines the degree of complementarity between urban and rural activities, and farm and non-farm activities in rural areas. However, these hypothesis has been challenging to test because of lack of good data. An important limitation for this purpose is that the granularity of the different mechanisms at play and data restrictions imply that many of these rural-to-urban spillovers are difficult to

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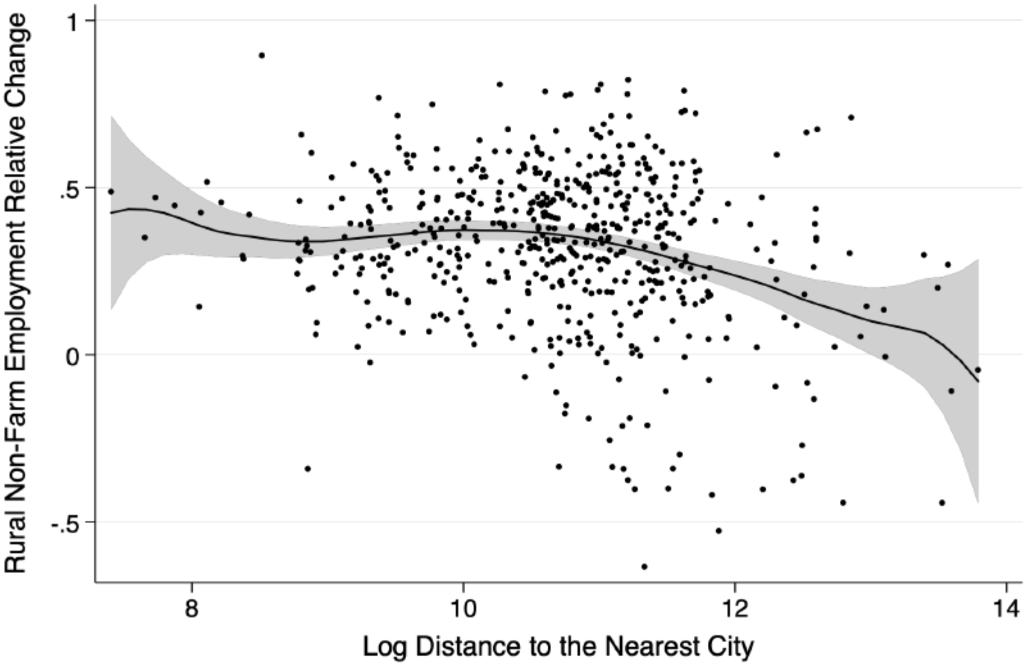
[108] Also known as *spread* and *backwash effects* (Colby, 1933; Gaile, 1980; Hughes and Holland, 1994; Barkley, Henry, and Bao, 1996; Chen and Partridge, 2013), or *urban-rural linkages* (Berdegué, Proctor, and Cazzuffi, 2014).



Notes: The figure shows the association between the logarithm of the distance to the nearest city and the change in the share of non-farm employment for a sample of more than 500 rural villages/communities identified across the censuses of 1992 and 2017 in Chile. The distance to the nearest city is constructed computing the straight euclidean distance between each rural village and each one of the 170 urban areas in Chile. The figure displays the local polynomial fit of the scatter plot using an Epanechnikov kernel function with a second-order degree. *Source:* Own elaboration based on data from the Chilean National Office of Statistics (INE).

Figure 5.1: Non-Farm Employment in Rural Communities and Distance to Urban Areas

measure and predict. Making a challenge to identify the potential real gains for rural areas from policies that improve access to urban markets, with effects that are expected to be highly heterogeneous given the small size of most rural communities.[109] Then, measuring the aggregate benefits of the linkages between cities and rural areas implies that these mechanisms have to be considered simultaneously in a framework (Wu, Weber, and Partridge, 2016).

Motivated by these facts, in this paper we estimate the effects in the growth and structural change out of agriculture in rural villages from gains in access to urban markets derived from road infrastructure development and economic growth in cities. For this purpose, we construct a granular spatial dataset using population and agricultural censuses, roads networks, and remote sensing data. Then, we estimate the effects of access to urban markets (induced

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[109] Such as for example the aggregate effects of integrating remote rural communities that might induce gains from trade but at the same time depopulation. Despite that even with rural decline can be individual welfare gains of rural population moving to cities. Even if it does in the average or it can generate welfare gains from rural to urban migrants.

by urban growth and transport infrastructure development) on the population, agricultural and non-agricultural employment, and agricultural potential (proxy of agricultural productivity), for more than 500 rural communities/villages in Chile over 25 years. Our results show an elasticity of market access for the population of rural communities of around 1.0 to 1.4 in our preferred estimations, and a positive significant effect in non-farm employment. These results are robust to different specifications for market access. [110]

This paper builds on the shoulders of contributions aiming to understand the causes and consequences of spatial structural change (e.g., Michaels, Rauch, and Redding, 2012b), the local economic impacts of transport infrastructure improvements (e.g., Asher and Novosad, 2020; Storeygard, 2016), the consequences of urbanization to spatial development (e.g., Michaels, Rauch, and Redding, 2012b), and the long-term dynamics of economic development in rural areas (e.g., Christiaensen, Weerdt, and Todo, 2013). This paper tries to give a comprehensive view on these topics, providing evidence on the mechanisms explaining the heterogeneity on the effects of urbanization and transport infrastructure development on the growth and economic development of rural areas for an emerging economy. Moreover, studying this relationship over the last decades is important given the dramatic explosion of urbanization in developing countries over the past century.

This article contributes to the literature in two different ways. First, we present a framework that allows us to understand the average and heterogeneous effects of urban growth on the economic development of rural areas, under the assumption of spatial equilibrium *á la Roback*, in which variations in population and employment of rural communities are informative of localization incentives of rural workers and firms that reallocates to compensate for differences in utility levels and costs across space. In addition, a wide existing empirical evidence on the impact of cities on the growth of rural areas are generalizations of the empirical partial adjustment models of Carlino and Mills (1987), which are usually not explicitly microfounded (e.g., Henry et al., 1999; Deller et al., 2001; Carruthers and Vias, 2005), with only few studies distinguishing between farm and non-farm rural employment. Notwithstanding, this distinction is more common in the literature on agricultural economics, where the evidence at household level suggest a positive impact on farm and non-farm income, and the intensification of the agricultural activity (for some recent evidence see: Binswanger-Mkhize and Savastano, 2017; Davis, Giuseppe, and Zezza, 2017; Vandercasteelen et al., 2018).

Second, using a market access approach and following recent advances in measuring the impact of infrastructure on local economic development (Donaldson and Hornbeck, 2016; Jedwab and Storeygard, 2022), we present a methodology to estimate the influence of urban

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[110] Variation in this market access variable comes from changes in urban growth and road networks.

markets on the economic development of rural communities using the richness of population censuses, and remote sensing data. Following the recent increase in the use of satellite imagery data in the contexts of unavailable or less reliable official information (Henderson, Storeygard, and Weil, 2012; Donaldson and Storeygard, 2016). In addition, this paper takes advantages of the remote sensing data to have a clear distinction between rural and urban areas, and in the same vein as Michaels, Rauch, and Redding (2012b), we adopt a more disaggregated spatial unit of analysis (community/village/locality) that leads to a better identification of the heterogeneity on the effects of urban growth on the economic development of rural areas.[111]

The remainder of the paper is organized as follows. Section 5.2 reviews the relevant literature. Section 5.3 presents the model. Section 5.4 details the econometric specifications. Section 5.5 describes the data and estimation issues. Section 5.6 shows the results and, finally, Section 5.7 summarizes main results and concludes the paper.

5.2 Literature Review

The agricultural economics literature proposes multiple causal mechanisms to understand the relationship between urbanization and the economic development of rural areas.[112] First, rural locations close to and connected to a densely populated area are more likely to receive more gains of trade than remote ones. This is because cities represent large markets for the commercialization of agricultural goods produced in rural areas, which would raise the prices of these goods, increasing farmers profits from trade (Jacoby, 2000; Donaldson and Hornbeck, 2016), and intensifying agricultural production (Binswanger-Mkhize and Savastano, 2017; Damania et al., 2017; Davis, Giuseppe, and Zezza, 2017). Trade between rural communities and cities could be one of the main channels for rural economic development (Fleming and Abler, 2013) and can contribute to its productive specialization, as well as to the diversification of its economy.

The economic specialization of rural areas tends to be concentrated toward agricultural products that require lower travel times from the production places to the market (Beckmann, 1972; Costinot and Donaldson, 2012). This specialization could lead to higher wages in the agricultural sector, derived from the division of labor (Yang and Liu, 2012). Nonetheless, the

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[111] Counties, districts, or municipalities are usually classified as rural when a large percentage of their population is living in rural villages. However, these spatial units are not usually entirely rural. As such, researchers cannot distinguish if growth is occurring only in rural communities, thus overestimating or underestimating the impact of urban growth on the growth and economic development of rural communities. In this study, rural areas are defined by the census as an agglomeration of rural villages.

[112] For a good critical summary on this relationship, see Wu, Weber, and Partridge (2016).

increasing demand for jobs in activities auxiliary to agricultural production (e.g., transportation, manufacturing, or sales) could also foster the economic diversification of rural communities through an increase in the number of non-farm activities (Foster and Rosenzweig, 2004). This diversification may also raise wages in the non-farm sector (Berdegué et al., 2001). However, this is not the rule, since some workers in non-farm jobs in rural or even urban areas may earn less than the average wage in the agricultural sector (Perloff, 1991; Lanjouw and Lanjouw, 2001).

The increase in rural non-farm employment could have two different origins. The first is the demand for jobs that are auxiliary to the agricultural sector due to the increasing number of non-farm activities in growing agricultural markets (Foster and Rosenzweig, 2004). The second is the demand for jobs in cities, which might increase the number of commuters living in rural communities and working in cities (Renkow, 2003). Both causes are likely to be related to low-skill jobs from rural communities in proximity to cities (So, Orazem, and Otto, 2001). Moreover, rural workers may also be working in remote cities or highly productive extractive places by long-distance commuting; however, this would typically be associated with medium-skill jobs or seasonal workers (Paredes, Soto, and Fleming, 2018).

The number of amenities and employment opportunities in cities could also influence the localization incentives of rural households, causing important migration flows from rural areas to cities, which lead to the decline of the population in rural communities (Goetz and Debertin, 2001). However, in theory, this process may also have a positive effect on the labor productivity of the rural place of origin.[113] This is because rural-urban migration reduces the number of agricultural workers and, since the agricultural production is subject to constant returns to scale, it increases the marginal productivity of each worker in that agricultural area (Harris and Todaro, 1970), accompanying a process of structural change in the economy (Alvarez-Cuadrado and Poschke, 2011; Michaels, Rauch, and Redding, 2012b). Similarly, the migration of rural workers to cities could, at the same time, increase the amount of remittances that families in the rural area of origin receive (Banerjee, 1984).

Another potential channel of the impact of urbanization on the development of rural communities is the rent of land (Von Thunen, 1826). Rural households and landowners have access to lower consumer prices and land rent than city residents, allowing a lower cost of living (Kurre, 2003; Loveridge and Paredes, 2016), and consequently a higher quality of life (Roback, 1982; Deller et al., 2001), which is also due to natural amenities such as open spaces

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[113] This holds only in theory because the empirical findings on this topic are ambiguous at this point. Some evidence of a more rapid growth in agriculture than in the non-agriculture sector are: Griliches (1957); Rasmussen (1962); Maddison (1980).

(Klaiber and Phaneuf, 2009) or the access to services that nearby cities might offer. Such price advantages in rural areas are widely exploited in urban processes, such as the relocation of the manufacturing industry (Lonsdale and Browning, 1971) and suburbanization (Lopez, Adelaia, and Andrews, 1988; Burchfield et al., 2006). The price of the land in rural locations near cities may also be affected by these factors, leading to price increases as market access improves.

The above review suggest that the positive effects derived from the trade between rural communities and cities may have a large spatial scope compared to the other mechanisms, which usually have a reduced spatial scope and ambiguous outcomes (Irwin et al., 2009; Castle, Wu, and Weber, 2011). In fact, empirical works relating the impacts of urban growth on rural development at county or municipality level found ambiguous results for the effect of this relationship on employment (e.g., Chen and Partridge, 2013 found a non-significant effect on employment in rural areas in China and a negative effect when only capital districts are considered), but also identified consistent positive effects on the population (Partridge et al., 2009). However, these results have to be carefully interpreted due to aggregation in their units of analysis (Briant, Combes, and Lafourcade, 2010). On the other hand, evidence at the household level indicates a positive association between market access and rural wages in the farm and non-farm sector (Binswanger-Mkhize et al., 2016). Therefore, this article uses a market access approach on measuring and understanding the role of urbanization and transport infrastructure development in the growth and structural transformation of rural communities.

5.3 Theory

The idea that access to urban markets is associated with a process of structural change out of agriculture in rural areas seems to be supported in Fig. 5.1 for the case study, but also suggest important heterogeneity. These facts are consistent with a Ricardian world in which different locations trade based on comparative advantages but are also affected by exogenous productivity shocks as driving technological differences and inducing the observed heterogeneity. With population and employment growing accordingly to this and respective migration frictions. Consequently, to inform our empirical analysis, we rely on a canonical new Ricardian trade model that builds over Eaton and Kortum (2002), and follows closely the work of Donaldson (2018) and Donaldson and Hornbeck (2016). The model will describe theoretically the mechanisms and provide a simple guide to the empirical identification.

5.3.1 Model Environment

The intuition of the model is that changes in urbanization and transport infrastructure development are captured by a market access effect. An increase in market access would generate a positive demand shock in a discrete number of locations that will move activities from a basic food sector producing a homogeneous non-tradable good, towards a tradable manufacturing sector producing a continuum of differentiated varieties. There is no a priory discrete distinction between rural and urban areas. The conceptual difference between both is that cities are large locations more specialized in the production of a wide range of manufacturing varieties, while rural areas are small locations that rely more on the production of a non-tradable food sector.[114] Then, structural transformation will imply a move of workers towards the production of manufacturing varieties, which for the case of rural areas can also be thought as agricultural products with more value added or less complex manufacturing goods than those produced in cities.[115] The idea is that as small rural locations get more connected to large agglomerations, this increase in market access would imply that they would start to rely more on the production and trade of manufacturing varieties.[116]

On the other hand, the heterogeneous effects of market access among different locations are explained by exogenous productivity shocks. These shocks would determine the degree of specialization in the tradable manufactured good, and therefore affect the pattern of structural transformation induced by an increase in market access. Changes in market access would also

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[114] This form of modelling structural transformation in rural areas is flexible enough to be consistent with situations in which the move from farm to non-farm employment might happen in activities that are related with the agricultural sector but rely more on some manufacturing processing, or activities related to the distribution and commercialization of those manufactured agricultural goods. These activities have shown to be important for rural economic development (Reardon, Berdegué, and Escobar, 2001; Reardon et al., 2009).

[115] As in Eaton and Kortum (2002), the specific goods that are traded are not relevant to the model. This is because one of the features of working with an stochastic component of productivity imply that all the adjustments are through the extensive margin of trade, given that the conditional distribution of prices are going to be equal to its unconditional distribution disregarding the origin location of those traded goods. In our context, this imply that smaller rural locations would have lower productivity and a smaller number of varieties produced there. However, more recently, Moneke (2020) worked a three sector model extension of Michaels, Rauch, and Redding (2012a) to make more clear the distinctive patterns of structural transformation by understanding better the complementarity/substitution between sectors.

[116] For our purposes there is no much gain in distinguishing a priory between rural and urban locations in a discrete form, although we made this separation in the empirics. As described in Donaldson and Hornbeck (2016), the distinction between rural and urban locations would lead to four different types of isomorphic market access measures that are empirically equivalent to the derived in this model. Therefore, to preserve parsimony in the theory, we instead consider that rural areas are locations less specialized in the production of manufacturing varieties, while urban areas are places more specialized in the production of a large variety of complex manufacturing tradable goods. In consequence, structural transformation in this paper is the transition towards a larger share of the workforce specialized in these complex tradable goods. This is consistent with our empirics in which we are particularly interested in small communities/villages that move from farm to non-farm employment due to increases in access to large markets.

affect technological adaptation in each location. These effects would induce a complementarity between productivity shocks and market access that is consistent with existing evidence documenting heterogeneous effects of transportation infrastructure investments and a growing literature on the effects of climate change in rural areas and agricultural production (Barwick et al., 2021).[117] The final equilibrium in rural areas would be determined by the relative strength of each one of these forces.

5.3.2 Demand

Let assume a small open economy consisting of a discrete number of locations $\Im$ indexed by an origin i and a destination j. Preferences for a representative individual in a given destination j are represented by

$$U_j = n_j C_j^{\delta} F_j^{1-\delta} \tag{40}$$

where $\delta, \in (0,1)$. The terms C_j and F_j describe the amount of consumption of a composite manufacturing and an homogeneous agricultural good respectively. n_j is an exogenous preference shifter representing local amenities. Individuals maximize their utility subject to a budget constraint given by $P_j C_j + F_j = Y_j$, where the agricultural good is the numeraire. In consequence, the optimal demand for the agricultural good is $(1-\delta)Y_j$ and the share of income spent in the composite good is δY_j, which is allocated according to the following CES preferences, $C_j = \left(\sum_{i\in\Im}\int_{\Omega} c_{ij}(\omega)^{\rho} d\omega\right)^{\frac{1}{\rho}}$. Consequently, the demand for varieties of the composite good is given by $c_j(\omega) = p_j(\omega)^{-\sigma}\delta Y_j P_j^{\sigma-1}$, where $p_j(\omega)$ is the price of a variety ω, and P_j is the Dixit-Stiglitz price index, defined by

$$P_j \equiv \left(\sum_{i\in\Im}\int_{\Omega_i} p_{ij}(\omega)^{1-\sigma} d\omega\right)^{\frac{1}{1-\sigma}} \tag{41}$$

where Ω_j is the set of varieties available in location j. Then, total welfare in j is $U_j = Y_j / P_j^{\delta}$, and the real wage can also be expressed as $w_j = W_j / P_j^{\delta}$, where W_j is the nominal wage. The total value of composite goods traded between origin i and destination j is $X_{ij} = p_j(\omega)c_j(\omega)$, which given the CES demand for varieties of the composite good, is equivalent to

$$X_{ij} = p_{ij}(\omega)^{1-\sigma}\delta Y_j P_j^{\sigma-1} \tag{42}$$

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[117] These ideas are also consistent with Gollin, Jedwab, and Vollrath (2016) and recent insights from the work of Vandercasteelen et al. (2018) and Damania et al. (2017) on the role of cities in agricultural intensification and transformation. These models summarize a large body of literature on structural change and agriculture (see Herrendorf, Rogerson, and Valentinyi, 2014 for a detailed survey).

while the trade of the agricultural good is given by the demand for this good from the optimization problem, i.e. $F_j = (1-\delta)Y_j$.

5.3.3 Supply

On the supply side, it is assumed that the production of the homogeneous agricultural good is under perfect competition and constant returns to scale, with a Cobb-Douglas technology $F_j = A_j L_j^{1-\alpha}$, $\alpha \in 0, 1$, in which the farmer produce one unit of F_j with one unit of labor L_j^F. For the case of the manufactured good, the price of a manufactured variety ω produced at origin location i and sell it in destination j, is

$$p_{ij}(\omega) = \frac{c_i}{z_i(\omega)}\tau_{ij} \tag{43}$$

where c_i is the unit cost measured in terms of labour, τ_{ij} are "iceberg" transport costs, and $z_i(\omega)$ are productivity independently draws from a Frechet distribution. The "iceberg" trade cost for the manufacturing varieties of selling each good from an origin i to a given destination location j, implies that $\tau_{ij} > 1$ units of the good must be send to reach one unit at the destination, $\tau_{ii} = 1 \ \forall\ i \in \Im$, and it is assumed that the no arbitrage condition holds, i.e. $\forall\ i, j, k \in \Im : \tau_{ij}\tau_{jk} \geq \tau_{ik}$. Consumers only purchase from the location with the lowest price, which implies that

$$p_j(\omega) \equiv \min_{i \in \Im} p_{ij}(\omega) = \min_{i \in \Im} \frac{c_i}{z_i(\omega)}\tau_{ij} \tag{44}$$

where the cumulative distribution that characterizes the productivity in each location is $F_{i(z)} \equiv \Pr\{z_i(\omega) \leq z\}$, which is assumed to be Fréchet, so $\forall\ z \geq 0$, $F_{i(z)} = exp\{-T_i z^{-\theta}\}$, where T_i is a measure of aggregate productivity in the location, and θ is assumed constant across locations. An intuitive interpretation of this function, is that the scale parameter of the Fréchet distribution T_i is measuring the local comparative advantage, while the dispersion parameter θ, measure the gains from trade on those goods. To the extent that θ is lower, i.e. a lower dispersion of the distribution, greater the gains from trading those goods. The idea is that any exogenous productivity shock in location i is captured by T_i, while transport infrastructure improvements would make the trading of those goods easier, which would imply a lower θ.

5.3.4 Equilibrium

The model is solved by following a probabilistic formulation. Where the probability that a location $i \in \Im$ offer to a location $j \in \Im$ a particular good $\omega \in \Omega$ for a particular price less than

p, i.e. $\Pr\{p_{ij}(\omega) \leq p\}$, is

$$G_{ij}(p) \equiv 1 - \exp\{-T_i \left(\frac{c_i}{p}\tau_{ij}\right)^{-\theta}\}$$

Equivalently, the probability that a location $j \in \Im$ pays for a good $\omega \in \Omega$, a price less than p, i.e. $\Pr\{p_j(\omega) \leq p\}$, considering that consumers in location j only buys from the least cost location, is $G_j(p) = 1 - \exp\{-p^{\theta}\Phi_j\}$, where $\Phi_j \equiv \sum_{i\in\Im} T_i(c_i\tau_i)^{-\theta}$, which is the distribution of prices of each variety for a destination j. Then, considering these conditions, the equilibrium price index P_j in location $j \in \Im$ is

$$P_j = C\left(\sum_{i\in\Im} T_i(c_i\tau_{ij})^{-\theta}\right)^{-\frac{1}{\theta}} \iff P_j^{-\theta}C^{\theta} = \sum_{i\in\Im} T_i(c_i\tau_{ij})^{-\theta} = \Phi_j \tag{45}$$

where $C \equiv \Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)^{\frac{1}{1-\sigma}}$ and $\Gamma(t) \equiv \int_0^{\infty} x^{t-1}e^{-x}dx$. A remarkable property of this price index, is that is no only dependent on the bilateral trade between an origin i and destination location j, but also depends on all the other locations, as the sum over $i \in \Im$ indicates. This implies that the cost of those traded goods is not only dependent on the technology productivity draws T_i in each location, but is going to be lower if the distance (or transport costs) to all other locations is low τ_{ij}, or equivalently, if the wages are lower (given perfect competition that implies $w_i = c_i$). This useful feature will be very important to derive an empirical measure of the market access variable that captures these multilateral trade frictions, as in Anderson and van Wincoop (2003).

5.3.5 Trade

Bilateral trade on the composite good between two pair of locations would be determined by the probability that a particular location $i \in \Im$ would be the least cost provider of a good ω to a destination $j \in \Im$, which is equal to the fraction of goods i sells to j, i.e.,

$$\pi_{ij} = \frac{T_i(c_i\tau_{ij})^{-\theta}}{\Phi_j}$$

or equivalently, the proportion of goods that $j \in \Im$ buys from $i \in \Im$. The intuition behind this remarkable feature of this model, is that bilateral trade between an origin i and destination j would depend in a source of absolute advantage in technology T_i, and local comparative advantages given by marginal costs c_i and bilateral distance τ_{ij}, relative to all other locations measured in the denominator as $\Phi_j \equiv \sum_{i\in\Im} T_i(c_i\tau_i)^{-\theta}$. Where high values on these two sources of comparative advantages are penalized by θ. Due that θ is capturing the dispersion of the Fréchet distribution, it governs the role of comparative advantages, which imply that low penalties on θ (or equivalently low trade costs) would lead to a higher probability of trade between the pair of locations ij. Given the Fréchet distribution, this is also equal to the proportion of income that consumers in j spend on manufacturing goods from location i, specifically $\Lambda_{ij} \equiv x_{ij}/\delta Y_j$. In consequence, we can write the trade of manufacturing varieties that a destination location j spent in goods from an origin i as

$$X_{ij} = \pi_{ij}\delta E_j = \frac{T_i(c_i\tau_i)^{-\theta}}{\Phi_j}\delta E_j = C^{-\theta}\tau_{ij}^{-\theta}w_i^{-\theta}T_i P_j^{\theta}\delta E_j$$

where $\Phi_j \equiv \sum_{i\in\Im} T_i(c_i\tau_i)^{-\theta}$, and using the fact that these goods are produced under perfect competition, i.e. $c_i = w_i$.[118] This equation is also known as the Eaton-Kortum gravity equation, in this case for the manufacturing good.

5.3.5.1 Market Access In general equilibrium, it would be the case that the value of goods purchased by a location i is equal to the income that consumers spent on that good, i.e., $\delta Y_j = \sum_{i\in\Im} X_{ij}$. In consequence (and assuming $Y_i = E_j$ the income received at the supply location i has to be equal to the expenditure spent in location j), the EK gravity equation can be expressed as $P_j^{-\theta} = C^{-\theta}\sum_{i\in\Im} T_i w_i^{-\theta}\tau_{ij}^{-\theta} \equiv CMA_j$, that is defined as consumer market access, as in Donaldson and Hornbeck (2016). Substituting the consumer market access into the EK gravity equation, and assuming again $Y_i = E_j$), Assuming that goods markets clear, so for manufacturing goods this means that $\delta Y_i = \sum_{j\in\Im} X_{ij}$, which implies that

$$\delta Y_i = C^{-\theta}T_i w_i^{-\theta}\sum_{j\in\Im}\tau_{ij}^{-\theta}CMA_j^{-1}\delta Y_i \iff \delta Y_i = C^{-\theta}T_i w_i^{-\theta}FMA_j \tag{46}$$

where $FMA_j \equiv \sum_{j\in\Im}\tau_{ij}^{-\theta}CMA_j^{-1}\delta Y_i$ is the firm market access in destination location $j \in \Im$. Under spatial equilibrium (workers perfectly mobile across locations), equalize utility across locations which implies that real wages also equalize across locations.[119] i.e. $\overline{U} = \frac{w_i}{P_i} = \frac{w_j}{P_j}$. In consequence, by substituting the nominal wage w_i in Eqn. 57, we obtain $\delta Y_i = C^{-\theta}T_i\overline{U}^{-\theta}CMA_j FMA_j$. Assuming symmetric transport $\tau_{ij} = \tau_{ji}$, firm and consumer market access have to satisfy a proportionality condition $MA_i \equiv FMA_i = \rho CMA_i \; \forall i \in \Im$ with $\rho > 0$. Which implies that $FMA_i \equiv \sum_{j\in\Im}\tau_{ij}^{-\theta}CMA_j^{-1}\delta Y_i \iff MA_i = \sum_{j\in\Im}\tau_{ij}^{-\theta}\rho MA_j^{-1}w_i N_i$, where

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[118] This is thanks to the convenient feature of the model, although strong, that $X_{ij}/X_j = \pi_{ij}$.

[119] Note that the assumption of spatial equilibrium is only used here at the end avoid the necessity to observe wages in the data. However, we also show results using nominal wages to see the robustness of this result to this assumption.

$\delta Y_i = w_i N_i$. Substituting $w_i = \overline{U} P_i = \overline{U}\left(CMA_i\right)^{-\frac{1}{\theta}} = \overline{U}\rho^{\frac{1}{\theta}} MA_i^{-\frac{1}{\theta}}$, yields

$$MA_i = \sum_{j\in\Im} \tau_{ij}^{-\theta} \rho MA_j^{-1} \left(\overline{U}\rho^{\frac{1}{\theta}} MA_i^{-\frac{1}{\theta}}\right) N_i \iff MA_j = \overline{U}\rho^{\frac{1+\theta}{\theta}} \sum_{j\in\Im} \tau_{ij}^{-\theta} MA_i^{-\frac{(1+\theta)}{\theta}} N_i \tag{47}$$

which is a convenient expression for the market access that can be directly approximately with available data.

5.3.6 Predictions

The model allows to have a direct mapping between market access and local population and sectoral employment. To yield more convenient expressions for this relation, we assume labor market clearing, i.e. $\delta Y_i = \delta w_i L_i$, together with the condition that $w_i = \overline{U} P_i = \overline{U}\left(CMA_i\right)^{-\frac{1}{\theta}}$, implies the following predictions.

5.3.6.1 Market Access and Population/Employment Market access increases local population. These effects are mediated by exogenous productivity shocks and changes in non-farm employment. Solving for the total number of workers (population) N_i and taking the logs gives

$$\log N_i = k_2 + \left(\frac{\theta}{1-2\theta}\right)\log T_i + \left(\frac{2-\theta}{\theta}\right)\log MA_j + \left(\frac{\theta+1}{2\theta-1}\right)\log L_i^C \tag{48}$$

where $k2 = \log\left(C^{\frac{\theta^2-\theta-1}{2\theta-1}}\overline{U}^{\frac{\theta(\theta-3)}{2\theta-1}}\rho^{\frac{\theta(\theta-1)+(2\theta-1)(1+\theta)}{\theta(2\theta-1)}}\right)$. Note here that T_i, MA_j and L_i^C are interrelated by the parameter θ. Each coefficient latter estimated in regression would be a proportion of θ. The condition for a positive effect of the market access is that $\theta < 2$.

5.3.6.2 Market Access and Non-Farm Employment Market access increases non-farm employment. Labor market clearing and spatial equilibrium implies

$$L_i^C = C^{-\theta} T_i \overline{U}^{-\theta} CMA_j FMA_j w_i^{-1} \iff L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} CMA_j^{\frac{\theta-1}{\theta}} FMA_j$$

where $\delta L_i = L_C$ is the labor in the manufacturing sector. Using Eqn. 61 and taking the logs gives the equation of the manufacturing employment

$$\log L_i^C = k_1 + \log T_i + \left(\frac{2\theta-1}{\theta}\right)\log MA_j \tag{49}$$

where $k_1 = \log\left(C^{-\theta}\overline{U}^{1-\theta}\rho^{\frac{1-\theta}{\theta}}\right)$. Here the condition for a positive effect of the market access is $\theta > 1/2$.

5.3.6.3 Market Access, Productivity Shocks, and Structural Transformation Substituting Eqn. 61 in Eqn. 62 yields

$$L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} \rho^{\frac{1-\theta}{\theta}} \left(\overline{U} \rho^{\frac{1+\theta}{\theta}} \sum_{j \in \Im} \tau_{ij}^{-\theta} MA_i^{-\frac{(1+\theta)}{\theta}} N_i \right)^{\frac{2\theta-1}{\theta}}$$

Then, with the proportionality condition $MA_i \equiv FMA_i = \rho CMA_i$ we can express Eqn. 60 as

$$L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} \left(\rho^{-1} MA_j \right)^{\frac{\theta-1}{\theta}} MA_j \iff L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} \rho^{\frac{1-\theta}{\theta}} MA_j^{\frac{2\theta-1}{\theta}} \tag{50}$$

Market access induces structural transformation but these changes are mediated by the exogenous productivity shocks. Which also can be expressed as employment share in manufacturing, as

$$\log \left(\frac{L_i^C}{N_i} \right) = k_3 + \left(\frac{\theta}{\theta+1} \right) \log T_i + \left(\frac{2(\theta-2)(\theta-\frac{1}{2})}{\theta(\theta+1)} \right) \log MA_j \tag{51}$$

where $k_3 = \log \left(C^{-\frac{\theta^2}{\theta+1}} \overline{U}^{\frac{-\theta^2-3\theta}{\theta+1}} \rho^{\frac{\theta(\theta-1)+(2\theta-1)(1+\theta)}{\theta(\theta+1)}} \right)$. As in the previous case, in this equation productivity shocks T_i and changes in market access MA_j, would have proportional effects on the structural transformation of each location, a complementarity that is mediated by transportation costs θ.

5.4 Empirics

5.4.1 Data

5.4.1.1 Rural Communities/Villages We use data from the Chilean censuses of population and housing of 1992, 2002 and 2017 (INE). The Chilean statistical office defines a rural community/village as any spatial entity with less than 3,000 inhabitants.[120] We select all those rural communities defined in 1992 with a population greater than 100 inhabitants for a total

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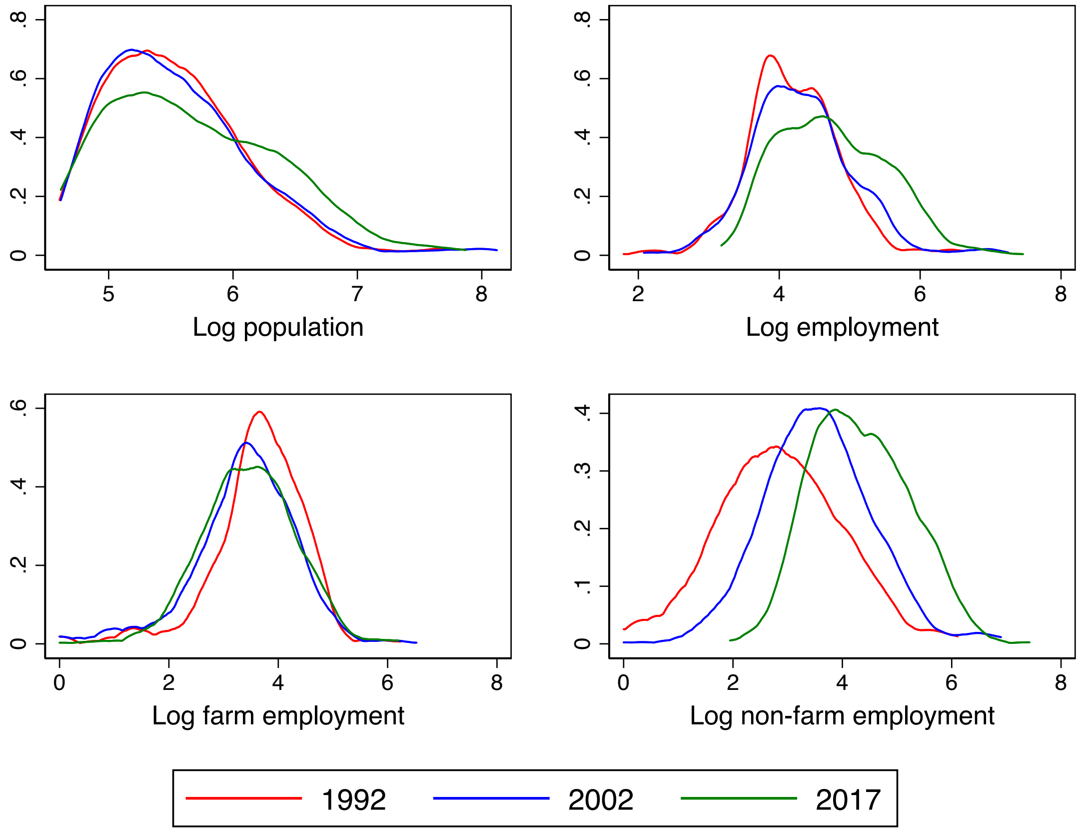
[120] This definition was established in 1992. Since 2002, a rural community is defined a spatial entity with less than 5,000 inhabitants and more than 35% of the labor force working in the agricultural sector. A rural community can be very heterogeneous, and can be a: *Town*, which is defined as a place between 1,000 and 5,000 inhabitants, or composed by more than 250 houses. It also can be an *Aldea*, which is a place between 300 and 1,000 inhabitants, or between 75 to 250 houses, without considering autonomous indigenous localities or agriculture communities. Also it can be a *Caserio*, which are places with less than 300 inhabitants. Within the category of places with less than 300 inhabitants, there can be mining campaments, a ranch, small human settlements withing agricultural land, or indigenous communities. These categories and the form of georeferencing these places is documented in INE (1995), INE (2005), and Carvajal, Poch, and Osorio (2012).

of 536 observations in each year.[121] This corresponds to approximately one third of the total number of rural communities in the census of 1992 (see Table A5.1 for summary statistics of the sample and Figure A5.2 shows the spatial distribution of rural communities and cities in the country). Overall, the changes across census years of the main variables are reported in Figure 5.2. Changes in population are mainly observed for the last census of 2017, as well as overall employment. Notwithstanding, non-farm employment in rural communities has been regularly increasing over the census years. Overall farm employment, on the other hand, has decreased between 1992 and 2002, but remains relatively stable between 2002 and 2017.



The figure shows the kernel (epanechnikov) density graphs for the log of population, employment, farm employment and non-farm employment in rural communities for 1992, 2002 and 2017.

Figure 5.2: Changes in Population and Employment in Rural Communities

5.4.1.2 Roads In order to properly compute the market access variable for each year, we use road network for each year of the census. The road network for Chile, however, is only available since 2011. Thus, we digitize information of the road network from previous years

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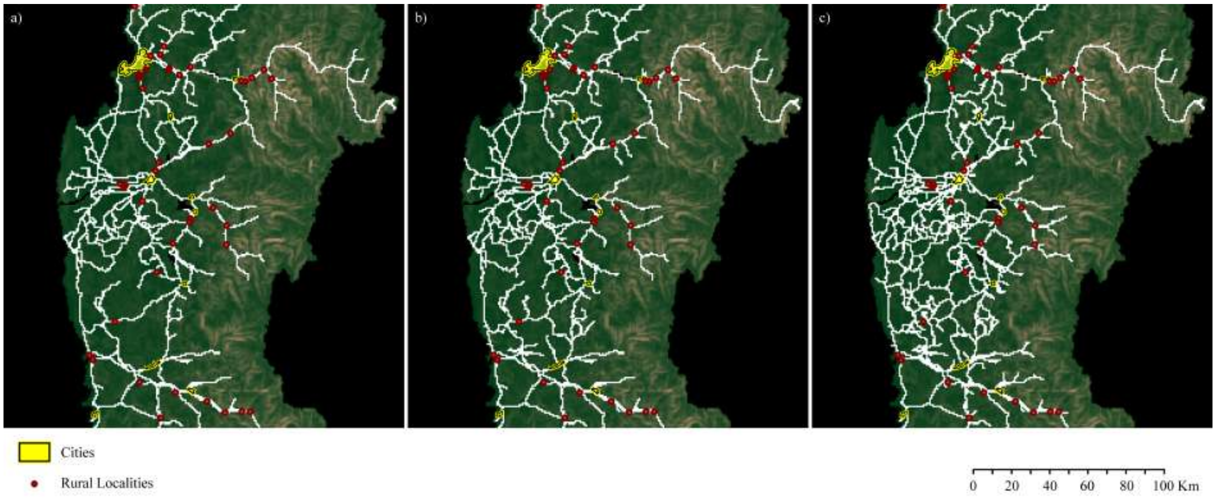
[121] We also perform robustness checks of our estimations modifying this threshold.

from the Ministry of Public Infrastructure (MOP), which are publicly available for years close to census periods (2003, 1999, 1986 and 1980). To have information for the specific census years, we complement this information using satellite images. To compute the least-cost route, we use the "fast-marching method", an algorithm introduced for the same purposes in Allen and Arkolakis (2014), and designed by Sethian (1996).



The figure shows the road network for the years 1992, 2002, and 2017, in the central-south part of Chile. Cities are displayed with a yellow polygon, while rural communities with a dark-red circle.

Figure 5.3: Road Infrastructure Development

5.4.1.3 Urban Growth For a proxy of the economic activity in cities, we use stable satellite nighttime light data, from the NASA Operational Line Scan Defense Meteorological Satellite Program (OLS-DMSP).[122] In the absence of economic data, the nighttime light satellite data was considered a good proxy of economic activity of the subnational units when used appropriately (Chen and Nordhaus, 2011; Henderson, Storeygard, and Weil, 2012; Donaldson and Storeygard, 2016).[123] We process the nighttime light satellite images at one kilometer of spatial resolution for 1992, 2002, and 2017. For each year, we compute the sum of the nighttime light contained within the official urban boundaries defined for the census of 2002 and for areas considering buffers of 2km from the urban boundaries (for similar applications, see Binswanger-Mkhize and Savastano 2017; Henderson et al. 2017).[124]

Fig. 5.4 compares the urban growth using nighttime lights between 1992, 2002 and 2013 (from

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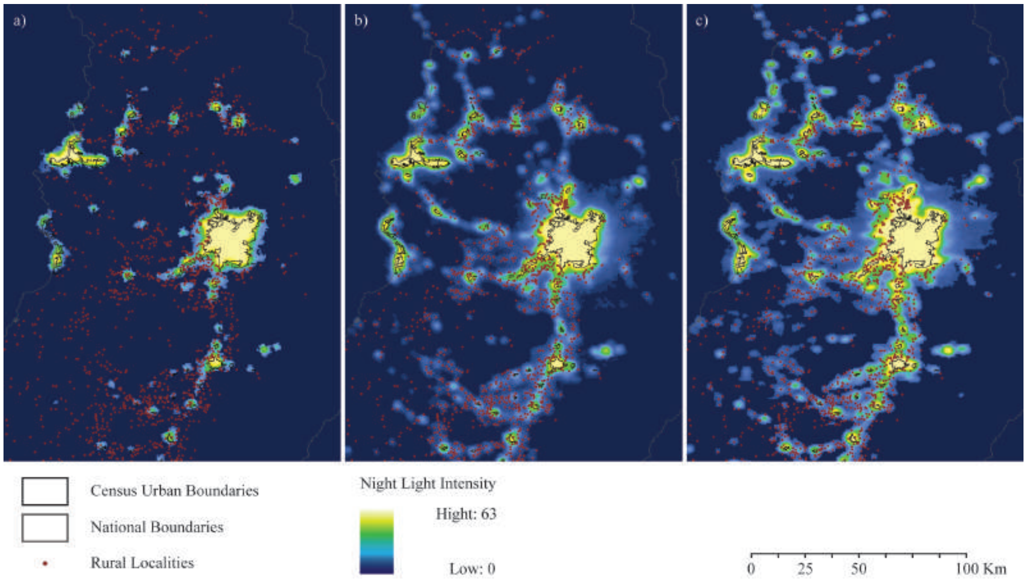
[122] Chile, as many developing countries, does not provide data on the economic activity at city level.

[123] Some other applications are those of Beakley and Lin (2012); Michalopoulos and Papaioannou (2014); Storeygard (2016); Axbard (2016); Pinkovsky and Sala-Martin (2016); Henderson et al. (2017)

[124] We also perform robustness checks to buffers of 5, 10 and 15km from the urban boundaries.

left to right), near the metropolitan area of Santiago de Chile.[125] Rural communities are represented by red points. The black lines are the census urban boundaries at 2002, and nighttime light intensity is represented by a color scale from dark-blue (low values) to light yellow (high values).



The figure describes the spatial distribution of rural communities (red points) near the metropolitan area of Santiago de Chile. Panel a) shows the image for 1992, panel b) for 2002 and panel c) for 2013. Urban boundaries (in black) are the official boundaries for the national census of 2002. The economic activity of urban areas was approximated for each year using nighttime light. Nighttime light intensity goes from zero (in dark-blue) to 63 (in light-yellow) and has a spatial resolution of one pixel per kilometer.

Figure 5.4: Urban Growth and Rural Communities

The literature on remote sensing had identified two main problems related with the use of nighttime light data, namely the "blooming" and "saturation" effects (Imhoff, Lawrence, Stutzer, and Elvidge, 1997). These effects are distortions in the satellite image due to the high intensity of light is some places. A simple analogy would be taking a photography with a source of light just in front of the camera. This would cause a saturation on the values of pixels from the direct source of light (saturation effect) and a light blurring to other pixels in the image (blooming effect). The main problem for our purposes is the blooming effect, due that overestimate the size of urban areas and, consequently, the sum of lights from cities. This is a problem that, until recent years, had been scarcely accounted for in the applied economics literature using nighttime light data (Abrahams, Oram, and Lozano-Gracia, 2018). Hence, we clean nighttime lights images following remote sensing literature, specifically Su et al.

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[125] Time-series comparison on satellite nighttime lights only allows reliables comparisons between 1992 and 2013 after the calibrations that we implemented.

(2015).[126] The basic idea of this cleaning process is that allow us to identify thresholds in the distribution of nighttime lights and extract built-up urban areas.

Fig. A5.5 describes the spatial distribution of rural communities near the metropolitan area of Santiago de Chile and the cleaning process of nighttime lights for 2002. Rural communities are represented by red points that correspond to the centroid of the area. The black lines represent the urban boundaries in 2002. The nighttime light information of each pixel is represented by a color scale from dark-blue (low values) to light yellow (high values). The maximum nighttime light intensity is 63 and the minimum nighttime light intensity is 0. The image on the left displays nighttime lights without blooming correction and the image on the right is corrected. White lines are used to represent the urban buffers of 2, 5, 10 and 15km from the urban boundaries. Since rural communities do not have boundaries delineating their areas, the sum of the nighttime light cannot be accurately computed for rural communities.[127] The distances between rural communities and cities were computed using the Euclidean distance between the centroids of rural communities and the centroids of cities.

5.4.1.4 Agricultural Productivity We follow recent studies that use remote sensing data to measure the agricultural potential of farms by computing vegetation indices (Costinot and Donaldson, 2012; Donaldson and Storeygard, 2016; Costinot, Donaldson, and Smith, 2016; Costinot and Donaldson, 2016; Burke and Lobell, 2017). Since true agricultural productivity is unobserved, both survey-based methods and remote sensing indicators represent limited but informative approximations of the agricultural productivity of farms (Burke and Lobell, 2017). Specifically, we use NASA's Landsat-5 and Lansat-7 satellite data to compute the vegetation indices. We compute three different vegetation indices for robustness check, namely the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Green Chlorophyll Vegetation Index (GCVI), as proxies of the agricultural potential in rural villages.[128] Due to the satellite coverage of the NASA Landsat-5, these indices cannot be computed for the entire country for almost the entire duration of the 1990s.

Consequently, we estimate the elasticities of market access for only 189 rural communities that have this information. The three vegetation indices differ in the spectral bands of the sensors of the satellite used for their computations, the GCVI being the most accurate to cap-

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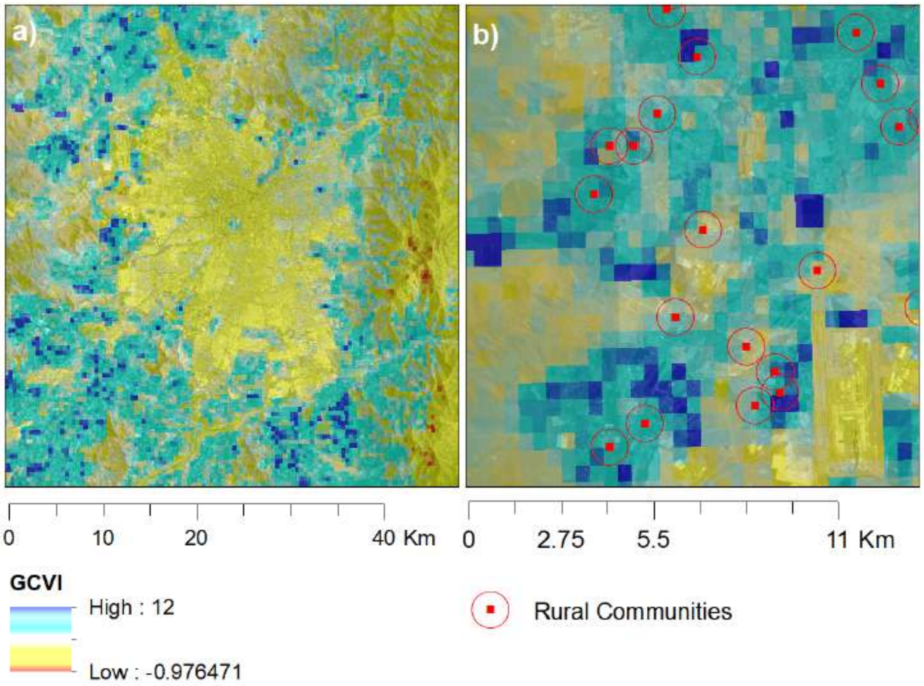
[126] See Abrahams, Oram, and Lozano-Gracia (2018) for a more recent approach.

[127] We also extract the value of the pixel interpolated with surrounding pixels. This reaches an area of approximately two square kilometers (for a similar computation of interpolated values of satellite images, see Nunn and Puga, 2012). However, only 99 rural communities had nighttime light information in 1992 mainly due to the low access to electricity in rural communities during that census.

[128] We describe in the Figure A8 the correlation between the vegetation index proxy of agricultural potential and the observed agricultural productivity using the agricultural census at 2007 at municipality level.



The figure describes the agricultural potential near the metropolitan area of Santiago de Chile in 2015. Agricultural potential is represented with the GCVI, with a spatial resolution of 500 meters per pixel using data from the NASA Landsat-7. Panel a) shows the overall hinterland of the city of Santiago, where high values of the GCVI are displayed with more intense blue colors. Panel b) displays a zoomed image of the hinterland of the city, in which rural communities are represented by a red circle.

Figure 5.5: Cities and Agricultural Productivity

ture the agricultural productivity of farms (for a detailed discussion of applicability of these indices for similar purposes, see Burke and Lobell, 2017).[129] A cloud-free annual median of each pixel at 30 meters of spatial resolution was used for each year to compute the vegetation indices using Google Earth Engine (Gorelick, Hancher, Dixon, Ilyushchenko, Thau, and Moore, 2017). Subsequently, the resulting raster images of the vegetation indices averaged to a spatial resolution of 500 meters per pixel were processed in Google Earth Engine platform and interpolated with surrounding pixels to impute a value of agricultural productivity considering a representative area of one square kilometer. Fig. 5.5 shows the GCVI index for 2015 in the hinterland of the metropolitan area of Santiago de Chile.

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[129] The NDVI is computed as $NDVI = (NIR - Red)/(NIR + Red)$, EVI is computed as $EVI = 2.5 * (NIR - red)/(NIR + 6 * Red + 7 * Blue + 1)$, and GCVI as $GCVI = (NIR/Green) - 1$, where NIR is the Near Infrared Band and each color represents a different wavelength band of the satellite sensors.

5.4.2 From Theory to Estimation

The following equations came as a first-order approximations to the gravity model presented in the previous section.

5.4.2.1 Market Access Prices and productivity in rural areas are rarely observed for a large number of rural locations, goods, and services. However, as specified in the theoretical section, we assume that market access captures those effects described in the model conditional on location specific fixed effects interacted with time dummies. Empirically, the influence of urban market access on the outcomes of rural areas is given by k cities influencing nearby rural communities through potential demand. Market access is a measure that captures this potential demand. The market access of a rural community c, located at a distance $d_{c,k}$ from a city with C_k income, is given by

$$MA_{ct} = \sum_k C_{kt} e^{-\theta d_{ck}} \tag{52}$$

where θ is a parameter that defines the shape of the distance discount over C_{kt}. This specific empirical approximation to the market access can be found in Hanson (2005). This imposes a negative exponential functional form structure to the variable.[130] The market access variable, is computed using stable satellite nighttime lights to approximate the values of C_{kt}, and the road distance between the centroids of rural communities and cities were used to compute d_{ck}. Since we are interested in estimating the impact of cities on the growth and development on rural areas, our relevant measure is the access to urban markets for each rural community/village.

Additionally, we are aware that the values of θ could affect the estimated elasticity of market access. Therefore, we follow a different approach to observe how the elasticity of market access can be affected by different values of θ, since we do not have precise information on transportation costs and flows of goods between rural communities and cities to an appropriate estimation of θ. Consequently, we operate under three different scenarios to check the robustness of our estimations. The estimation of θ is important because this parameter summarize trade relations that are implicit in the market access equation (Donaldson and Hornbeck, 2016; Donaldson, 2018). And our different scenarios give an insight on how much of the

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[130] Which implies a faster decay rate of nighttime lights with distance in comparison to the polynomial functional form frequently used (Harris, 1954). This decay rate is more intensified when the distance variable is to the power of 2.

variation in θ can influence the market access elasticities of population and employment.[131]

Under the first scenario, we compute market access following an approximation of Harris (1954). This is the baseline scenario, as the case in which $\theta = 1$ and the square of $d_{j,k}$ is used, which is also the most widely used empirical approximation for market access. For the second scenario, we rely on the literature on planning and transportation, based on the early works of Carrothers (1956), Hansen (1959), and Weibull (1976) and recently used for similar applications in agricultural economics by Binswanger-Mkhize et al. (2016) and Binswanger-Mkhize and Savastano (2017). In this scenario, we use a standard negative exponential distance decay function, in which $\theta = 1/2a^2$ and the square of $d_{j,k}$ is used, where a is a parameter that represents the distance to the point of inflection of the distance decay function. We estimate it by using a representative value for $a = 50$ and $a = 100$, as in Binswanger-Mkhize et al. (2016).

Therefore, in addition we estimate parameter θ of the market access function adjusted by using three different distance decay functions according to the size of cities (a similar approach has been explored by Halas, Klapka, and Kladivo, 2014).[132] This allows us to account for the fact that the spatial distribution of medium- and small-sized cities is more spread and easier to access by the population of rural communities, together with the fact that large cities are usually more concentrated in some areas and have less spatial scope over the entire spatial distribution of rural communities.[133]

5.4.2.2 Market Access and Rural Population and Employment Growth

From Eqn. 48, we can derived an empirical approximation as:

$$\ln Y_{ct} = \beta \ln MA\left(\mathbf{C}_k, \mathbf{d}_{ck}, \hat{\theta}\right)_{ct} + \delta_m + \delta_t + \delta_{mt} + f(x_c, y_c) + \epsilon_{ct} \tag{53}$$

where Y_{ct} = is population, employment (farm and non-farm) in rural community j in year t, MA_{ct} = access to urban markets of the rural community j in year t, $MA_{ct} = \sum_k C_{kt} e^{-\theta d_{c,k}}$, δ_m = municipality fixed effect, δ_t = year fixed effect, δ_{mt} = municipality-year fixed effect, $f(x_c, y_c)$ = cubic polynomial in latitude and longitude of the rural community. Standard errors are clustered at the rural community level. Due that the effects of urban growth on the

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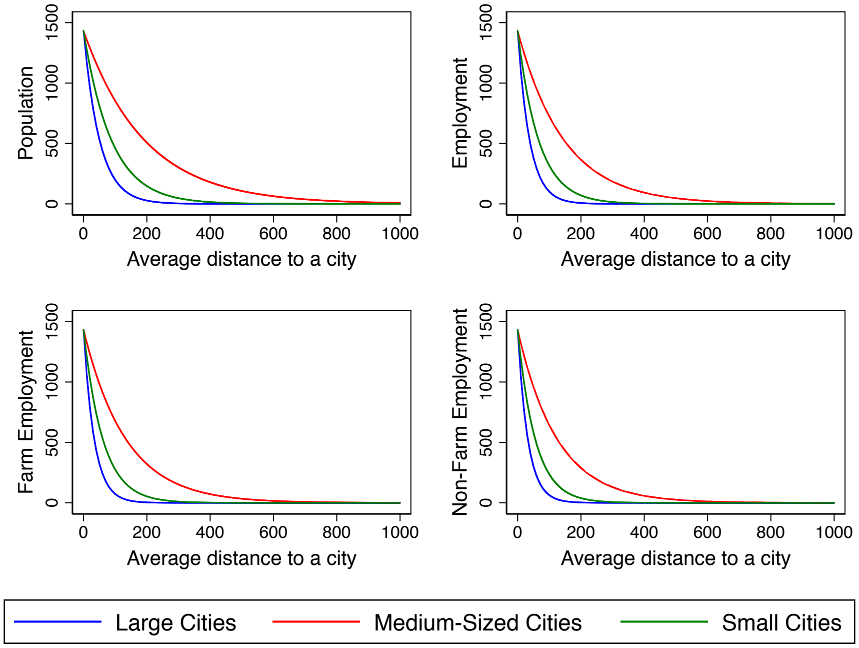
[131] Usually, this parameter is estimated using trade flows, but in this case we assume that the structure of the trade relationship depends on the outcome in the destination locality (Donaldson, 2018). Therefore, the parameter that describe contemporaneous population is the similar to the parameter that describe flows (Donaldson and Hornbeck, 2016).

[132] This mimic the approach of computing different θ for different transport modes with the distinction that here we assume that transport infrastructure might vary depending on the size of cities. Considering that usually better infrastructure is founded to access to larger cities.

[133] This stylized fact can be inferred from Fig. A5.2 and Fig. A5.6, and confirmed in Fig. 5.6 for the case of study.



The figure shows the market access predictions for population, total employment, farm and non-farm employment by city-size at 1992 using non-linear least squares. The estimated parameters of these distance decay functions were used to construct the city-size adjusted market access variable. In all cases, there are larger effects of medium-sized cities (the red line) over rural population and employment. These effects are because the aggregate wealth of medium-sized cities is larger and they are more equally distributed in space, having a larger spatial scope of their positive effects, compared to big or small-sized cities.

Figure 5.6: Market Access Functions Adjusted by City-Size

population and employment of rural communities would take time to manifest, we estimates these equations using a one-year lagged market access variable. There are demographic and cultural factors such as social norms, as well as other externalities affecting local population. If these are specific to municipalities, then the time by municipality fixed effects can capture those effects.

According to our framework, the effects of market access on farm and non-farm employment may be associated with two main mechanisms: the demand for agricultural goods and changes in agricultural productivity. Both of these mechanisms are captured by market access. On one hand, a higher access to urban markets is associated with a higher demand for agricultural products and, consequently, a higher employment in the farm sector and also in the non-farm sector but in activities auxiliary to agriculture, such as the commerce and transportation of agricultural goods. On the other hand, rural communities with better connectivity to cities may have more access to technology for agricultural production. This would increase the agricultural productivity of these rural communities, diminishing the price of agricultural goods in relation to manufactured goods, leading to a movement of workers from the farm to the non-farm sector. However, even in this scenario, is likely that some non-farm jobs would be in activities that are auxiliary to agriculture. Location specific fixed effects interacted with year dummies would take variation caused by local differences in technology and prices and left the variation that is induced due to economic growth in cities and improvements in access to urban markets.

The effects of market access on non-farm employment of rural communities may also impact activities not related to agricultural production. For example, if the opportunity cost of producing agricultural goods is higher in the hinterland of cities due to the reallocation of some urban activities such as manufacturing production, this would lead to an increase in the employment of rural communities in the non-farm sector in activities not necessarily related to agricultural production. However, this effect is likely to be found only in the hinterland of cities. This implies that if prices and productivity of the non-tradable sector increases more than prices and productivity in the farm sector, which is in theory expected as higher the market access, then the impact in the farm employment would be negative.[134] However, in the case of the non-farm employment, the effect of the size of the non-tradable sector has a major weight masking negative effects in the tradable sector.

From our setting and assuming that workers are indifferent to working in either sector and have free mobility, the farm employment of a rural community j depend on the way farm and non-farm workers substitute agricultural and manufactured goods. If the demand for agricultural goods is inelastic (as suggested by Tobin, 1950; Tolley, Wang, and Fletcher, 1969; Van-Driel, Nadall, and Zeelenberg, 1997), any improvement in agricultural productivity could induce a movement of farm workers to the non-farm sector since an increase in agricultural productivity decreases the price of the agricultural good. However, since a proportion of non-farm employment is generated in rural communities, this migration from the farm to the non-farm sector does not always imply a reduction in the total employment level of the rural community. This allows for the possibility that the diversification of the employment in rural communities could also generate growth in total population and offset the decline in the farm employment. This also is consistent with the literature of agricultural intensification and can allow rural growth with structural change, or a decline in rural growth if the increase in the non-farm sector do not offset the decrease in the farm-employment.

The population of rural communities, is an important indicator of their development and also

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[134] Empirically we do not observe prices and productivity for each rural community and time, however it is an, arguably, plausibly assumption that productivity and prices in the agricultural sector are lower than in the non-tradable and tradable non-agricultural sector.

determines total employment (Carlino and Mills, 1987; Henry, Schmitt, Kristensen, Barkley, and Bao, 1999; Partridge and Rickman, 2003; Hoogstra, Van-Dijk, and Florax, 2011; Chen and Partridge, 2013; Olfert, Partridge, Berdegué, Escobal, Jara, and Modrego, 2014), considering both the number of workers in the farm and non-farm sector. Despite the migration effects of workers to cities, on average, this may be offset by the benefits of higher market access. From our setting, the expected effect of market access on the non-farm employment of rural communities is positive and if this offset any decline in the farm employment in these communities, a positive effect would be expected for the population of these communities. An increase in the non-farm employment, however, may also induce a decrease in the farm employment. Notwithstanding, this only would affect negatively the average population of rural communities if this migration is to urban areas.

However, only rural communities that are very close to cities are likely to be affected by both of these factors. Following a similar approach as Donaldson and Hornbeck (2016), we account for this issue by constructing buffers/polygons of 10 and 15 kilometers from the boundaries of cities and select those rural communities outside these areas. Farther away from these thresholds, the average effect of market access on the population and farm and non-farm employment of rural communities is expected to be positive. Moreover, we also estimate the results with and without small rural communities to observe the robustness of our results to different cut-off points for the inhabitants of rural communities.

Additionally, we instrument the market access using the historical census of population in cities in $t = 1865$, 1889, and 1900 $\left(G_{j,t} = \sum_k Pop_{k,t} e^{-d_{j,k}}\right)$.[135] Most of places where rural communities are nowadays where inhabited in those early years, just fifty years after the Chilean independence, making the instrument relevant. In the sense that is a good predictor of the location and growth of rural communities only because it explains the location and growth of cities. Identification comes from historical population influencing contemporaneous population in cities.

5.4.2.3 Market Access, Agricultural Potential and Farm Employment It might be the case that the effects of the market access depends on the heterogeneity in specialization on agricultural activities in rural communities. This is the hypothesis that market access have a positive effect on agricultural intensification. It is important to understand this because in areas that are more specialized in agricultural activities, it would be more convenient to invest on the development of the agricultural sector, but in areas that are more diversified it might be better

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[135] This approximate of the market access in 1865 is expected to only have an effect on contemporaneous population and employment growth in rural communities through contemporaneous market access. The urban system at 1865 was composed of 30 cities, while at 1992 it was composed of 160 cities.

to support non-farm activities. Consequently, we estimate the heterogeneous effects of market access across rural communities with different levels of agricultural potential. This would be given by

$$\ln L_{ct}^{F} = \alpha A_{ct}^{F} \ln MA \left(\mathbf{C}_k, \mathbf{d}_{ck}, \hat{\theta}\right)_{ct} + \delta_m + \delta_t + \delta_{mt} + \delta_l + f(x_c, y_c) + \epsilon_{ct} \tag{54}$$

with L_{ct}^{F} = farm employment in rural community c in year t, A_{ct}^{F} = agricultural potential in rural community c in year t, Normalized Difference Vegetation Index (**NDVI**), Enhanced Vegetation Index (**EVI**), Green Chlorophyll Vegetation Index (**GCVI**), δ_c = municipality fixed effect, δ_t = year fixed effect, δ_{mt} = municipality-year fixed effect, δ_l = land-cover fixed effect, $f(x_c, y_c)$ = cubic polynomial in latitude and longitude of the rural community, Identification comes from: exogenous geography influencing agricultural productivity. Standard errors clustered at the rural community level. Therefore, we also estimate the elasticities of the market access incorporating in the farm employment equation the agricultural potential proxy with the vegetation index. The square of the agricultural potential is also incorporated in this set of equations, following the evidence in Damania et al. (2017), that suggest non-linear effects of agricultural potential on production, due to increasing or diminishing returns of crop suitability that different crops on modern and traditional production might have.

5.4.2.4 Farm to Non-Farm Employment Multipliers The growth in the agricultural sector, still can be one of the main drivers for rural economic development in some rural areas. And, given that market access have a positive effect for rural communities that have more agricultural potential, then it is useful to understand better to what extent farm employment generate employment in the non-farm sector, by activities that can be auxiliary to agriculture or that are associated with the intensification of agricultural activities in those areas.

$$\ln L_{ct}^{NF} = \gamma L_{ct}^{F} + \delta_m + \delta_t + \delta_{mt} + f(x_c, y_c) + \epsilon_{ct} \tag{55}$$

L_{ct}^{NF} = non-farm employment in rural community c in year t, L_{ct}^{F} = farm employment in rural community c in year t, δ_m = municipality fixed effect, δ_t = year fixed effect, δ_{mt} = municipality-year fixed effect, $f(x_c, y_c)$ = cubic polynomial in latitude and longitude of the rural community. Identification comes from exogenous geography influencing agricultural productivity, standard errors clustered at the rural community level.

5.4.3 Evidence

5.4.3.1 General Effects Table 5.1 reports the results of the impact of market access on the log of population, farm employment, and non-farm employment of rural communities. The table describes the different scenarios used to compute the market access variable. Panel a) shows the baseline case, which assumes that the parameter $\theta = 1$ (i.e., the market access variable used in these estimations), which is approximately similar to that of Harris (1954). We choose this as the baseline scenario because is the most widely used measure of market access. All regressions include fixed effects at the rural community level and standard errors are clustered at the municipality level.[136] The first three columns of Table 5.1 show the Ordinary Least Squares (OLS) estimations of the impact of market access on the log of population, farm employment, and non-farm employment of rural communities. The last three columns of the table present the Instrumental Variable (IV) estimations to account for the endogeneity of the market access variable. The observations in this set of regressions are 1,451, that correspond to rural communities with a population between 100 and 3,000 inhabitants at 1992. This rural villages have an average population of 500 inhabitants (see Table A5.1). Across all estimations elasticities might be particularly high, and this is expected due to the small size of the rural communities, but also an important degree of heterogeneity is expected, as some rural communities are growing while other are loosing population as a function of the market access and the importance of the agricultural sector.

Across all IV estimates in Table 5.1, conditional on local demographic trends captured by locality fixed effects, the impact of the market access on the population of rural communities is positive and statistically significant. Although the significance is not too strong, that might reveal the low gains in average due that the heterogeneity that is underlying the estimates and that the overall population in rural communities just has an important increase during the last 15 years, as it is shown in 5.2.

The IV estimated 25-year elasticity of market access on population in Panel a), suggests that a 10% more market access led to an increase of approximately 3% in the population of rural communities, while this effect is between 1% and 4% for the low- to high-distance friction scenarios of the distance decay market access function (Panel b and c), and approximately 3% for the city-size adjusted market access function (Panel d). The assumption that rural communities face similar distance frictions to get to large and small size cities is difficult to maintain because infrastructure is usually better for accessing large cities. Therefore, Panel

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[136] Each municipality has several rural communities or villages. There are 346 municipalities in Chile, but approximately 90 have rural communities. Most of the municipalities at the extreme north and south of the country do not have agro-ecological conditions favourable for agricultural production.

Table 5.1: Market Access, Population and Farm and Non-Farm Employment

	OLS			2SLS		
	Log Population	Log Farm Employment	Log Non-Farm Employment	Log Population	Log Farm Employment	Log Non-Farm Employment
Panel a): Baseline Market Access with $MA_c = \sum_k C_k e^{-d_{c,k}}$						
Log Market Access	0.105	0.093	0.178*	0.316**	-0.134	0.951***
	(0.069)	(0.083)	(0.102)	(0.163)	(0.212)	(0.254)
R^2	0.470	0.528	0.646			
F-stat				114.561	114.485	122.253
Observations	1,451	1,451	1,451	1,451	1,451	1,451
Panel b): Distance Decay Market Access Function with $MA_c = \sum_k C_k e^{-\frac{1}{2(50)^2} d_{c,k}}$						
Log Market Access	0.021	0.012	0.030	0.097*	-0.042	0.301***
	(0.018)	(0.020)	(0.025)	(0.163)	(0.066)	(0.086)
R^2	0.470	0.527	0.646			
F-stat				50.103	47.874	50.195
Observations	1,451	1,451	1,451	1,451	1,451	1,451
Panel c): Distance Decay Market Access Function with $MA_c = \sum_k C_k e^{-\frac{1}{2(200)^2} d_{c,k}}$						
Log Market Access	0.107	0.064	0.151	0.396*	-0.170	1.222***
	(0.078)	(0.084)	(0.105)	(0.205)	(0.271)	(0.343)
R^2	0.471	0.528	0.646			
F-stat				53.674	51.885	54.801
Observations	1,451	1,451	1,451	1,451	1,451	1,451
Panel d): City-Size Adjusted Market Access Function with $MA_c = \sum_k Y_k e^{-\hat{\theta}_m d_{j,k}}$						
Log Market Access	0.153*	0.095	0.167**	0.326*	-0.099	0.693***
	(0.080)	(0.066)	(0.082)	(0.167)	(0.156)	(0.183)
R^2	0.473	0.529	0.647			
F-stat				120.152	136.927	147.121
Observations	1,451	1,451	1,451	1,451	1,451	1,451

$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. *Note*: All models include municipality fixed effects, year fixed effects, municipality-year fixed effects, and cubic polynomial in latitude and longitude of the centroid of the rural community. The 2SLS uses as an instrument historical urban market access.

d) present the results using a market access variable calculated to allow rural communities to face different distance frictions to reach different types of cities. Consequently, in this scenario, we do not assume a particular value of θ for the computation of the market access variable, but use different values of θ to adjust the market access variable for different distance decay functions (these functions are presented in Figure 5.6). Given the small population size of rural communities, these are not too important effects, due that double the population of the largest rural community according to the census definition at 1992 just would mean to reach almost 6,000 inhabitants. However, the effects on population tend to be robust across the different market access functions.

The impact of market access on the change of non-farm employment of rural communities is also positive and stronger than the effect on the rural population, with particularly high elasticities that tend to vary in an important magnitude between the different market access functions. Specifically, for the baseline scenario in Panel a), the IV estimate is of nearly 1, however, these elasticities vary between 0.3 and 1.2 between the low- and high- distance frictions scenarios of the distance decay market access function. The city-size adjusted market access function, however, gives a more intermediate elasticity of approximately 0.7. In consequence, it is more likely that non-farm employment effects tend to be more heterogeneous and depend more on the accessibility than the population that is probably more stable. It might be the case that many of these jobs require of certain low commuting time to urban center to be created, and then estimations are more sensible to the selection of the parameter of distance friction.

On the other hand the market access elasticity on farm employment is non-significant in all the periods, both in OLS and IV estimations. This higher elasticity of market access for non-farm employment relative to farm employment is robust across all estimations and is likely to be associated with the process of structural change in the rural economy (Irwin, Bell, Bockstael, Newburn, Partridge, and Wu, 2009; Castle, Wu, and Weber, 2011). The important differences between the OLS and IV estimates are likely to be explained because these effects tend to be more local. The instruments are taking the variation of the market access variable that is being explained by historical population in cities and then explaining the contemporary patterns of rural population and employment.

The elasticity of market access for the population is similar to that in the literature (Jedwab and Storeygard, 2022). However, the elasticity is particularly high for farm and non-farm employment, but not much other empirical evidence exists to compare with these results. However, the distinction between farm and non-farm employment in rural communities is crucial. When no distinction is made and the elasticities of market access are computed for the total employment of the rural areas, the results may not be well understood, in the sense that, in many locations, particularly near cities, the behavior of farm employment and non-farm employment in rural communities may follow different patterns, leading to negative effects of market access on farm employment. This could also be the case in some articles that argue a negative or non-significant effect of market access on the total employment of rural areas but a positive and significant effect on the population, as in Chen and Partridge (2013) for China. The high values of the elasticities of market access for the non-farm employment of rural communities in relationship to the elasticities for the farm employment of rural communities are also indicative of the growing importance of the non-farm sector for rural areas, something that has been widely studied in agricultural economics (Berdegué, Ramirez, Reardon, and Escobar, 2001). However, there is an important heterogeneity in rural communities, evidenced when our proxy of agricultural productivity was included in estimations.

A movement of workers from agriculture to the non-farm sector in rural communities may explain the lack of a significant effect of the market access on farm employment, and the high elasticities in the non-farm employment. If this movement, on average, was inside rural communities would also explain a consistently positive market access effect in the population of rural. Otherwise, we should observe a negative effect on rural population.

5.4.4 Mechanisms of Structural Change

One of the key elements of heterogeneous impacts of the market access on rural population and employment is agricultural productivity. Consequently, in order to provide more evidence on the mechanisms behind the growth of rural communities, Table 5.2 shows the regressions including our proxy of agricultural potential in the farm-employment equation. For this purpose, we use remote sensing data to construct a proxy of agricultural productivity, which as the evidence suggests, might be as informative as survey-based methods (Burke and Lobell, 2017). We estimate this relationship using three indices. Namely, the NDVI, EVI, and GCVI. The different market access variables are used to show the robustness of the results. Due to the availability of daytime cloud-free satellite data for the entire country, the sample is reduced. In Table 5.2, we also allow the market access vary with the agricultural potential to observe if market access has a positive effect in farm employment in rural communities that have better conditions for agricultural production. This would be more in line with the hypothesis of agricultural intensification. To do this we interact the market access with the agricultural potential.

Our estimations show significant negative elasticities of the market access interacting the agricultural potential farm employment of rural communities and are robust across the different

Table 5.2: Market Access, Agricultural Potential and Farm Employment

	Log Farm Employment					
	OLS			2SLS		
	GCVI	NDVI	EVI	GCVI	NDVI	EVI
$A^F_{jt} \ln MA$	-0.034**	-0.033**	-0.028**	-0.492***	-0.365***	-0.296***
	(0.015)	(0.014)	(0.012)	(0.167)	(0.112)	(0.088)
A^F_{jt}	0.169***	0.066	0.082	0.876***	0.254**	0.183**
	(0.066)	(0.065)	(0.063)	(0.275)	(0.100)	(0.078)
R^2	0.562	0.547	0.547			
Observations	1,021	1,008	1,010	1,021	1,008	1,010
F-stat				15.675	20.379	23.066
P-val LM stat				0.000	0.000	0.000

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. *Note*: All models include municipality fixed effects, year fixed effects, municipality-year fixed effects, and cubic polynomial in latitude and longitude of the centroid of the rural community. The 2SLS uses as an instrument historical urban market access.

proxies of agricultural productivity. Therefore, is likely that rural communities highly specialized in agriculture, or at least with good agro-ecological conditions for the production of agriculture (probably captured by our vegetation indices), experiences decreases in the farm employment, that to some extents can be explained by technological productivity improvements, or diversification. Taking large advantages of the access to urban markets with also a growth in the non-farm sector, probably in activities that are auxiliary to agriculture, such as the transportation of agricultural goods or commerce, rather than in activities that are not related to agriculture. This is consistent with the hypothesis of the intensification of agricultural activities in places with more market access. The elasticity of agricultural labor supply to market access is an important indicator on how the impact of increasing demand generated in urban areas would impact rural inhabitants Jayachandran (2006).

To understand to what extent the growth in non-farm employment is related with agricultural production due to the requirements of activities that are auxiliary to agriculture, or might be explained by other activities that are not related even indirectly with agriculture. Table 5.3 shows the multipliers effects of farm employment on non-farm jobs. The IV estimate reveal an employment multiplier of approximately 0.9. This is a high elasticity that shows that it might be the case that the growth in the agricultural sector might induce growth in non-farm sector in activities that are not directly related. Then for some rural communities with better conditions for agriculture or more specialized on it, public investments in the sector might have a high social return.

Table 5.3: Farm to Non-Farm Employment Multipliers

	Log Non-Farm Employment	
	OLS	2SLS
Log Farm Employment	0.330***	0.865***
	(0.050)	(0.303)
R^2	0.672	
Observations	1,451	1,451
F-stat		17.491
P-val LM stat		0.000

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. *Note*: All models include municipality fixed effects, year fixed effects, municipality-year fixed effects, and cubic polynomial in latitude and longitude of the centroid of the rural community. The 2SLS uses as an instrument agricultural potential captured with satellite images.

5.5 Conclusion

In an increasingly urbanized world, the idea of cities as engines of economic growth and development has gained a large number of supporters. Even for rural development policies, it is argued that the positive effects derived from urbanization that spill over to the countryside such as trade integration or the growth of non-farm activities, are a potential source to outweigh the economic decline that is induced at the same time by rural-to-urban migration. In fact, far from being new, the idea that cities can shape the development of rural areas has been on the mind of scholars for a long time. It is not entirely clear, however, to what extent the positive spillover effects would offset the negative ones.

To provide evidence on the dynamics of urbanization for rural areas, we follow a market access approach to develop a framework to better understand how urban growth and transport infrastructure development influence the growth and structural change out of agriculture of rural communities through market access. Consequently, we estimate the effect of cities on the development of rural communities as the effect of the market access on the population, farm and non-farm employment of rural communities in Chile for a 25-year period.

The results can be summarized by the following four main points. First, we found, in our preferred estimations, that a 10% higher market access led to an average 25-year increase of nearly 3% in the population of rural communities in Chile. This elasticity is robust across all estimations. Second, a high access to urban markets is in the short-term generally associated with increasing both farm employment and non-farm employment in rural communities. Third, higher elasticities of market access were found for non-farm employment rather than in the farm sector. However, rural communities more specialized in agriculture might experience higher levels of growth induced by cities in the farm employment rather than in the non-farm sector.

Various policy implications can be derived from this work. First, improvements in the infrastructure connecting rural communities and cities could lead to important effects in the growth and development of rural communities, thus accelerating the process of structural change for those rural communities nearby cities. Second, these improvements in infrastructure can be prioritized for rural communities that are near medium-sized cities, since they can reach a larger number of rural communities. Third, for rural communities that are farther away from cities, policies can be oriented to develop both the farm and non-farm sector, but should carefully consider the conditions for agricultural production in those areas. Finally, for rural communities highly specialized in agriculture, rural development policies may be created to provide farmers with a better comprehension of the products that are highly demanded in cities, together with increased access to farming technology. These policies aiming rural-urban linkages are at the hearth of the objectives of the UN sustanaible development goals to promote rural development.

More research could be conducted to better understand the dynamics of rural communities near the boundaries of cities. The effects associated with the changes in land use, rural non-farm employment that is generated in the city, and other commuting opportunities for rural inhabitants could be leading to different patterns of development for those rural communities located farther away from cities. Despite that, on average, the effect of cities is positive and significant for population, the dynamics of nearby communities could be playing an important role and there is limited evidence available in this respect. On the other hand, analyzing the distributional impacts on welfare from urban growth on rural households would help to clarify many of the mechanism that are included in the model and were not treated in this paper due to data limitations.

5.6 Appendix

5.6.1 Model Appendix

The previous part of the mathematical model are standard to solve in the literature (see Allen and Arkolakis, 2015). However, the derivation of the market access requires some additional particular assumptions. In general equilibrium, it would be the case that the value of goods purchased by a location i is equal to the income that consumers spent on that good, i.e.,

$$\delta Y_j = \sum_{i \in \Im} X_{ij}$$

In consequence (and assuming $Y_i = E_j$ the income received at the supply location i has to be equal to the expenditure spent in location j), then the gravity equation can be expressed as

$$\delta Y_j = \sum_{i \in \Im} C^{-\theta} \tau_{ij}^{-\theta} w_i^{-\theta} T_i \delta E_j P_j^{\theta} \iff 1 = C^{-\theta} \sum_{i \in \Im} w_i^{-\theta} T_i \tau_{ij}^{-\theta} P_j^{-\theta}$$
$$\iff P_j^{-\theta} = C^{-\theta} \sum_{i \in \Im} T_i w_i^{-\theta} \tau_{ij}^{-\theta} \equiv CMA_j$$

that we define as consumer market access, as Donaldson and Hornbeck (2016). Substituting the consumer market access into the gravity equation, and assuming again $Y_i = E_j$), yields

$$X_{ij} = C^{-\theta} T_i w_i^{-\theta} \tau_{ij}^{-\theta} P_j^{\theta} \delta E_j \iff X_{ij} = C^{-\theta} T_i w_i^{-\theta} \tau_{ij}^{-\theta} CMA_j^{-1} \delta Y_i. \tag{56}$$

Assuming that goods markets clear, so for manufacturing goods this means that $\delta Y_i = \sum_{j \in \Im} X_{ij}$, which implies that

$$\delta Y_i = C^{-\theta} T_i w_i^{-\theta} \sum_{j \in \Im} \tau_{ij}^{-\theta} CMA_j^{-1} \delta Y_i \iff \delta Y_i = C^{-\theta} T_i w_i^{-\theta} FMA_j \tag{57}$$

where $FMA_j \equiv \sum_{j \in \Im} \tau_{ij}^{-\theta} CMA_j^{-1} \delta Y_i$ is the firm market access in destination location $j \in \Im$. Under spatial equilibrium (workers perfectly mobile across locations), utility equalize across locations which implies that real wages also equalize across locations.[137] i.e.

$$\overline{U} = \frac{w_i}{P_i} = \frac{w_j}{P_j}. \tag{58}$$

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[137] Note that the assumption of spatial equilibrium is only used here at the end avoid the necessity to observe wages in the data. However, we also show results using nominal wages to see the robustness of this result to this assumption.

In consequence, by substituting the nominal wage w_i in Eqn. 57, we obtain

$$\delta Y_i = C^{-\theta} T_i \overline{U}^{-\theta} P_j^{-\theta} FMA_j \iff \delta Y_i = C^{-\theta} T_i \overline{U}^{-\theta} CMA_j FMA_j \tag{59}$$

Another condition of the spatial equilibrium imposed in these types of models is that the labor market clears, i.e. $\delta Y_i = \delta w_i L_i$, together with the condition that $w_i = \overline{U} P_i = \overline{U} \left(CMA_i \right)^{-\frac{1}{\theta}}$ which implies that

$$L_i^C = C^{-\theta} T_i \overline{U}^{-\theta} CMA_j FMA_j w_i^{-1} \iff L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} CMA_j^{\frac{\theta-1}{\theta}} FMA_j \tag{60}$$

where $\delta L_i = L_C$ is the labor in the manufacturing sector. Taking the logs, we can express the previous equation as

$$\log L_i^C = -\theta \log C + \log T_i + (1-\theta) \log \overline{U} + \left(\frac{\theta - 1}{\theta} \right) \log CMA_j + \log FMA_j$$

Assuming symmetric transport $\tau_{ij} = \tau_{ji}$, firm and consumer market access have to satisfy a proportionality condition $MA_i \equiv FMA_i = \rho CMA_i \; \forall i \in \Im$ with $\rho > 0$. Which implies that

$$FMA_i \equiv \sum_{j \in \Im} \tau_{ij}^{-\theta} CMA_j^{-1} \delta Y_i \iff MA_i = \sum_{j \in \Im} \tau_{ij}^{-\theta} \rho MA_j^{-1} w_i N_i$$

where $\delta Y_i = w_i N_i$. Substituting $w_i = \overline{U} P_i = \overline{U} \left(CMA_i \right)^{-\frac{1}{\theta}} = \overline{U} \rho^{\frac{1}{\theta}} MA_i^{-\frac{1}{\theta}}$, yields

$$MA_i = \sum_{j \in \Im} \tau_{ij}^{-\theta} \rho MA_j^{-1} \left(\overline{U} \rho^{\frac{1}{\theta}} MA_i^{-\frac{1}{\theta}} \right) N_i \iff MA_j = \overline{U} \rho^{\frac{1+\theta}{\theta}} \sum_{j \in \Im} \tau_{ij}^{-\theta} MA_i^{-\frac{(1+\theta)}{\theta}} N_i \tag{61}$$

Then, with the proportionality condition $MA_i \equiv FMA_i = \rho CMA_i$ we can express Eqn. 60 as

$$L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} \left(\rho^{-1} MA_j \right)^{\frac{\theta-1}{\theta}} MA_j \iff L_i^C = C^{-\theta} T_i \overline{U}^{1-\theta} \rho^{\frac{1-\theta}{\theta}} MA_j^{\frac{2\theta-1}{\theta}} \tag{62}$$

Taking the logs gives the equation of the manufacturing employment

$$\log L_i^C = k_1 + \log T_i + \left(\frac{2\theta - 1}{\theta} \right) \log MA_j \tag{63}$$

where $k_1 = \log\left(C^{-\theta}\overline{U}^{1-\theta}\rho^{\frac{1-\theta}{\theta}}\right)$. Substituting Eqn. 61 in Eqn. 62 yields

$$L_i^C = C^{-\theta}T_i\overline{U}^{1-\theta}\rho^{\frac{1-\theta}{\theta}}\left(\overline{U}\rho^{\frac{1+\theta}{\theta}}\sum_{j\in\Im}\tau_{ij}^{-\theta}MA_i^{-\frac{(1+\theta)}{\theta}}N_i\right)^{\frac{2\theta-1}{\theta}}$$

Solving for the total number of workers (population) N_i and taking the logs gives

$$\iff \log N_i = k_2 + \left(\frac{\theta}{1-2\theta}\right)\log T_i + \left(\frac{2-\theta}{\theta}\right)\log MA_j + \left(\frac{\theta+1}{2\theta-1}\right)\log L_i^C \qquad (64)$$

where $k2 = \log\left(C^{\frac{\theta^2-\theta-1}{2\theta-1}}\overline{U}^{\frac{\theta(\theta-3)}{2\theta-1}}\rho^{\frac{\theta(\theta-1)+(2\theta-1)(1+\theta)}{\theta(2\theta-1)}}\right)$. Which also can be expressed as employment share in manufacturing, as

$$\log\left(\frac{L_i^C}{N_i}\right) = k_3 + \left(\frac{\theta}{\theta+1}\right)\log T_i + \left(\frac{2(\theta-2)(\theta-\frac{1}{2})}{\theta(\theta+1)}\right)\log MA_j \qquad (65)$$

where $k_3 = \log\left(C^{-\frac{\theta^2}{\theta+1}}\overline{U}^{\frac{-\theta^2-3\theta}{\theta+1}}\rho^{\frac{\theta(\theta-1)+(2\theta-1)(1+\theta)}{\theta(\theta+1)}}\right)$.

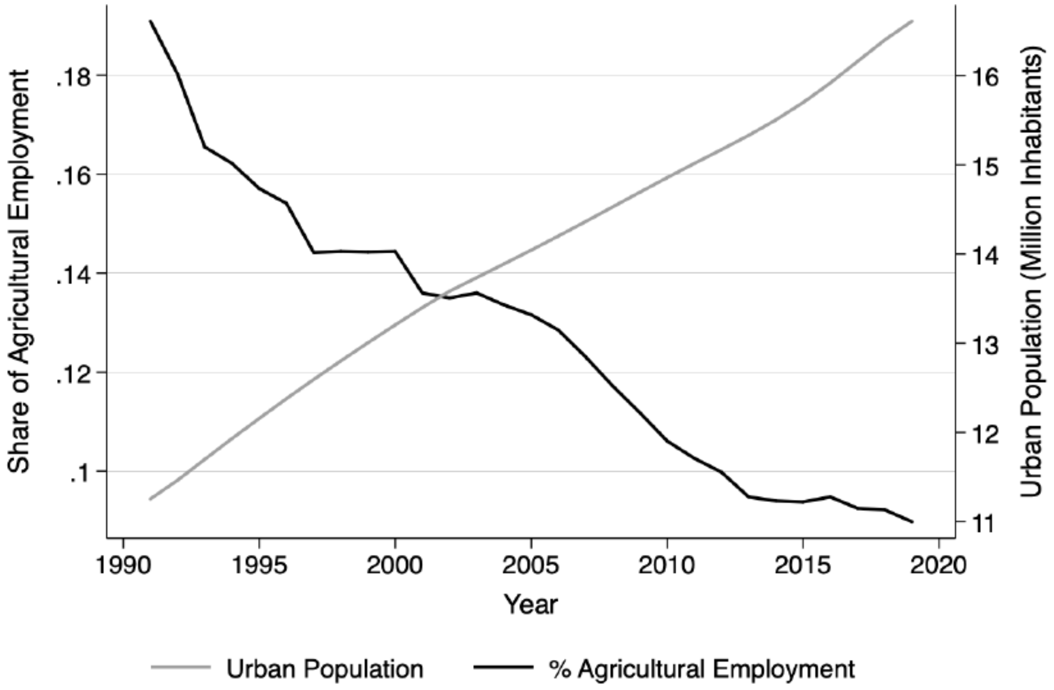
5.6.1.1 Agricultural Activities and Occupations in Rural Areas On the definition of farm employment, the following activities were considered:

- Agriculture, livestock, hunting and related activities
- Crops: market-oriented crops, horticulture
- Domestication and animal breeding
- Mixed exploitation of crops, domestication and animal breeding
- Agriculture and livestock services (except veterinary)
- Hunting and related activities
- Forestry, timber extraction and related activities
- Agroforestry
- Fishing and related activities

On the definition of farm employment by occupation, is considered the following activities, from the Census of 1992:

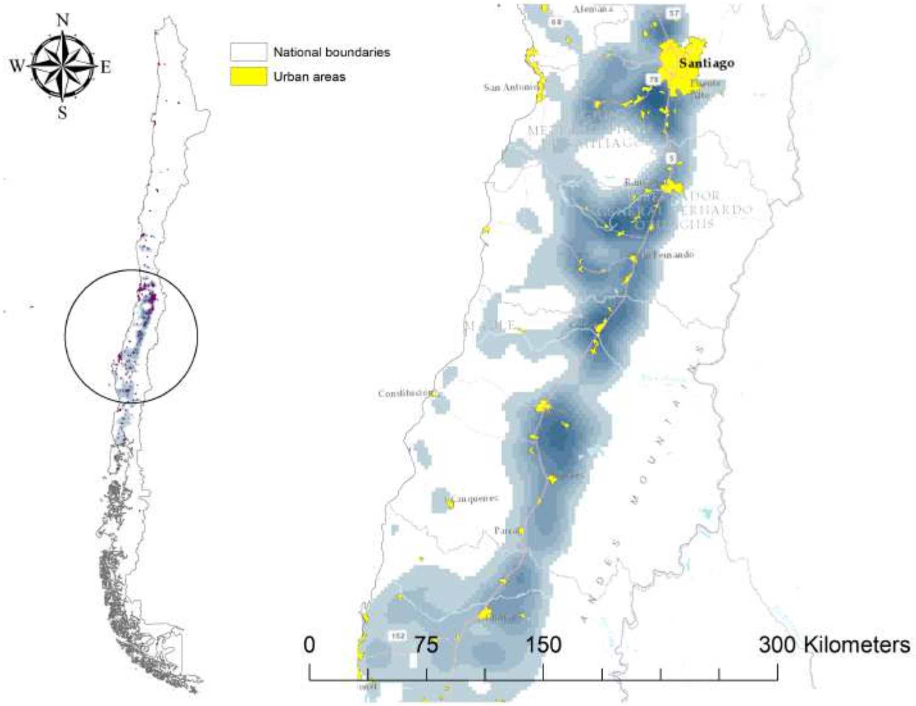
- Farmers and market oriented qualified agricultural workers and fisherman
- Farmers and market oriented qualified workers in agricultural farms, forestry, and fisherman
- Farmers and qualified workers in market-oriented crops
- Farmers and qualified workers in extensive crops
- Farmers and qualified workers in forest plantation and shrubs
- Farmers and qualified agricultural workers in orchards and greenhouses
- Farmers and qualified workers in mixed crops cultivation
- Market oriented breeders and livestock qualified workers
- Cattle and other domestic breeders, diary produces and subproducts
- Poultry farmers and qualified workers in poultry (eggs, meet, and feathers)
- Beekepers and sericulturists, and qualified workers in these items
- Breeders and qualified workers in breeders and other domestic animals
- Breeders and qualified livestock workers in breeding of wild animals for markets

- Market oriented producers and agricultural qualified workers
- Qualified workers in forest plantation and related tasks
- Three fellers and choppers, and other workers in forest related activities
- Charcoal workers and related activities
- Fishermen, hunters, and trappers
- Breeders of aquatic species
- Freshwater and coastal fishermen
- Deep sea fishermen (fishing and related tasks)
- Hunters and trappers
- Subsistence farming and fishing workers



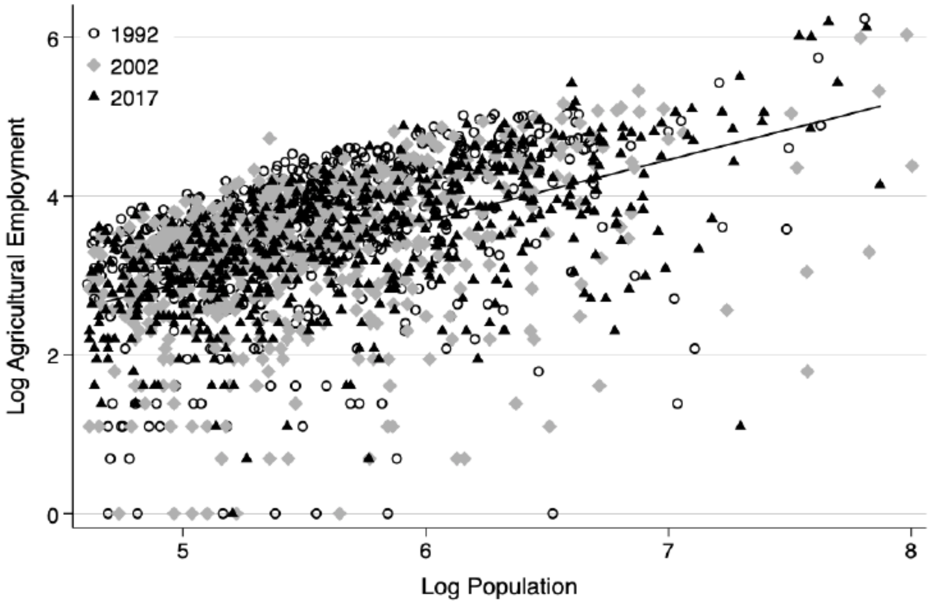
Notes: The figure displays the aggregate trends in agricultural employment and the urban population in Chile between 1991 and 2019. Over the same time the share of urban population increased by approximately 4%, from about 83.4% in 1991 to 87.6% by 2019. *Source:* Own elaboration based on data compiled by the World Bank from the International Labour Organization (ILOSTAT database), and the United Nations Population Division's World Urbanization Prospects: 2018 Revision.

Figure A5.1: Agricultural Employment and Urban Population

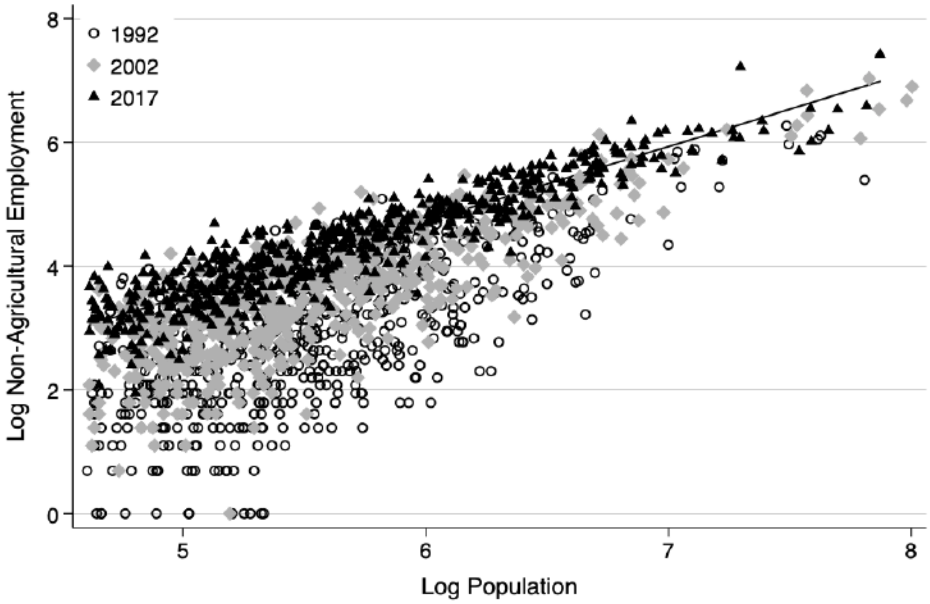


The figure describes the spatial distribution of cities and rural villages defined by the census in Chile. The yellow color represents urban areas using the administrative city borders at 2002. The blue scale represents the density of rural villages. These areas were defined as communities with less than 3,000 inhabitants. A spatial kernel density of the centroids of the rural villages weighted by their population in 2002 is used in the figure. The darker blue color represents more densely populated rural areas. Fig. A5.2 shows the spatial distribution of rural communities and cities in the country. Chile is 4,700 km long and 450 km wide at its widest point. However, agro-climatic conditions mean that most of the rural communities are located in the central-south part of the country, where the majority of the population is also concentrated as are the three most important cities in the country: the metropolitan areas of Santiago and Valparaiso—located at one and a half hours car-driving distance from each other—and Concepción—located on the coastal central south zone of Chile, at eight hours of car-driving distance from Santiago. In this area, between the cities Santiago-Valparaiso and Concepción, there are an important number of small- and medium-sized cities surrounded by a dense "green belt" of rural communities (represented by the blue-color gradient in the Fig. A5.2), where the majority of the rural population works and lives. Urban density is also particularly concentrated in this area.

Figure A5.2: The Spatial Distribution of the Urban and Rural Population



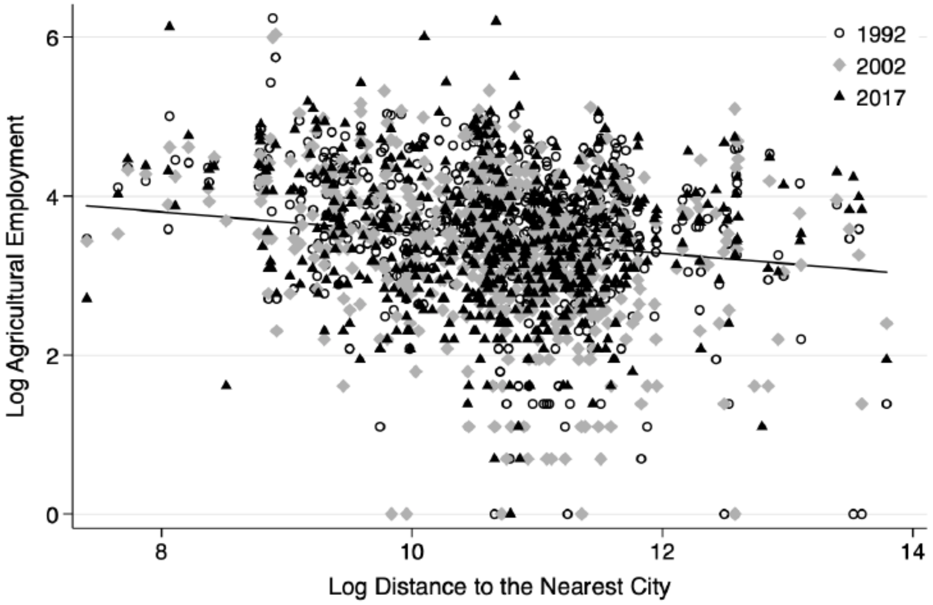
(a) Population and Agricultural Employment in Rural Villages



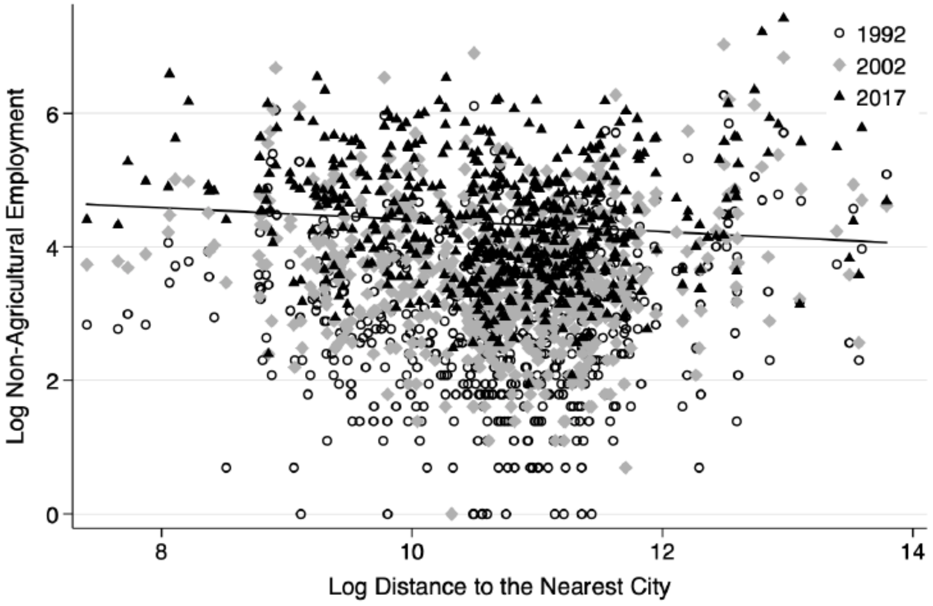
(b) Population and Non-Agricultural Employment in Rural Villages

The figure shows the linear relationship between the population and agricultural and non-agricultural employment in rural villages in Chile, Panel a) and b) respectively. The fitted line is constructed over the average values across the different years of the census. Larger rural locations are endowed with larger agricultural and non-agricultural employment. However, employment in the non-agricultural sector is larger than in the agricultural sector for more bigger rural areas. In addition, the non-agricultural sector has been increasing in time, as it is also shown in Fig. 5.1.

Figure A5.3: Population and Specialization in Agricultural and Non-Agricultural Activities



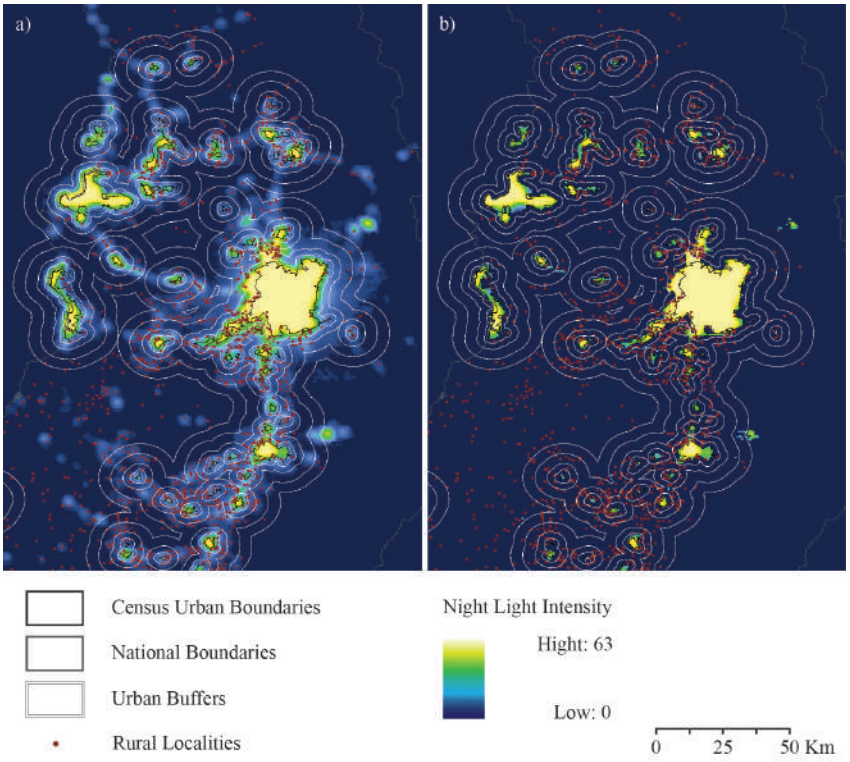
(a) Distance to the Nearest City and Agricultural Employment in Rural Villages



(b) Distance to the Nearest City and Non-Agricultural Employment in Rural Villages

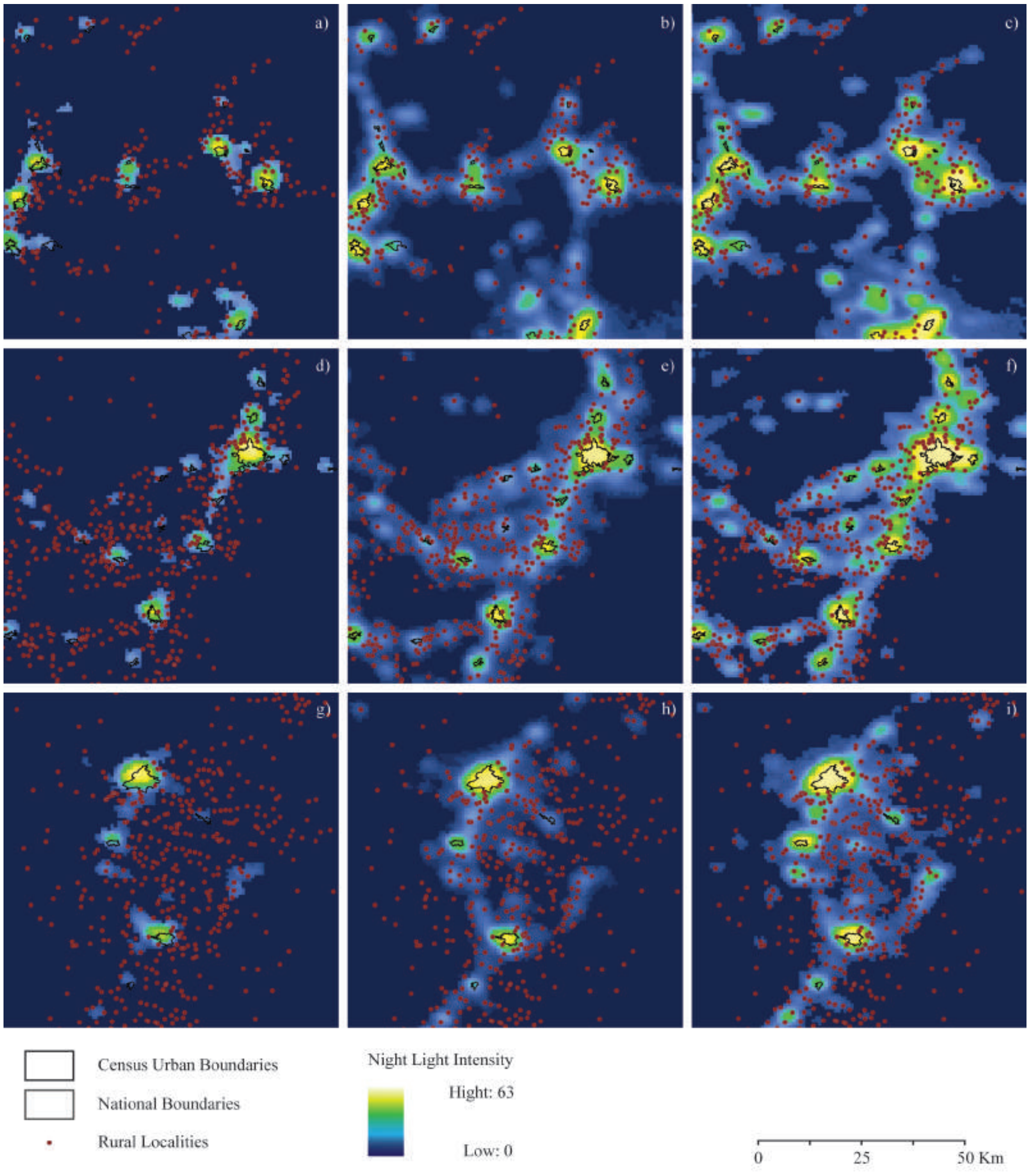
The figure shows the linear relationship between the distance to the nearest city and agricultural and non-agricultural employment in rural villages in Chile, Panel a) and b) respectively. The fitted line is constructed over the average values across the different years of the census. These values of sectoral employment for rural communities correspond to the levels over which Fig. 5.1 is constructed.

Figure A5.4: Access to Urban Markets and Specialization in Agricultural and Non-Agricultural Activities



The figure describes the nighttime lights image correction for the blooming effect following (Su, Chen, Wang, Zhang, Liao, Ye, and Wang, 2015). Both images display nighttime lights in the area surrounding the metropolitan area of Santiago de Chile in 2002. Panel a) displays the nighttime lights image without correction and Panel b) shows the image corrected. In addition, the figure describes urban buffers for 2, 5, 10 an 15 kilometers from 2002 the census urban boundaries.

Figure A5.5: Nighttime Lights Image Correction



The figures describes the spatial distribution of rural communities near medium-sized cities in Chile. The left-hand side panel of the figure shows the scenario for 1992, the center at 2002, and the right-hand side for 2013. Urban boundaries (in red), are the official boundaries delimited for the national census of 2002 by the Chilean National Statistical Office (INE).

Figure A5.6: Medium-Sized City Growth and Rural Communities

Table A5.1: Descriptive Statistics

	1992	2002	2017	$\geq 20km$	$\geq 50km$	$\geq 100km$
Population and Employment						
Population	311.41	328.15	391.29	329.03	394.79	669.76
	(360.52)	(420.43)	(347.17)	(378.77)	(490.14)	(707.70)
Employment	86.80	105.75	165.31	109.83	152.88	283.02
	(107.52)	(155.89)	(168.29)	(150.22)	(238.65)	(316.48)
Farm Employment	47.62	47.62	47.62	41.30	24.77	22.88
	(45.73)	(45.73)	(45.73)	(34.85)	(19.36)	(18.45)
Non-Farm Employment	39.18	39.18	39.18	48.44	83.60	187.06
	(84.00)	(84.00)	(84.00)	(99.06)	(138.41)	(218.42)
Market Access						
Distance to a City	20.95	20.95	20.95	39.52	83.25	160.64
	(22.39)	(22.39)	(22.39)	(28.88)	(46.88)	(54.32)
Baseline	-13.77	2.29	1.73	-4.06	-5.10	-6.52
	(1.56)	(1.43)	(1.23)	(7.62)	(7.74)	(7.78)
Distance Decay ($a = 50$)	-2.48	-2.88	-3.25	-5.28	-11.93	-34.68
	(6.59)	(5.30)	(7.16)	(7.91)	(14.68)	(19.13)
Distance Decay ($a = 200$)	-0.09	-0.13	-0.21	-1.01	-3.80	-12.29
	(3.92)	(1.95)	(2.49)	(3.27)	(6.67)	(9.72)
City Size Adjusted	0.47	0.40	-0.57	-0.85	-3.11	-8.28
	(1.25)	(1.30)	(1.75)	(2.01)	(3.51)	(3.92)
Observations	1292	1292	1292	1377	240	48
Agricultural Productivity						
GCVI	-0.14	-1.03	-0.30	-0.70	-1.14	-1.81
	(0.51)	(0.93)	(0.65)	(0.93)	(1.05)	(1.17)
NDVI	-1.41	-1.87	-1.36	-1.61	-1.95	-2.41
	(0.59)	(0.88)	(0.57)	(0.77)	(0.91)	(0.99)
EVI	-2.50	-2.80	-2.19	-2.53	-2.92	-3.40
	(0.66)	(0.93)	(0.63)	(0.87)	(0.97)	(1.01)
Observations	433	1152	1220	944	177	32

Mean and standard deviation (in parentheses).

Table A5.2: Data Description (GIS Variables)

Variable	Description	Primary Source
1. Baseline Market Access	$g_j = \sum_j Y_k e^{-d_{j,k}}$	NASA DMSP-OLS
2. Distance Decay Market Access with $a = 50$	$g_j = \sum_j Y_k e^{-\frac{1}{2(50)^2} d_{j,k}}$	NASA DMSP-OLS
3. Distance Decay Market Access with $a = 100$	$g_j = \sum_j Y_k e^{-\frac{1}{2(200)^2} d_{j,k}}$	NASA DMSP-OLS
4. City Size Adjusted Market Access (Population)	$g_j = \sum_j Y_k e^{-\theta_m d_{j,k}}$, $\theta_m =$\{0.0196(large-cities), 0.0052(medium-sized-cities), 0.0113(small-cities), 0.0095(towns)\}	NASA DMSP-OLS
5. Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{(NIR-Red)}{(NIR+Red)}$, pixel by pixel annual average at 500m spatial resolution	NASA/USGS LandSat L5 and L7
6. Enhanced Vegetation Index (EVI)	$EVI = \frac{2.5(NIR-Red)}{(NIR+6*Red+7*Blue+1)}$, pixel by pixel annual average at 500m spatial resolution	NASA/USGS LandSat L5 and L7
7. Green Chlorophyll Vegetation Index (GCVI)	$GCVI = \frac{NIR}{Green} - 1$, pixel by pixel annual average at 500m spatial resolution	NASA/USGS LandSat L5 and L7
8. Ruggedness	Average (interpolated) terrain ruggedness in a neighborhood of 2km from the centroid of the rural community using terrain elevation data	NASA SRTM 90m DEM
9. Precipitation of driest month	Average precipitation (≈1960-1990) of driest month	WorldClim v1.4
10. Min temperature in coldest month	Average (interpolated) minimum temperature (≈1960-1990) in coldest month	WorldClim v1.4
11. Distance to minor water sources	Euclidean distance between the centroid of the rural community and the nearest minor source of water (polyline shape with water springs and wells)	SIIT-BCN-Chile

For 1–6, $d_{j,k}$ is the Euclidean distance between the centroid of a rural community j and the centroid of a city k, with Y_k sum of night-time light intensity. For 7–12, pixels were interpolated for an area of 2km from the centroid of each rural community.

Table A5.3: Robustness Checks Using Alternative Measures of Agricultural Potential

Panel a): Including EVI	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Population	Farm Employment	Non-Farm Employment	Population	Farm Employment	Non-Farm Employment	Population	Farm Employment	Non-Farm Employment
1. Baseline Specification	1.183**	3.152***	1.959***	-0.060	2.938**	0.882*	1.844***	2.562***	1.995***
	(0.504)	(0.923)	(0.527)	(0.159)	(1.392)	(0.501)	(0.526)	(0.592)	(0.510)
2. Distance Decay Market Access with $a = 50$	0.140**	0.526***	0.458***	0.046*	1.036**	0.718***	0.077**	0.084**	0.085**
	(0.068)	(0.145)	(0.104)	(0.026)	(0.412)	(0.184)	(0.033)	(0.040)	(0.038)
3. Distance Decay Market Access with $a = 100$	0.583**	1.964***	1.579***	0.171*	4.305**	2.895***	0.383***	0.340**	0.383***
	(0.269)	(0.571)	(0.380)	(0.097)	(1.672)	(0.732)	(0.144)	(0.160)	(0.141)
4. City-size Adjusted Market Access	2.065***	1.101**	0.985***	0.367***	1.519**	1.278**	1.015**	1.204***	1.271***
	(0.432)	(0.464)	(0.317)	(0.133)	(0.752)	(0.546)	(0.416)	(0.370)	(0.383)
Panel b): Including NDVI	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	Population	Farm Employment	Non-Farm Employment	Population	Farm Employment	Non-Farm Employment	Population	Farm Employment	Non-Farm Employment
1. Baseline Specification	1.262**	3.108***	1.867***	-0.003	3.145**	0.833*	1.715***	2.491***	2.022***
	(0.494)	(0.943)	(0.536)	(0.156)	(1.482)	(0.483)	(0.396)	(0.585)	(0.462)
2. Distance Decay Market Access with $a = 50$	0.112*	0.606***	0.514***	0.049*	1.248***	0.868***	0.074**	0.084**	0.086**
	(0.068)	(0.161)	(0.118)	(0.026)	(0.484)	(0.243)	(0.032)	(0.041)	(0.039)
3. Distance Decay Market Access with $a = 100$	0.446*	2.339***	1.841***	0.179*	5.150***	3.496***	0.368***	0.341**	0.388***
	(0.268)	(0.649)	(0.447)	(0.098)	(1.987)	(1.005)	(0.142)	(0.163)	(0.145)
4. City-size Adjusted Market Access	1.941***	1.035**	0.949***	0.349***	1.690**	1.460***	1.090**	1.152***	1.196***
	(0.394)	(0.474)	(0.333)	(0.130)	(0.846)	(0.559)	(0.430)	(0.377)	(0.383)

$*p < 0.1$, $**p < 0.05$, $***p < 0.01$. All models were estimated by 2SLS and include control variables and fixed effects at municipality level. The EVI (Panel a) and NDVI (Panel b) is used as a proxy of agricultural productivity and included in the Farm Employment Equation. The The EVI is computed as $EVI = 2.5 * (NIR - red)/(NIR + 6 * Red + 7 * Blue + 1)$, and NDVI is computed as $NDVI = (NIR - Red)/(NIR + Red)$, where NIR is the Near Infrared Band and each color represents a wavelength band of the satellite sensors. Images from LanSat L5 was used for 1992 and LanSat L7 for 2002. Due to spatial coverage of L5 this set of regression is estimated for 189 rural communities (see Fig. **??** for a visualization of the spatial coverage of daytime satellite images in years of censuses).

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Supplementary Material

6.1 Booming Sector, Multinationals, and Local Economic Development

6.1.1 Relative Effects on Population

Effects on Population – Overall – (extended results)

	Log Population							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.009**	0.007	0.006	0.006	0.006	0.005	0.004	0.003
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)
Local economic conditions:								
- % of High-Skill Workers		0.241**	0.009	-0.015	-0.016	-0.153	-0.201	-0.186
		(0.094)	(0.130)	(0.146)	(0.149)	(0.160)	(0.162)	(0.151)
- Krugman Specialization Index			-0.112**	-0.132**	-0.132**	-0.138**	-0.115*	-0.124*
			(0.041)	(0.051)	(0.052)	(0.054)	(0.059)	(0.068)
- Mining Royalty				0.000	0.000	0.000	0.000	0.001
				(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
- Fiscal Dependency					0.000	-0.005	-0.010	-0.008
					(0.000)	(0.006)	(0.008)	(0.008)
- Fiscal Windfalls (per capita)						0.006*	0.003	0.004
						(0.003)	(0.004)	(0.005)
Local amenities:								
- Crime							0.011	0.011
							(0.008)	(0.008)
- No of Sports Clubs								-0.003
								(0.006)
Constant	-0.114*	-0.101	-0.062	-0.056	-0.057	-0.097	-0.107	-0.105
	(0.061)	(0.061)	(0.057)	(0.068)	(0.068)	(0.074)	(0.068)	(0.080)
Adjusted R^2	0.062	0.081	0.107	0.101	0.098	0.073	0.077	0.064
F-stat	4.870	9.656	8.173	4.412	5.642	3.315	4.614	3.501
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Population – Multinationals – (extended results)

	Log Population							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.015**	0.012**	0.012**	0.014*	0.014*	0.012	0.011	0.010
	(0.005)	(0.005)	(0.005)	(0.007)	(0.007)	(0.009)	(0.009)	(0.008)
Local economic conditions:								
- % of High-Skill Workers		0.210**	-0.005	-0.035	-0.035	-0.129	-0.162	-0.158
		(0.089)	(0.114)	(0.139)	(0.142)	(0.140)	(0.137)	(0.131)
- Krugman Specialization Index			-0.115**	-0.139**	-0.139**	-0.143**	-0.123*	-0.134*
			(0.040)	(0.051)	(0.053)	(0.056)	(0.060)	(0.068)
- Mining Royalty				-0.000	-0.000	-0.000	-0.000	0.000
				(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
- Fiscal Dependency					-0.000	-0.006	-0.010	-0.008
					(0.000)	(0.006)	(0.008)	(0.008)
- Fiscal Windfalls (per capita)						0.005	0.002	0.003
						(0.003)	(0.003)	(0.005)
Local amenities:								
- Crime							0.010	0.009
							(0.007)	(0.007)
- No of Sports Clubs								-0.002
								(0.005)
Constant	-0.180**	-0.160**	-0.124*	-0.142*	-0.142*	-0.169*	-0.170*	-0.161*
	(0.068)	(0.071)	(0.065)	(0.079)	(0.079)	(0.091)	(0.085)	(0.089)
Adjusted R^2	0.069	0.087	0.115	0.112	0.109	0.081	0.083	0.070
F-stat	8.762	9.700	7.979	4.955	6.220	2.997	3.532	2.811
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Population – Domestic – (extended results)

	Log Population							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.016***	0.015***	0.015***	0.020***	0.020***	0.022**	0.021**	0.021***
	(0.005)	(0.005)	(0.004)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)
Local economic conditions:								
- % of High-Skill Workers		0.201*	-0.021	-0.053	-0.050	-0.170	-0.184*	-0.186*
		(0.097)	(0.109)	(0.126)	(0.124)	(0.099)	(0.097)	(0.098)
- Krugman Specialization Index			-0.118***	-0.149**	-0.148**	-0.146**	-0.137**	-0.155**
			(0.039)	(0.052)	(0.053)	(0.054)	(0.059)	(0.068)
- Mining Royalty				-0.001	-0.001	-0.003	-0.002	-0.002
				(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
- Fiscal Dependency					-0.000	-0.010*	-0.012	-0.010
					(0.000)	(0.005)	(0.007)	(0.007)
- Fiscal Windfalls (per capita)						0.007**	0.006*	0.006
						(0.003)	(0.003)	(0.005)
Local amenities:								
- Crime							0.004	0.003
							(0.006)	(0.005)
- No of Sports Clubs								-0.001
								(0.004)
Constant	-0.177***	-0.172***	-0.140***	-0.180***	-0.180***	-0.252***	-0.251***	-0.244**
	(0.054)	(0.051)	(0.043)	(0.057)	(0.058)	(0.083)	(0.076)	(0.088)
Adjusted R^2	0.106	0.123	0.153	0.163	0.160	0.136	0.134	0.119
F-stat	13.369	30.759	21.074	8.073	9.135	3.109	2.770	2.187
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

6.1.2 Relative Effects on Employment

Effects on Employment – Overall – (extended results)

	Log Employment							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.003^{*}	0.002	0.002	-0.000	-0.000	0.002	0.002	0.000
	(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Local economic conditions:								
- % of High-Skill Workers		0.114	0.213	0.041	0.055	0.082	0.095	0.183
		(0.086)	(0.134)	(0.137)	(0.139)	(0.189)	(0.207)	(0.192)
- Krugman Specialization Index			0.048	0.040	0.046	0.082	0.076	0.064
			(0.050)	(0.048)	(0.050)	(0.069)	(0.060)	(0.071)
- Mining Royalty				0.000	0.000	-0.003^{**}	-0.003^{**}	-0.001
				(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
- Fiscal Dependency					-0.001	0.000	0.001	0.005
					(0.001)	(0.004)	(0.008)	(0.009)
- Fiscall Windfalls (per capita)						0.001	0.002	0.007
						(0.003)	(0.004)	(0.006)
Local amenities:								
- Crime							-0.003	-0.002
							(0.011)	(0.012)
No. of Sports Clubs								-0.013^{**}
								(0.005)
Constant	-0.013	-0.007	-0.024	0.025	0.029	-0.020	-0.017	-0.042
	(0.023)	(0.023)	(0.026)	(0.041)	(0.043)	(0.053)	(0.047)	(0.057)
Adjusted R^2	0.200	0.199	0.198	0.209	0.207	0.222	0.218	0.221
F-stat	3.237	2.197	2.314	0.688	0.730	1.573	1.975	0.948
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Employment – Multinationals – (extended results)

	Log Employment							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.006**	0.006**	0.006**	0.005*	0.005*	0.005	0.006	0.001
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)
Local economic conditions:								
- % of High-Skill Workers		0.024	0.126	-0.086	-0.090	-0.020	-0.006	0.066
		(0.150)	(0.217)	(0.223)	(0.224)	(0.288)	(0.307)	(0.280)
- Krugman Specialization Index			0.055	0.016	0.014	0.051	0.043	0.038
			(0.058)	(0.052)	(0.053)	(0.069)	(0.057)	(0.060)
- Mining Royalty				0.000	0.000	-0.003***	-0.003***	-0.002
				(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
- Fiscal Dependency					0.000	-0.003	-0.002	0.002
					(0.000)	(0.003)	(0.006)	(0.007)
- Fiscal Windfalls (per capita)						0.002	0.003	0.014**
						(0.003)	(0.004)	(0.005)
Local amenities:								
- Crime							-0.004	-0.004
							(0.009)	(0.011)
- No of Sports Clubs								-0.017***
								(0.004)
Constant	-0.057	-0.054	-0.072*	-0.039	-0.039	-0.037	-0.036	-0.100*
	(0.033)	(0.031)	(0.035)	(0.047)	(0.047)	(0.050)	(0.053)	(0.049)
Adjusted R^2	0.153	0.150	0.149	0.165	0.162	0.181	0.178	0.196
F-stat	6.699	3.520	2.574	1.071	1.003	2.991	3.391	3.778
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Employment – Domestic – (extended results)

	Log Employment							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.006^{***}	0.005^{***}	0.005^{**}	0.003	0.003	0.006^{**}	0.007^{**}	0.005
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Local economic conditions:								
- % of High-Skill Workers		0.027	0.127	-0.081	-0.084	-0.031	-0.015	0.060
		(0.150)	(0.216)	(0.224)	(0.225)	(0.289)	(0.308)	(0.278)
- Krugman Specialization Index			0.053	0.015	0.014	0.050	0.039	0.032
			(0.058)	(0.052)	(0.052)	(0.069)	(0.057)	(0.060)
- Mining Royalty				0.000	0.000	-0.004^{***}	-0.004^{***}	-0.003^{*}
				(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
- Fiscal Dependency					0.000	-0.004	-0.002	0.002
					(0.000)	(0.003)	(0.006)	(0.007)
- Fiscal Windfalls (per capita)						0.003	0.004	0.014^{***}
						(0.004)	(0.004)	(0.005)
Local amenities:								
- Crime							-0.005	-0.006
							(0.009)	(0.010)
- No of Sports Clubs								-0.017^{***}
								(0.004)
Constant	-0.041^{*}	-0.040^{**}	-0.054^{**}	-0.011	-0.011	-0.043	-0.044	-0.133^{***}
	(0.019)	(0.018)	(0.024)	(0.040)	(0.040)	(0.043)	(0.049)	(0.036)
Adjusted R^2	0.153	0.151	0.150	0.165	0.162	0.182	0.179	0.197
F-stat	12.490	6.470	4.376	0.938	0.811	2.838	4.024	5.218
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

6.1.3 Wage Equations

Mincerian Wage Equations

	Log of Wages			
	(1) OLS	(2) OLS	(3) OLS	(4) 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)
Occupation dummies		✓	✓	✓
Industry dummies			✓	✓
Year dummies				✓
Constant	11.061***	11.061***	11.061***	9.838***
	(0.031)	(0.031)	(0.031)	(0.028)
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.

6.1.4 Rent Equations

Hedonic Rent Equations

	Log of Rents		
	(1) OLS	(2) OLS	(3) OLS
Number of bedrooms	0.081*** (0.007)	0.081*** (0.007)	0.080*** (0.006)
Number of toilets	0.128*** (0.027)	0.128*** (0.027)	0.092*** (0.022)
Water source	✓	✓	✓
Water system	✓	✓	✓
Sanitation	✓	✓	✓
Electricity source	✓	✓	✓
Floor material		✓	✓
Floor condition		✓	✓
Roof material		✓	✓
Roof condition		✓	✓
Walls material		✓	✓
Walls condition		✓	✓
Year dummies			✓
Constant	10.310*** (0.065)	10.310*** (0.065)	10.458*** (0.056)
Adjusted R^2	0.278	0.278	0.634
Observations	341,974	341,974	341,974

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$. Residuals from Column (3) are used in main estimations. Robust standard errors in parentheses.

6.1.5 Relative Effects on Wages

Effects on Wages – Overall – (extended results)

	Log Wage (city-level aggregate residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.005	0.004	0.006	0.003	0.003	0.008	0.008	0.008
	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
Local economic conditions:								
- % of High-Skill Workers		0.109	0.221	0.106	0.111	0.117	0.111	0.143
		(0.127)	(0.141)	(0.152)	(0.152)	(0.156)	(0.154)	(0.165)
- Krugman Specialization Index			0.140^{**}	0.122	0.129	0.093	0.109	0.076
			(0.062)	(0.083)	(0.088)	(0.113)	(0.117)	(0.134)
- Mining Royalty				0.001	0.001	-0.001	-0.002	-0.002
				(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
- Fiscal Dependency					-0.001	-0.004	-0.007	-0.004
					(0.001)	(0.005)	(0.007)	(0.008)
- Fiscal Windfalls (per capita)						-0.004	-0.006	-0.009
						(0.005)	(0.005)	(0.008)
Local amenities:								
- Crime							0.007	0.009
							(0.007)	(0.011)
- No of Sports Clubs								-0.005
								(0.006)
Constant	0.063	0.064	-0.001	0.062	0.068	0.092	0.089	0.109
	(0.066)	(0.073)	(0.076)	(0.096)	(0.097)	(0.095)	(0.099)	(0.102)
Adjusted R^2	0.662	0.663	0.664	0.679	0.678	0.732	0.731	0.708
F-stat	1.354	0.916	2.696	1.378	1.013	1.293	1.040	1.568
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Wages – Multinationals – (extended results)

	Log Wage (city-level aggregate residual)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Log exposure to mining	0.004	0.003	0.005	-0.002	-0.002	0.003	0.002	0.003
	(0.005)	(0.006)	(0.007)	(0.008)	(0.008)	(0.006)	(0.006)	(0.007)
Local economic conditions:								
- % of High-Skill Workers		0.112	0.219	0.108	0.113	0.112	0.105	0.137
		(0.127)	(0.142)	(0.156)	(0.155)	(0.159)	(0.157)	(0.169)
- Krugman Specialization Index			0.133^{*}	0.120	0.127	0.086	0.104	0.069
			(0.065)	(0.085)	(0.090)	(0.112)	(0.117)	(0.135)
- Mining Royalty				0.002	0.002	0.000	0.000	0.000
				(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
- Fiscal Dependency					-0.001	-0.004	-0.007	-0.004
					(0.001)	(0.006)	(0.008)	(0.009)
- Fiscal Windfalls (per capita)						-0.004	-0.006	-0.008
						(0.005)	(0.005)	(0.008)
Local amenities:								
- Crime							0.008	0.010
							(0.007)	(0.012)
- No of Sports Clubs								-0.006
								(0.006)
Constant	0.077	0.084	0.025	0.127	0.131	0.160	0.161	0.177^{*}
	(0.077)	(0.084)	(0.085)	(0.108)	(0.110)	(0.097)	(0.098)	(0.095)
Adjusted R^2	0.662	0.663	0.664	0.678	0.678	0.731	0.730	0.707
F-stat	0.663	0.666	2.287	0.542	0.431	1.007	0.736	1.470
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Wages – Domestic – (extended results)

	Log Wage (city-level aggregate residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.004	0.003	0.004	-0.003	-0.002	-0.003	-0.004	-0.006
	(0.004)	(0.004)	(0.004)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Local economic conditions:								
- % of High-Skill Workers		0.113	0.221	0.108	0.113	0.111	0.103	0.135
		(0.126)	(0.141)	(0.156)	(0.155)	(0.161)	(0.160)	(0.173)
- Krugman Specialization Index			0.132*	0.121	0.128	0.085	0.108	0.076
			(0.065)	(0.085)	(0.090)	(0.110)	(0.115)	(0.134)
- Mining Royalty				0.002	0.002	0.001	0.001	0.002
				(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
- Fiscal Dependency					-0.001	-0.003	-0.007	-0.003
					(0.001)	(0.006)	(0.008)	(0.009)
- Fiscal Windfalls (per capita)						-0.004	-0.007	-0.008
						(0.005)	(0.005)	(0.007)
Local amenities:								
- Crime							0.010	0.012
							(0.007)	(0.011)
- No of Sports Clubs								-0.007
								(0.006)
Constant	0.094*	0.088	0.041	0.125	0.126	0.216**	0.220*	0.251***
	(0.048)	(0.052)	(0.049)	(0.090)	(0.090)	(0.098)	(0.102)	(0.078)
Adjusted R^2	0.662	0.663	0.664	0.679	0.678	0.731	0.730	0.707
F-stat	0.936	0.818	2.849	0.547	0.429	1.144	0.956	1.515
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

6.1.6 Relative Effects on Rents

Effects on Rents – Overall – (extended results)

	Log Rent (city-level aggregate residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.022**	0.018*	0.019*	0.022**	0.022*	0.029**	0.029**	0.032**
	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.012)	(0.012)	(0.012)
Local economic conditions:								
- % of High-Skill Workers		0.422***	0.461**	0.480*	0.474*	0.555**	0.570**	0.574**
		(0.116)	(0.186)	(0.242)	(0.242)	(0.219)	(0.211)	(0.227)
- Krugman Specialization Index			0.049	0.034	0.026	-0.061	-0.100	-0.197
			(0.113)	(0.140)	(0.138)	(0.155)	(0.168)	(0.141)
- Mining Royalty				0.001	0.001	0.010*	0.010*	0.007
				(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
- Fiscal Dependency					0.001	-0.006	0.001	-0.001
					(0.005)	(0.011)	(0.014)	(0.015)
- Fiscal Windfalls (per capita)						-0.012*	-0.007	-0.004
						(0.006)	(0.008)	(0.018)
Local amenities:								
- Crime							-0.017	-0.021
							(0.015)	(0.017)
- No of Sports Clubs								0.001
								(0.018)
Constant	-0.199	-0.196	-0.219	-0.271	-0.278	-0.172	-0.163	-0.200
	(0.149)	(0.156)	(0.159)	(0.163)	(0.173)	(0.171)	(0.167)	(0.205)
Adjusted R^2	0.893	0.895	0.895	0.894	0.894	0.916	0.916	0.916
F-stat	5.553	7.988	6.103	5.339	5.006	15.053	14.105	18.590
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Rents – Multinationals – (extended results)

	Log Rent (city-level aggregate residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.024	0.018	0.018	0.014	0.014	0.024	0.026*	0.030*
	(0.014)	(0.014)	(0.014)	(0.013)	(0.014)	(0.014)	(0.014)	(0.016)
Local economic conditions:								
- % of High-Skill Workers		0.434***	0.454**	0.475*	0.469*	0.542**	0.556**	0.559**
		(0.116)	(0.189)	(0.240)	(0.239)	(0.218)	(0.211)	(0.229)
- Krugman Specialization Index			0.025	0.016	0.009	-0.088	-0.127	-0.232
			(0.121)	(0.143)	(0.142)	(0.157)	(0.172)	(0.145)
- Mining Royalty				0.005	0.005	0.014**	0.014**	0.011*
				(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
- Fiscal Dependency					0.001	-0.007	0.000	-0.002
					(0.005)	(0.011)	(0.013)	(0.015)
- Fiscal Windfalls (per capita)						-0.012*	-0.008	-0.004
						(0.007)	(0.009)	(0.020)
Local amenities:								
- Crime							-0.017	-0.021
							(0.016)	(0.017)
- No of Sports Clubs								0.001
								(0.019)
Constant	-0.184	-0.157	-0.168	-0.147	-0.151	-0.072	-0.075	-0.128
	(0.198)	(0.200)	(0.201)	(0.199)	(0.207)	(0.164)	(0.171)	(0.193)
Adjusted R^2	0.892	0.894	0.894	0.893	0.893	0.915	0.915	0.915
F-stat	2.857	7.127	6.400	4.450	4.171	12.130	10.730	15.707
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

Effects on Rents – Domestic – (extended results)

	Log Rent (city-level aggregate residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Log exposure to mining	0.004	0.001	0.001	-0.006	-0.006	0.000	0.002	0.007
	(0.010)	(0.010)	(0.010)	(0.008)	(0.008)	(0.011)	(0.010)	(0.012)
Local economic conditions:								
- % of High-Skill Workers		0.456^{***}	0.463^{**}	0.489^{*}	0.482^{*}	0.533^{**}	0.544^{**}	0.546^{**}
		(0.118)	(0.184)	(0.237)	(0.236)	(0.205)	(0.199)	(0.213)
- Krugman Specialization Index			0.009	0.020	0.012	-0.088	-0.119	-0.225
			(0.121)	(0.139)	(0.138)	(0.155)	(0.172)	(0.147)
- Mining Royalty				0.009	0.009	0.018^{**}	0.017^{**}	0.015^{**}
				(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
- Fiscal Dependency					0.001	-0.006	-0.001	-0.003
					(0.004)	(0.011)	(0.013)	(0.014)
- Fiscal Windfalls (per capita)						-0.010	-0.006	-0.001
						(0.007)	(0.008)	(0.019)
Local amenities:								
- Crime							-0.013	-0.018
							(0.015)	(0.016)
- No of Sports Clubs								-0.001
								(0.021)
Constant	0.102	0.080	0.077	0.086	0.085	0.181^{*}	0.175^{*}	0.110
	(0.123)	(0.125)	(0.121)	(0.123)	(0.128)	(0.100)	(0.097)	(0.145)
Adjusted R^2	0.891	0.894	0.893	0.893	0.893	0.914	0.914	0.914
F-stat	0.157	7.524	6.102	4.227	3.852	16.465	12.961	20.423
Observations	365	365	365	300	300	236	236	221

Notes: $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors in parenthesis and 95%. Standard errors are clustered at the regional level.

6.1.7 Effects on the Productivity of Manufacturing Firms

Productivity Spillovers – Overall – (extended results)

	Log TFP (plant-level OLS residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) IV
Log Exposure	0.100**	0.070*	0.066	0.066	0.063	0.064	0.066	0.088
	(0.041)	(0.039)	(0.037)	(0.037)	(0.039)	(0.039)	(0.039)	(0.061)
Firm-level controls:								
- % of domestic ownership shares			0.003***	0.003***	0.002**	0.008***	0.008***	0.008***
			(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
- Total Value of Exported Goods				-0.000	0.000	0.000	0.000	0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummies for size					✓	✓	✓	✓
Dummies for type of property						✓	✓	✓
Dummies for type of firm							✓	✓
Plant FE		✓	✓	✓	✓	✓	✓	✓
Industry (CIIU-3) FE		✓	✓	✓	✓	✓	✓	✓
Constant	-1.005*	-0.658	-0.872*	-0.871*	0.309	-0.248	-0.305	
	(0.493)	(0.465)	(0.482)	(0.486)	(0.920)	(0.933)	(0.923)	
Adjusted R^2	0.004	0.021	0.025	0.025	0.045	0.045	0.044	-0.013
Observations	2,497	2,492	2,492	2,492	2,492	2,492	2,492	2,492
Kleibergen-Paap rk Wald F statistic								23.514

	Log TFP (plant-level Olley-Pakes residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) IV
Log Exposure	0.087*	0.064	0.060	0.060	0.056	0.058	0.060	0.076
	(0.041)	(0.039)	(0.037)	(0.037)	(0.038)	(0.038)	(0.038)	(0.059)
Firm-level controls:								
- % of domestic ownership shares			0.003***	0.003***	0.003**	0.007***	0.008***	0.008***
			(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
- Total Value of Exported Goods				-0.000	0.000	0.000	0.000	0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummies for size					✓	✓	✓	✓
Dummies for type of property						✓	✓	✓
Dummies for type of firm							✓	✓
Industry (CIIU-3) FE		✓	✓	✓	✓	✓	✓	✓
Constant	-0.853	-0.582	-0.805	-0.801	0.305	-0.190	-0.259	
	(0.496)	(0.463)	(0.479)	(0.483)	(0.937)	(0.959)	(0.948)	
Adjusted R^2	0.003	0.021	0.027	0.026	0.038	0.039	0.038	-0.021
Observations	2,497	2,492	2,492	2,492	2,492	2,492	2,492	2,492
Kleibergen-Paap rk Wald F statistic								23.514

Notes: Standard errors are clustered at the regional level.

* $p < .10$, ** $p < .05$, *** $p < .01$

Productivity Spillovers – Multinationals – (extended results)

	Log TFP (plant-level OLS residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) IV
Log Exposure	0.148***	0.098***	0.098***	0.098***	0.074**	0.078**	0.082**	0.070*
	(0.032)	(0.029)	(0.029)	(0.027)	(0.031)	(0.031)	(0.030)	(0.033)
Firm-level controls:								
- % of domestic ownership shares			0.002	0.001	0.001	0.004	0.004	0.004
			(0.001)	(0.001)	(0.002)	(0.003)	(0.002)	(0.002)
- Total Value of Exported Goods				-0.000	-0.000	-0.000	-0.000	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummies for size					✓	✓	✓	✓
Dummies for type of property						✓	✓	✓
Dummies for type of firm							✓	✓
Plant FE		✓	✓	✓	✓	✓	✓	✓
Industry (CIIU-3) FE		✓	✓	✓	✓	✓	✓	✓
Constant	-1.442***	-0.885**	-1.026***	-0.996***	0.470	0.095	0.028	
	(0.364)	(0.326)	(0.304)	(0.309)	(0.699)	(0.863)	(0.844)	
Adjusted R^2	0.004	0.014	0.015	0.016	0.036	0.037	0.037	
Observations	2,222	2,215	2,215	2,215	2,215	2,215	2,215	2,215
Kleibergen-Paap rk Wald F statistic								88.108

	Log TFP (plant-level Olley-Pakes residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) IV
Log Exposure	0.131***	0.087**	0.087**	0.086***	0.065*	0.069**	0.075**	0.067*
	(0.026)	(0.029)	(0.029)	(0.028)	(0.031)	(0.030)	(0.029)	(0.035)
Firm-level controls:								
- % of domestic ownership shares			0.002	0.001	0.001	0.004	0.004	0.004
			(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
- Total Value of Exported Goods				-0.000	-0.000	-0.000	-0.000	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummies for size					✓	✓	✓	✓
Dummies for type of property						✓	✓	✓
Dummies for type of firm							✓	✓
Industry (CIIU-3) FE		✓	✓	✓	✓	✓	✓	✓
Constant	-1.251***	-0.760**	-0.907***	-0.876**	0.532	0.185	0.091	
	(0.295)	(0.330)	(0.296)	(0.297)	(0.731)	(0.929)	(0.912)	
Adjusted R^2	0.004	0.015	0.016	0.017	0.029	0.030	0.031	
Observations	2,222	2,215	2,215	2,215	2,215	2,215	2,215	2,215
Kleibergen-Paap rk Wald F statistic								88.108

Notes: Standard errors are clustered at the regional level.

* $p < .10$, ** $p < .05$, *** $p < .01$

Productivity Spillovers – Domestic – (extended results)

	Log TFP (plant-level OLS residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) IV
Log Exposure	0.080***	0.042	0.040	0.040	0.038	0.042*	0.042*	0.039*
	(0.021)	(0.023)	(0.023)	(0.023)	(0.024)	(0.023)	(0.022)	(0.022)
Firm-level controls:								
- % of domestic ownership shares			0.002	0.001	0.001	0.004	0.004	0.004
			(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
- Total Value of Exported Goods				-0.000	-0.000	-0.000	-0.000	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummies for size					✓	✓	✓	✓
Dummies for type of property						✓	✓	✓
Dummies for type of firm							✓	✓
Plant FE		✓	✓	✓	✓	✓	✓	✓
Industry (CIIU-3) FE		✓	✓	✓	✓	✓	✓	✓
Constant	-0.586**	-0.201	-0.333	-0.305	1.016*	0.639	0.625	
	(0.214)	(0.240)	(0.243)	(0.259)	(0.564)	(0.769)	(0.762)	
Adjusted R^2	0.003	0.013	0.014	0.015	0.036	0.037	0.037	
Observations	2,222	2,215	2,215	2,215	2,215	2,215	2,215	2,215
Kleibergen-Paap rk Wald F statistic								111.774

	Log TFP (plant-level Olley-Pakes residual)							
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) IV
Log Exposure	0.058**	0.025	0.023	0.023	0.022	0.025	0.026	0.018
	(0.019)	(0.022)	(0.022)	(0.021)	(0.022)	(0.021)	(0.020)	(0.021)
Firm-level controls:								
- % of domestic ownership shares			0.002	0.001	0.001	0.004	0.004	0.004
			(0.001)	(0.001)	(0.002)	(0.003)	(0.003)	(0.003)
- Total Value of Exported Goods				-0.000	-0.000	-0.000	-0.000	-0.000
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummies for size					✓	✓	✓	✓
Dummies for type of property						✓	✓	✓
Dummies for type of firm							✓	✓
Industry (CIIU-3) FE		✓	✓	✓	✓	✓	✓	✓
Constant	-0.369*	-0.031	-0.170	-0.140	1.131*	0.789	0.758	
	(0.199)	(0.225)	(0.225)	(0.242)	(0.545)	(0.765)	(0.758)	
Adjusted R^2	0.002	0.013	0.015	0.016	0.028	0.029	0.030	
Observations	2,222	2,215	2,215	2,215	2,215	2,215	2,215	2,215
Kleibergen-Paap rk Wald F statistic								111.774

Notes: Standard errors are clustered at the regional level.

* $p < .10$, ** $p < .05$, *** $p < .01$