Natural Resources and Local Communities: Evidence from a Peruvian Gold Mine

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Abstract

This paper examines the local economic impact of Yanacocha, a large gold mine located in Northern Peru. Using annual household data from 1997 to 2006, we find robust evidence of a positive effect of the mine’s demand of local inputs on real income. The effect, an average 1.7% per 10% additional mine’s purchases, is only present in the mine’s supply market and surrounding areas. Results suggest that the effect is channeled to rural areas through an increase in the price of locally produced food. We examine and rule out that the effects are explained by a fiscal revenue windfall, or by other plausible mechanisms. Taken together, our results underline the potential of backward linkages from extractive industries to create positive spillovers in less developed economies.

JEL: O13, O18, Q32, Q33, R20

Keywords: Natural resources, mining, local development.

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The grudge against what has become known as the “enclave” type of development is due to this ability of primary products from mines, wells, and plantations to slip out of a country without leaving much of a trace in the rest of the economy.

Hirschman (1958, p. 110)

1 Introduction

Developing countries have access to many of the world’s richest oil and mineral reserves. They are among the largest producers of key minerals and account for most of the recent growth in mineral production (Humphreys, 2009). Despite resource abundance being deemed as an economic opportunity (World Bank, 2002), we still lack a good understanding of how it can be managed to generate economic prosperity.

The existing empirical literature suggests that abundance of natural resources may fail to improve living standards, or even hinder economic performance, specially in the presence of bad institutions (Sachs and Warner, 1999; Sachs and Warner, 2001; Mehlum et al., 2006). Most of this evidence, however, uses aggregate data at country level and offers little guidance about the local economic effects of resource abundance. Do natural resources improve living conditions of the local population? If so, which are the mechanisms? These are key questions to better assess the net impact of extractive industries, and to design policies to mitigate potential side effects such as pollution and population displacement- that have an inherently local scope.

This paper contributes to this debate by examining the local impact of a large mine in the context of a developing country. We show that, at least in the short run, the expansion of the mine has a positive impact on the living standards of the local population, and that the effects are driven mainly by the mine’s backward linkages.

We use the case of Yanacocha, one of the largest gold mines in the world. The mine is located near the city of Cajamarca in the Northern Highlands of Peru (see Figure 1). This region is extremely poor and predominantly rural and, before Yanacocha, had no history of mining. The economic interactions between the mine and the local economy are scant. Yanacocha, as other large modern mines in developing countries, is an export-oriented, capital-intensive operation.

1 This region was not subject to the mita system during the Spanish colony. This feature reduces concerns of the presence of long term effects associated to this institution, as the ones found by Dell (2010) in the Peruvian South.
and most of its inputs are not procured locally. The most visible contribution is the revenue windfall to local governments, who benefit from a share of the mine’s tax payments. Since 2000, however, the demand for local inputs also increased significantly. As we document below, this expansion was driven by the growth of gold production and the implementation of a corporate policy directed at increasing local employment and supply linkages.

The increase in demand of local inputs provides the opportunity to study the effects of a localized demand shock originated by a large mine, and its geographical spillovers. Moreover, it allow us to contrast the importance of the mine’s backward linkages, vis-à-vis the fiscal revenue windfall, in generating positive effects on local living standards.

We examine the effect of the expansion of the mine on local living standards using households’ survey data for the period 1997 to 2006. Our identification strategy exploits the expansion of the mine’s demand of local inputs and distance to Cajamarca city, the mine’s supplying market. More specifically, we implement a difference in difference approach using the expansion of the mine as a treatment and comparing households located close to Cajamarca city to households further away. The validity of the identification strategy relies on the assumption that the effects of the mine expansion decrease with distance (an assumption that we test) and that households in areas close and far to Cajamarca city would have experienced similar performance in the absence of the mine.

We find that the expansion of the mine has a positive effect in real income. In particular, a 10 percent increase in the mine’s demand of local inputs is associated to a 1.7 percent increase in real income. The raise in income is paralleled by an increase in household consumption and poverty reduction. The results are similar using alternative measures of mine activity, such as number of workers and quantity of gold produced, and remain robust to the exclusion of groups that may have benefited directly from the mine expansion, such as mining and public sector workers.

The effects are present in Cajamarca city and the surrounding rural areas. We show that the effects decline monotonically with distance to the city and become insignificant beyond 100 km. We also observe increments in the relative price of local food crops, such as potatoes and maize. This change on relative prices accounts for the increase in rural income, and explains how the impact of the mine is transmitted from the city to the rural areas. Finally, we explore
some issues that may invalidate the identification strategy. We are particularly concerned with the existence of different trends in areas far and close to cities, and the (potential) changes of population composition due to internal migration. The increase in income, however, does not seem to be a spurious result driven by these confounding factors.

We interpret these findings as evidence that the local population benefited from the expansion of the mine due to the presence of backward linkages. There are, however, at least two other alternative explanations. First, the increase in income may be due to the significant revenue windfall accruing to local governments. We show that the revenue windfall is associated to an increase in local public spending and investment, but find no evidence that the expansion of the public sector contributes to the increase in real income. Instead, the observed phenomena seems to be driven entirely by the expansion of the mine’s demand of local inputs. To the best of our knowledge, there is not previous empirical work contrasting the relative importance of these two mechanisms.\footnote{These findings are consistent with Auty (2001), who argues that the distribution of rents from natural resources through market channels may be more beneficial than through political channels.}

Second, the increase in income may just be compensating for negative externalities from the mine. In contrast to other traditional mining grounds in Peru, such as La Oroya and Cerro de Pasco, the extent of environmental degradation in Cajamarca has been small. There have been, however, several concerns about the risk of water pollution and discomfort for the social changes associated to the mine (Pascó-Font et al., 2001). To explore this issue, we use self-reported house rental prices, as a measure of the willingness to live in a place, and the incidence of health problems and crime. We find no evidence, however, supporting the argument that income increases just reflects compensating differentials. At least in the short run, we do not observe an increase in health or social problems or a decrease in the willingness to pay for living in locations closer to Cajamarca city.

This paper contributes to the literature studying the effect of natural resources on development. A main finding in this literature is that resource abundance may have a negative effect on growth (Sachs and Warner, 1999; Sachs and Warner, 2001). This natural resource curse seems to be linked to bad institutions (Mehlum et al., 2006). Latest evidence also points out to other negative effects such as conflict (Brckner and Ciccone, 2010; Ross, 2006) and undermining of democracy (Tsui, 2011). Our analysis differs in that we focus on the effects of resource
abundance within a country. This allows us to study the local economic effects and analyze other mechanisms that may be relevant at local level. In particular, we document a case where mineral abundance has a positive effect on local communities, and identify backward linkages as a plausible mechanism for this to happen.

There is an emerging literature exploiting within country variation to analyze the effect of resource boons. For example, Michaels (2011) studies the effect of oil abundance on specialization and long-term income in U.S., while Monteiro and Ferraz (2009) find a relation between oil royalties and corruption among Brazilian mayors. Within this literature, our paper is closely related to Caselli and Michaels (2009). They study the effect of a fiscal windfall from oil royalties to Brazilian municipalities. Consistent with our results, they find that the fiscal windfall has no effect on local income and little improvement on living standards. Our paper complements their findings by showing that, in the presence of strong enough backward linkages, the effect can be positive.

This paper also relates to a literature examining the effect of local demand shocks on regional markets; see for example Carrington (1996), Greenstone and Moretti (2003), and Black et al. (2005). This literature, mostly using U.S. data, finds evidence of positive effects of demand shocks - such as construction projects, coal price fluctuations, and new industrial plants - on local wages, employment and welfare. We show that similar phenomena can occur in the context of a rural, poor economy.

In the next section, we provide an overview of the Yanacocha case. In Section 3 we present the data and discuss the empirical strategy. Section 4 presents the main results and Section 5 explores alternative explanations. Section 6 concludes.

2 The Case of Yanacocha Gold Mine

Peru has a long tradition as a mining country and ranks among the top producers of minerals in the world. In the late 1990s, it experienced a mining boom and the sector expanded significantly, driven by the opening and expansion of large mining operations of gold, copper and silver. One of the most important of those new mines is Yanacocha, the second largest gold mine in the world, and producer of around 45 percent of Peruvian gold.

\footnote{In 2006 it was the first producer of gold, zinc, silver, lead and tin in Latin America and among the top five producers of those minerals in the world (Ministerio de Energía y Minas, 2006).}
Yanacocha mine is located in the department of Cajamarca in the North Highlands of Peru, a very mountainous area located almost 800 km from Lima, the country’s capital. The region where the mine is located is very poor and mostly rural. In 2000, around 65 percent of the population was poor and the urbanization rate was just 20 percent. Despite the mining sector representing almost half of the regional output, agriculture remains the main employer. During the period of analysis, the employment share in agriculture was around 70 percent.

The mine site is located 50 km away from Cajamarca city. This city is the department’s regional government center and, with almost 200,000 inhabitants, the largest urban settlement. There are also other three major cities in the surroundings (Trujillo, Chiclayo and Chachapoyas) and some small and medium-scale mines in the south. Figure 1 shows the location of the main cities and Yanacocha mine. The grey area represents the area of study, and the insert in the top left displays the location of the North Highlands’ departments in Peru.

![Figure 1: Area of study](image)

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4 These mines are in the neighboring department of La Libertad and have a much smaller scale than Yanacocha. Their production remained stable over the period of analysis.
The extraction of gold is from open pits using a capital intensive technology. All the gold is exported as ingots, without further local processing or added value. In addition, the mine is privately owned but its owners are not local residents. These features preclude the creation of forward linkages and the increase in local income due to the distribution of profits.

Yanacocha’s workforce is composed by workers hired directly by the mine and indirectly, through service contractors. Workers that are hired directly by Yanacocha tend to be skilled as opposed to low-skilled workers employed by contractors.

The mine procures some inputs from local suppliers. These goods tend to be relatively simple and with low quality requirements such as construction materials, chemicals and cleaning products, and basic hardware. Crucially, the mine does not purchase local agricultural products. Due to the proximity to Cajamarca city, most mine workers and local suppliers live there. This feature facilitates our analysis, because the city becomes the geographical market where the mine purchases local goods and services.

2.1 Expansion of the mine

Yanacocha opened in 1993 and its production has increased steadily over time due to the opening and development of new pits (see Figure 2). We study the impact of the mine on the local economy during the period 1997 to 2006. As we document below, there was a significant expansion of the mine activities during that period.

During the first years of operation, Yanacocha had little economic interaction with the regional economy. The number of workers hired by the mine was small and the amount of inputs purchased locally was also low (Kuramoto, 1999). In the late 1990s, however, there was a change in this trend, with an increase in the value of local purchases, wage bill and number of workers, most of them hired through local contractors (see Figures 2 and 3). We exploit this increase in demand of local inputs as a source of variation to study the effect of the expansion of the mine on the local economy.

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5 The production process starts by drilling holes in the ground, filling them with explosives and removing the ore with controlled demolitions. The ore is transported to leaching pads where the gold is separated using a cyanide solution. The gold-rich solution is then processed to separate the gold from the cyanide using a Merrill-Crowe process. The resulting gold is smelted and refined to obtain ingots. Finally, the waste material is returned to its original position, covered with soil and reforested.

6 The mine’s shareholders are Newmont Mining Corporation, a US based company, Minas Buenaventura, located in Lima, and the International Finance Corporation, a member of the World Bank Group.

7 For a firm to be considered local it has to be registered in Cajamarca and have at least 50 percent of local residents among their shareholders.
The increase in local procurement and employment was driven by two factors. First, the growth of gold production, fueled by the opening of a new pit in 2001. Second, an explicit corporate policy aimed to increase the participation of local firms and workers. This policy was promoted by the International Finance Corporation, one of Yanacocha’s shareholders and Newmont’s main lender, as a way to increase the economic impact of the mine in the region and minimize the risk of conflict with the local population (Jenkins et al., 2007).

The expansion of the mine’s workforce was relatively large for Cajamarca city, but not for the whole region. For instance, in 2005 the mine’s workforce represented around 20 percent of workers in Cajamarca city, but only between 4 to 5 percent of the workers in the department.

In addition to the increase in local procurement and employment, the expansion of Yanacocha has created a significant revenue windfall to local governments, due to a tax-sharing scheme called ‘canon minero’. This scheme allocates 50 percent of the mine’s corporate tax revenue to local governments located in the department of Cajamarca. The amount each local government receives is defined by a formula that takes into account population size, density and poverty incidence (Minera Yanacocha, 2006). The tax collection and sharing scheme is managed by the central government without involvement of local authorities.

This source of local fiscal revenue has increased significantly in parallel to the expansion of

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8 The most important features of the mine procurement policy were to give priority to local suppliers and workers in competitive bids, and to encourage suppliers to hire local workers.

9 Part of the revenue is also distributed to local universities and the regional government.
the mine’s demand of local inputs (see Figure 4). The location of these two shocks, however, is different. While most of the expenditure in wages and local purchases occurred in Cajamarca city, the canon minero was transferred to all local governments in the department. In the empirical analysis, we exploit these locational differences to disentangle whether the effects in income we observe are due to the mine’s demand of local inputs or to the fiscal revenue windfall.

Finally, Yanacocha also funds development projects in small rural villages within few kilometers of the mine pits\(^\text{10}\). These projects consist mostly of development of local infrastructure—such as electricity, sanitation and classrooms—as well as staffing of village schools and health centers. This social expenditure has increased only recently and is much smaller than the amount transferred as canon minero or spent in local inputs (see Figure 4).

### 2.2 How could Yanacocha avoid being an ‘enclave’?

As pointed out by Hirschman (1958) in the opening quote, natural resource ventures in very poor areas are often perceived as ‘enclaves’ that do not provide direct positive effects. These ventures tend to be capital intensive with almost no local employment, foreign-owned (i.e. no profits distributed), and with almost no linkages to the economy, whether forward (e.g. production of goods with added value) or backward (e.g. local procurement of goods and services). This is a

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\(^{10}\) Yanacocha considers as potential beneficiaries the inhabitants of 65 rural communities adjacent to the mine site. This represents at most around 28,000 persons, or less than 2 percent of the department’s population (Minera Yanacocha, 2002, p. 24).
fair description of Yanacocha before the procurement policy change, as provided by Kuramoto (1999).

In this context, it becomes relevant to understand under which circumstances Yanacocha’s new procurement policy can be an instrument for regional income growth. As a starting point, we have to point out that Yanacocha’s policy has targeted labor-intensive good and services that increased labor demand in Cajamarca city. In the short run, with a relatively inelastic labor supply, a first order effect of the demand shock could be an increase in the wage, and income, of city workers. Real effects would be present if the supply of goods is relatively elastic (e.g. due to spare capacity or rigidities in some input prices). This is the standard approach used in studies of the effect of local demand shocks on employment and wages (see for example Carrington (1996) and Black et al. (2005)).

Nonetheless, it is less clear how second order effects will show up, when considering general equilibrium effects in the region. Note that most of the people in the region are rural farmers not selling goods or labor directly to the mine or the mine’s suppliers.

One possible channel is through migration of rural workers to the city. In that case, the real wage in the rural area would also increase with city wages. Another channel is through trade. We can consider, for example, a city exchanging an urban good for food produced in the surrounding rural hinterland. The increase in income in the city would increase demand, and price, of food and the income of agricultural producers. In both cases, the mobility of factors and goods between the city and rural area, and the subsequent change in prices, could transmit the demand shock through the local economy. However, further assumptions would
be needed for these mechanisms to allow for a net positive real effect on income. For example, frictions such as costly inter-regional migration or costly intra-regional trade, access to import goods with elastic supply, or gains in productivity (e.g. due to agglomeration economies). In the appendix, we formalize this argument using an extension of the mono-centric city model developed by Fujita and Krugman (1995).

3 Data and Method

3.1 Data and main variables

Household data The empirical analysis uses data from repeated cross sections of the Peruvian Living Standards Survey (ENAHO), an annual household survey collected by the National Statistics Office. The survey consists of a stratified household sample representative at regional level. We focus on the North Highlands statistical region, the area where the mine is located. Figure 1 shows the area of study and highlights in gray the districts in the survey’s universe. Districts are the smallest political jurisdictions, usually composed by a main town and a surrounding rural area. The data set covers 10 years, between 1997 and 2006, and includes more than 7,700 households.

To quantify exposure to the mine’s center of activities, Cajamarca city, we construct a measure of the distance from the household’s location to the city. This measure varies at district level. In particular, we measure distance as the length of the shortest path between the main town of the district and Cajamarca city using the existing road network. We perform the calculation using the ArcGIS software and maps produced by the Ministry of Transport of Peru. The road map corresponds to the network available in 2001 and includes only tracks usable by motorized vehicles. The measure of distance ranges from 0 to 400 km, with an average value of 100 km. As we will discuss below, we use this threshold to define districts close and far from the city. Figure 5 shows the districts with households included in the survey sample, and highlights in dark grey the districts within 100 km to the city. Note that the sample includes districts in the vicinity of other cities, such as Chachapoyas.

Table 1 shows some statistics of the main variables at household level. We estimate the means and standard errors using sample weights and clustering by primary sampling unit to

11 The results are robust to alternative measures of distance.
account for the sampling design.

**Firm data** To measure the expansion of the mine activities, we collect data from Yanacocha reports on total payment to workers, local purchases and total production (Minera Yanacocha, 2006). The frequency of this data is annual and covers the period 1993 to 2006. Local purchases include goods and services bought to local suppliers and contractors. The wages of workers indirectly employed in the mine, through contractors, are included in this variable. The wage bill includes all work-related payments to Yanacocha’s directly employed workers. This includes wages, bonuses and a share of the mine’s profits. We include this last item as part of the wage bill, since it is effectively part of the total remuneration of workers.

We measure the mine’s demand of local inputs as the sum of the wage bill and local purchases. Panel A in Table 2 presents summary statistics for the firm level data over the period 1997 to 2006. The value of wage bill and local purchases is measured in million of US dollars while the quantity produced is measured in million of ounces.

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12. 8 percent of the mine profits are distributed among mine workers. This benefit is defined by law and accrue only to workers directly employed by the mine, not to workers employed through contractors.

13. The results are robust to the exclusion of the workers share of mine’s profits of the measure of wage bill.
Table 1: Mean of main variables at household level

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=7738</td>
<td></td>
</tr>
<tr>
<td><strong>Household head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years of education</td>
<td>4.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Age</td>
<td>48.4</td>
<td>0.7</td>
</tr>
<tr>
<td>% female</td>
<td>0.129</td>
<td>0.021</td>
</tr>
<tr>
<td><strong>Household</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income per capita</td>
<td>143.7</td>
<td>10.8</td>
</tr>
<tr>
<td>Consumption per capita</td>
<td>149.0</td>
<td>8.8</td>
</tr>
<tr>
<td>Poverty line</td>
<td>155.9</td>
<td>1.6</td>
</tr>
<tr>
<td>% poor</td>
<td>0.651</td>
<td>0.048</td>
</tr>
<tr>
<td>% extreme poor</td>
<td>0.374</td>
<td>0.040</td>
</tr>
<tr>
<td>% access to electricity</td>
<td>0.163</td>
<td>0.031</td>
</tr>
<tr>
<td>% access to piped water</td>
<td>0.616</td>
<td>0.054</td>
</tr>
<tr>
<td>Nr. Household members</td>
<td>4.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Nr. Income earners</td>
<td>2.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Distance to Cajamarca city (km)</td>
<td>108.2</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Note: The mean and its standard error are calculated using sample weights and clustering by primary sampling unit.

Municipality data We complement the household and firm data with data at municipality level. Municipalities are the lowest tier of autonomous local government with jurisdiction over districts. We obtain annual data about revenues and expenditures for each municipality in the North Highlands region and within 400 km from Cajamarca city. This geographical scope corresponds to the distance range observed in the household data. The data set covers information on 179 municipalities over the period 1998 to 2006, and contains detailed information about the sources of revenue, including the amount of mining transfers received. This information provides a reliable measure of the magnitude of the revenue windfall experienced by each local government.

Panel B in Table 2 displays some summary statistics. The average municipality has an annual budget of 3.5 million of Nuevos Soles, but a slightly smaller expenditure. The difference is kept by the local government and rolled forward to subsequent periods.

We use this data in Section 5.1 to evaluate the role of the fiscal revenue windfall as an alternative explanation of the observed phenomena.
### Table 2: Summary statistics of firm and municipality data

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Firm data</strong></td>
<td></td>
</tr>
<tr>
<td>Wage bill</td>
<td>55.5 (33.9)</td>
</tr>
<tr>
<td>Local purchases</td>
<td>42.3 (27.7)</td>
</tr>
<tr>
<td>Gold production</td>
<td>2.18 (0.76)</td>
</tr>
<tr>
<td>% local purchases</td>
<td>0.12 (0.05)</td>
</tr>
<tr>
<td><strong>B. Municipality data</strong></td>
<td></td>
</tr>
<tr>
<td>Total revenue</td>
<td>3.53 (8.20)</td>
</tr>
<tr>
<td>Mining transfer</td>
<td>0.41 (2.08)</td>
</tr>
<tr>
<td>Total expenditure</td>
<td>2.96 (6.52)</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>1.26 (2.42)</td>
</tr>
</tbody>
</table>

Note: The value of wage bill and local purchases is measured in million of US$ while the quantity produced is measured in million of ounces. The municipal data is measured in million of Nuevos Soles.

### 3.2 Identification strategy

The aim of the empirical exercise is to evaluate the effect of the mine expansion on measures of living standards, such as real income. To do that, we exploit two sources of variation. First, we use the significant increase in Yanacocha’s demand of local inputs that started in 2000. As previously mentioned, this growth was driven by the increment on gold extraction and implementation of mine’s policies directed at increasing local procurement and employment.

Second, we exploit the household’s distance to Cajamarca city as a source of heterogeneous exposure to the demand shock from the mine. In the main specification, we use the average distance of 100 km as the threshold to divide the districts in two categories: far and close to the city (see Figure 5).

Our identification strategy is basically a difference in difference that uses the expansion of the mine as the treatment, and compares households located close to Cajamarca city to households further away. The validity of the empirical strategy relies on the assumption that the effect of the mine declines with distance (an assumption that we test below), and that the evolution of outcomes in areas far and close to the city would have been similar in the absence of the mine expansion.

Figure 6 illustrates the basic idea behind the identification strategy. It plots the conditional mean of real income per capita for households located within 100 km from the city and those
located further away.\footnote{The mean is conditional on schooling, age and gender of the household head, access to piped water and electricity, number of household members, and number of income earners.} Note that until 2001 the real income follows similar trends in both locations. After that, it diverges and shows a relative increase in areas located closer to the city.

The similarity of trends in both areas before the expansion of the mine is a necessary condition for the validity of our difference in difference strategy. There may be, however, other unobserved time-varying factors correlated with the expansion of the mine and affecting differently areas closer and farther from the city, which would invalidate our identification assumption. We address these concerns in more detail in Section 5.

![Figure 6: Conditional mean of real income](image)

To formally evaluate the effect of the mine, we estimate the following regression:

$$\ln y_{hdt} = \alpha_d + \eta_t + \beta (\ln M_t \times distance_d) + X_{hdt} \gamma + \varepsilon_{hdt},$$

where $y_{hdt}$ is the outcome variable of household $h$ in district $d$ in year $t$. The outcome variables could be real income, relative price or others measure of living standards such as consumption or poverty. To obtain relatives values we use as a deflator the value of the poverty line.\footnote{The poverty line is estimated by the National Statistics Office as the value of the minimum consumption basket that guarantees an adequate living standard. It is calculated using local prices and varies within region and over time. A discussion of the validity of using the poverty line as a price deflator is available from the authors upon request.} $M_t$ is a measure of the mine activity, lagged two periods to allow adjustments in market prices. In the baseline specification we use the mine’s demand of local inputs as a measure of activity. This
variable is the sum of the mine’s wage bill and local purchases. We also check the robustness
of the results using alternative measures such as the number of workers or quantity of gold
produced. \( distance_d \) is the measure of distance which is a dummy equal to one if the district
where the household lives is within 100 km of Cajamarca city, and zero otherwise. We also use
more flexible definitions, such as a spline or the continuous measure, to explore the heterogeneous
effects. In this specification, the parameter of interest is \( \beta \) which captures the effect of the mine
expansion.

All regressions include year (\( \eta_t \)) and district (\( \alpha_d \)) fixed effects, and a vector of household
characteristics \( \mathbf{X}_{hdt} \) (see footnote of Table 3 for details). We estimate the regressions using
sample weights and clustering the standard errors at the level of the primary sampling unit,
a jurisdiction smaller than a district.\(^{17}\) We cluster the errors at this level to account for spa-
tial correlation of households exposed to similar shocks and market conditions, or surveyed
simultaneously.

4 Main Results

4.1 Effect on Real Income

Table 3 reports the estimates of \( \beta \), the parameter associated to the interaction of the mine
activity and distance. Column (1) uses as measure of the mine activity the demand of local
inputs. This is our preferred measure of the mine activity since it better reflects the market
interaction between the mine and the local economy. The estimate of \( \beta \) is positive and signif-
icant, suggesting that the expansion of the mine is associated to an increase in real income in
households close to Cajamarca city, relative to households further away. The results are robust
to alternative measures of the mine local procurement such as total number of workers and
quantity of gold production (Columns 2 and 3).\(^{18}\) The increase in real income is associated to
increments in household real consumption and was strong enough to reduce poverty (Columns
4 and 5).

Under the assumption that the evolution of real income in locations far and closer to the
city would have been similar in the absence of Yanacocha, we can interpret these results as

\(^{17}\) See Magee et al. (1998) for a discussion on the use of sample weights with complex survey data.
\(^{18}\) We also estimate the baseline regression using the quantity of gold as an instrument for the mine’s demand
of local inputs and obtained similar results.
the evidence of a positive effect of the mine on real income. The magnitude of the effect is economically significant: the smallest estimate suggests that a 10 percent increase in the mine’s activity is associated to an increase of 1.7 percent in the real income of households located closer to the city. Note that the evolution of Yanacocha implies large changes in household incomes since, by any measure, the activity of the mine has multiplied by at least a factor of two.

**Heterogeneous effects by distance** The identification strategy relies on the effect of the mine declining with distance to Cajamarca city.\(^\text{19}\) We evaluate this feature in two ways. First, we use a spline of distance instead of the dummy variable. In particular, we divide the households in six groups according to the distance to the city. The categories start with households living in Cajamarca city and then group them in blocks of up to 50 km, with the last category containing all households located at least 200 km from the city. Then, we estimate the baseline regression (1) using the demand of local inputs interacted with each of the distance dummies.

Figure 7 shows the estimates of $\beta$ for households located at each of the distance brackets, as well as the 95 percent confidence interval. The estimates are positive and significant for households located within 100 km of Cajamarca city, but become insignificant for households located in farther locations. These results support the assumption that the effect declines with distance. They also provide the basis for using a dummy variable of distance and reduce concerns about the observed average effect being driven exclusively by city residents.\(^\text{20}\)

Second, we run a regression on the interaction of the measure of the mine’s activity and the continuous measure of distance expressed in hundreds of kilometers. The results are displayed in column (6) of Table 3. Note that the estimated parameter is negative and significant.\(^\text{21}\)

### 4.2 Transmission to rural areas: migration and relative prices

Results so far have shown that the effects on income are present beyond the boundaries of the city. As discussed in section 2, the effects in rural areas could be explained by, at least, two possible transmission mechanisms: migration and an increase in the relative prices of locally produced agricultural goods.

\(^{19}\)This could be due to transportation costs, for example.

\(^{20}\)For example if the distribution of household income improvements was only concentrated in Cajamarca city, the reduced form estimates would be just averaging out large positive effects in the city and negative or zero effects in the vicinity.

\(^{21}\)These results are robust to the use of alternative measures of distance and non-linear effects of distance.
Table 3: Effect of Yanacocha’s expansion on real income, consumption and poverty

<table>
<thead>
<tr>
<th></th>
<th>Real income</th>
<th>Household consumption</th>
<th>Poor</th>
<th>Real income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Mine activity × distance &lt; 100 km</td>
<td>0.174**</td>
<td>0.240**</td>
<td>0.313**</td>
<td>0.140***</td>
</tr>
<tr>
<td></td>
<td>0.078</td>
<td>0.109</td>
<td>0.131</td>
<td>0.049</td>
</tr>
<tr>
<td>Mine activity × continuous distance</td>
<td>-0.128**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.062</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure of mine activity</td>
<td>Demand of local inputs</td>
<td>Nr. total workers</td>
<td>Gold production</td>
<td>Demand of local inputs</td>
</tr>
<tr>
<td>Observations</td>
<td>7,738</td>
<td>7,738</td>
<td>7,738</td>
<td>7,738</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.521</td>
<td>0.524</td>
<td>0.529</td>
<td>0.549</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects. The additional control variables are: household head’s education, age, gender and dummies indicating her industry of occupation and type of job, plus household access to water, electricity and number of household members and income earners. Demand of local inputs is the sum of Yanacocha’s wage bill and local purchases. Gold production is measured in million of ounces. Poor is a dummy equal to 1 if household is poor. Column (5) is estimated using a linear probability model. Column (6) uses a measure of continuous distance, expressed in hundreds of kilometers.
To explore the presence of intra-regional migration, we use data from two most recent population censuses (1993 and 2007) and calculate the intercensal population growth rate in Cajamarca city and surrounding areas, up to 400 km.

We find that between the two censuses, the region grew at an annual rate of 0.7 percent, below the national average of 2 percent. Cajamarca city, however, experienced a faster growth, with population increasing at a rate of 3.4 percent per year. In contrast, the surrounding areas grew at a much slower pace, below the regional average. Interestingly, the growth rate decreases with distance to the city, as shown in Figure 8. A possible explanation consistent with this observation is that migration costs are increasing with distance. This evidence is suggestive of migration from the rural hinterland to the city. Nonetheless, we cannot interpret it as evidence of the mine expansion causing migration because, given data constraints, we do not know whether migration occurred before or after the expansion of the mine.

To test whether prices of locally produced food have increased, we start by identifying the main crops in the area of study. We use information from the household survey about agricultural production and rank the crops according to its contribution to the regional agricultural gross product. In our sample, the two most important crops are potatoes and maize. Together they account for almost half of the agricultural gross product. These results are consistent

\[^{22}\text{This extension corresponds to the range of distances observed in the data.}\]

\[^{23}\text{In the period 1997 to 2006, they represented 30 percent and 16 percent of the value of agricultural production, respectively. Their contribution remained relatively constant over the period of analysis.}\]
with the data from the 1994 Agricultural Census. The Census records that potatoes and maize are the most widespread crops in the region’s highlands and represent more than 50 percent of the cultivated land.

For each crop and producer, we obtain the farm gate price based on reported quantity and value of production. In addition, we calculate the unit value paid by consumers using information about total expenditure and quantity purchased. This variable is a proxy of the actual consumer price. The producer prices and unit values are then divided by the value of the poverty line to obtain measures of relative prices. Finally, we estimate the baseline regression using as dependent variable the logarithm of the measure of relative prices. When using unit values, we include as an additional control variable the logarithm of the household real income to account for quality choices (Deaton, 1997).

Columns (1) to (4) in Table 4 display the results. In most cases, the estimates suggest that the relative prices of local crops in areas closer to the city increase relative to prices in markets located in farther locations. The lack of effect in the case of the price of maize received by producers (Column 2) may be due to the poor development of the maize market. According to the survey, only 40 percent of the maize production was sold to the market. In contrast, the proportion sold to the market of the potatoes production was 63 percent. Note, however, that there is a positive and significant effect on the price paid by consumers.

The unit values do not correspond exactly to market prices because they are also affected by the household’s quality choice.

The results however are similar excluding this additional control.
We replicate the exercise using the price of other food staples, less important for local producers, such as rice, sugar, and cooking oil (Columns 5 to 7)\(^\text{26}\). For these three products, we use unit prices reported by consumers. In contrast to the price of local food crops, the price of these goods is not affected by the mine’s activity. These results reduce concerns that the increase in price of potatoes and maize is simply reflecting a general increase in food prices.

4.3 Other measures of well-being

4.3.1 Health and Crime

A main limitation of the previous analysis is that income may fail to fully capture the net effect on household welfare, even in the short run. To address this issue, we test directly for the presence of some negative effects that could be associated to the expansion of the mine. In particular, we use data from the household survey to construct dummy variables to indicate whether an individual had a health problem, and whether a household member was victim of a criminal activity\(^\text{27}\). Then, we use these dummies as the dependent variables in the baseline regression (1) and estimate it using a linear probability model. As control variables we use an indicator of whether the household lives in a urban or rural area, access to water, sanitation and electricity, number of household members and income earners, and individual’s sex and age\(^\text{28}\).

Table 5 shows the results. Column (1) uses the whole sample of individuals, including children, while in column (2) we restrict the sample to children under the age of five, who may be more vulnerable to negative health spillovers. Note that in both cases the incidence of self-reported health problems has actually decreased with the expansion of the mine. Column (3) shows that there is no apparent increase in crime associated with the expansion of the mine.

Nonetheless, we need to interpret these results with caution. They only suggest that there is no evidence that individuals in the area of influence of the mine have suffered more occasional illnesses, that could result from a more polluted environment. But, we cannot say anything about long run effects, such as general deterioration in health or chronic afflictions that could result from exposure to the activities of the mine. Similarly, the measure of crime only informs

\(^{26}\)For instance, rice represents only 1.6 percent of the agricultural product in the sample, while sugar and cooking oil are processed food stuff traded at national level.

\(^{27}\)The survey questions are “In the last four months, have you felt sick, suffered a chronic disease or an accident?” and “In the last 12 months, has any member of the household been affected by a criminal act?”.

\(^{28}\)The results are robust to the exclusion of the control variables.
Table 4: Effect of mine expansion on relative prices

<table>
<thead>
<tr>
<th></th>
<th>Local food crops</th>
<th>Other food staples</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Potatoes (1)</td>
<td>Maize (2)</td>
<td>Rice (5)</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(4)</td>
<td>Sugar (6)</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td></td>
<td>Cooking oil (7)</td>
</tr>
<tr>
<td>Demand of local inputs × distance &lt; 100 km</td>
<td>0.128* (0.074)</td>
<td>-0.026 (0.082)</td>
<td>0.110*** (0.038)</td>
</tr>
<tr>
<td>Prices reported by:</td>
<td>producer no</td>
<td>consumer yes</td>
<td>rice consumer no</td>
</tr>
<tr>
<td>Real income per capita</td>
<td>consumer yes</td>
<td>yes</td>
<td>consumer yes</td>
</tr>
<tr>
<td>Observations</td>
<td>3407</td>
<td>4072</td>
<td>4253</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.417</td>
<td>0.524</td>
<td>0.374</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects. All regressions include year and district fixed effects. Columns (1) and (3) do not include any additional control variable. The rest of columns include ln(real income) as additional control variable.
us about the perceived level of crime but may fail to account for other forms of social disorder or crimes within the household. Moreover, it may reflect changing perceptions of crime.

These results do not rule out the presence of negative externalities. They suggest, however, that their magnitude, at least as perceived by the residents, may not be too important.

Table 5: Yanacocha’s expansion and measures of health and crime

<table>
<thead>
<tr>
<th>Health problems</th>
<th>Crime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand of local inputs × distance &lt; 100 km</td>
<td>-0.087*** (0.039)</td>
</tr>
</tbody>
</table>

Sample: All individuals under 5 years; Children; Households

Observations: 39674; 4189; 6663

R-squared: 0.076; 0.157; 0.048

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Health problems is a self-reported measure of whether an individual was sick in the recent past, while Crime is a self-reported measure of anyone in the household being victim of a crime in the recent past. All regressions are estimated using a linear probability model. Columns (1) and (2) include as control variables an indicator of the house being in a urban area, access to water, sanitation and electricity, number of household members and income earners, and individual’s sex and age. Column (3) use similar controls but exclude individuals’ age and sex.

4.3.2 Distributional Impacts

A relevant policy question with respect to the benefits of expanding local procurement is whether the effects are evenly distributed or whether only the richer benefit from the mine expansion. So far, the reduction in poverty, along with the increase on average income, that were observed in Table 3 suggest that some of the benefits trickle down. To obtain a more direct answer to this concern, we explore the distributional impact of the mine expansion. In particular, we estimate the effect of the mine on real income at different points of the conditional income distribution using quantile regressions. The model specification is the same as the baseline regression.

Figure 9 plots the estimates of the effect of the mine expansion on real income and the 95

29See Koenker and Hallock (2001) for a survey of the literature on quantile regressions.

30The estimator does not use the sampling weights nor cluster the errors by primary sampling unit.

23
percent confidence interval at different quantile values. The estimated parameter is positive and significant for all quantiles except for the top 20 percent. These results mean that households with income below the 80th percentile, conditional on the control variables, experienced an increase of real income associated to the mine expansion in areas within 100 km from Cajamarca city. We cannot conclude from this result that inequality has not increased, but we can claim that the positive effects were evenly distributed across income groups, even among the poorer households.

![Figure 9: Effect of Yanacocha’s demand of local inputs on real income, by quantile](image)

5 Alternative Explanations

We interpret the previous results as evidence that the local population benefited from the expansion of the mine due to the presence of backward linkages. This section explores whether explanations, different from the expansion of local procurement, could explain the same results.

5.1 Fiscal Revenue Windfall

As mentioned in Section 2, local governments receive a mining transfer funded with a share of the corporate taxes paid by the mine. This source of local revenue, called *canon minero*, grew in the last years following the expansion of the mine and represented a substantial revenue windfall for local governments. For instance, between 1998 and 2006 the total amount of mining transfers in the area multiplied by a factor of seven and its contribution to the municipal budget.
increased from 8 to 25 percent.

This revenue windfall, and the subsequent increase in public spending, may explain the observed relation between the mine expansion and real income. For example, local wages could have increase due to the additional demand from public works, or local governments could have reduced taxes, effectively transferring part of the windfall to local residents.

We first check whether the revenue windfall from the mining transfer translated into higher revenue and expenditure for local governments. To do that, we estimate the following regression:

\[ y_{it} = \alpha_i + \eta_t + \beta \text{transfer}_{it} + \epsilon_{it}, \]  

where \( y_{it} \) is a measure of the revenue or expenditure of municipality \( i \) in year \( t \), and \( \text{transfer}_{it} \) is the logarithm of the amount of mining transfer received. This specification includes year and municipality fixed effects, and exploits within municipality variation. The standard errors are clustered at municipality level to address possible serial autocorrelation.

Table 6 displays the results using different dependent variables. All the variables, except the share of capital expenditures, are expressed as logarithms. In all the cases the estimates of \( \beta \) are positive and significant. This result supports the claim that the revenue windfall associated to the mining transfer has increased both the available budget and spending. Capital expenditure increased even faster than other expenditures, as the increase in its share of total expenditure indicates. This result is expected since, by law, the revenues from the mining transfer should be used only for capital expenditures. As an additional check, in column (5) we investigate whether public infrastructure has improved with the increase in mining transfers. We consider access to piped water, since it is the most important public service in the remit of local governments. The results, consistent with the increase in capital expenditure, show that households in municipalities that received the revenue windfall have actually improved their access to piped water. Note that this specification uses municipality fixed effects, meaning that there is substantial variation over time within municipalities. Unreported results show that there are no improvements in the provision of electricity, a utility that is not under control of the municipalities.

In order to assess whether the increase in public expenditure could explain the positive effects on income, we include in the baseline regression the value of the mining transfers received by the
Table 6: Effect of mining transfers on municipal revenue and spending

<table>
<thead>
<tr>
<th></th>
<th>Municipal revenue (1)</th>
<th>Municipal spending (2)</th>
<th>Capital expenditure (3)</th>
<th>Share of capital expenditure (4)</th>
<th>Access to piped water (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining transfer</td>
<td>0.034***</td>
<td>0.030***</td>
<td>0.047***</td>
<td>0.007***</td>
<td>0.329**</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.005)</td>
<td>(0.001)</td>
<td>(0.138)</td>
</tr>
<tr>
<td>Observations</td>
<td>1414</td>
<td>1414</td>
<td>1414</td>
<td>1414</td>
<td>7738</td>
</tr>
<tr>
<td>Nr. Municipalities</td>
<td>179</td>
<td>179</td>
<td>179</td>
<td>179</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.738</td>
<td>0.733</td>
<td>0.476</td>
<td>0.156</td>
<td>0.414</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors clustered by municipality. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects. All the variables, except the share of capital expenditure and access to piped water, are expressed as logarithms. Column (5) is a linear probability regression.

local government where the household resides. If the effect was driven by the revenue windfall, and subsequent public spending, we could expect the parameter associated to the effect of the mine expansion to become insignificant.

Column (1) in Panel A, Table 7 reports the results including the log of mining transfers, while Panel B includes the variable interacted with the measure of proximity to the city. Columns (2) to (4) use other measures of municipal revenue or expenditure. In all cases, the relation between mining transfers and real income is insignificant, while the effect of the mine’s demand of local inputs remains very stable, positive and significant.

These results reduce concerns that the observed effect is driven by the revenue windfall to local governments. Moreover, they suggest that the market mechanism may have been more effective on enhancing household income than public spending.

The lack of a positive effect of public spending is surprising. A first explanation is the need of a longer period for public projects to mature. We replicate the results lagging the variables one and two periods, but the effect remains insignificant. An alternative explanation is that public spending increased well being through better public good provision, but not through income gains. Finally, it could be that the additional public spending had very small social

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31 The difference in the sample size in this last 3 regressions is due to the lack of observations on municipal spending for 1997.

32 Results upon request. We cannot explore longer lags since we only have budgetary data from 1998. Additionally, the use of lags reduces the number of observations in the period before the mine expansion and may attenuate the results.
Table 7: Effect of the mine on real income, controlling for municipal revenue or expenditure

<table>
<thead>
<tr>
<th></th>
<th>Ln(real income per capita)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Demand of local inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× distance &lt; 100 km</td>
<td>0.175**</td>
<td>0.180*</td>
<td>0.164*</td>
<td>0.164*</td>
</tr>
<tr>
<td></td>
<td>(0.083)</td>
<td>(0.094)</td>
<td>(0.089)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>Municipal revenue or expenditure</td>
<td>-0.025</td>
<td>-0.142</td>
<td>0.045</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>(0.209)</td>
<td>(0.093)</td>
<td>(0.126)</td>
<td>(0.126)</td>
</tr>
<tr>
<td>Observations</td>
<td>7738</td>
<td>6305</td>
<td>6305</td>
<td>6305</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.521</td>
<td>0.536</td>
<td>0.536</td>
<td>0.536</td>
</tr>
</tbody>
</table>

Panel A: Adding municipal revenue or expenditure

Panel B: Adding municipal revenue or expenditure × proximity to city

Demand of local inputs × distance < 100 km

Municipal revenue or expenditure × distance < 100 km

Observations

R-squared

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects and the same control variables of the baseline regressions (see notes of Table 3). The measures of municipal revenue and expenditure are expressed as logarithms of the total amount.
returns.\textsuperscript{33} A similar phenomenon is reported by Caselli and Michaels (2009) in the context of oil-rich Brazilian municipalities. They find that municipalities increased significantly their expenditure using the revenue windfall associated to the oil operations. They find, however, no evidence of a positive effect on local income and interpret this result as suggestive that the additional revenue was wasted if not stolen.

5.2 Direct Beneficiaries

There are at least three groups of individuals that may have benefited directly from the mine: workers directly employed by Yanacocha, public sector workers, and beneficiaries of Yanacocha’s social development programs.

In the case of mine workers, the benefit is explained by the higher wages paid by the mine. For example, in 1997 the average salary for a Yanacocha employee was almost three times the salary for a similar job in Cajamarca city (Pascó-Font et al., 2001, p.165). The higher wages may be a compensation for the (potentially) more dangerous working environment or efficiency wages paid for roles deemed as vital for the mine’s normal operation.

In the case of public workers, their income would have increased if the revenue windfall associated to mining levies was redistributed in the form of higher wages or benefits.\textsuperscript{34} We rule out direct redistribution to citizens since local governments are constrained by law to do so.

A concern is that the increase in real income would be reflecting direct transfers to these beneficiaries instead of positive spillovers. To evaluate this alternative explanation, we exclude from the sample households with at least one mining or public worker.\textsuperscript{35} In addition, we exclude households living in the districts targeted by Yanacocha’s development projects.

In our sample, these three groups of households represent around 16 percent of total observations. We estimate the baseline regression (1) excluding these households in turns. The results, displayed in columns (1) to (4) in Table 8, are similar to the baseline regressions and dissolves concerns about the source of the observed effect on income. The spillover effects in

\textsuperscript{33}Anecdotal evidence suggests that some recipients of mining transfers embarked in unproductive projects such as refurbishing the town main square or erecting monuments.

\textsuperscript{34}Caselli and Michaels (2009) find evidence of redistribution of oil revenues to public workers in Brazilian municipalities in the form of higher wages and housing benefits.

\textsuperscript{35}The industry of occupation is based 2-digit International Standard Industry Code of the main activity of working individuals. We classify education workers as part of the public sector given that most teachers are in the government payroll.
the region derived from local market interactions remain a plausible explanation.

Table 8: Direct Beneficiaries and Compensating Differentials

<table>
<thead>
<tr>
<th></th>
<th>Ln (real income per capita)</th>
<th>House rental price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Demand of local inputs × distance &lt; 100 km</td>
<td>0.174**</td>
<td>0.198**</td>
</tr>
<tr>
<td>(0.078)</td>
<td>(0.085)</td>
<td>(0.086)</td>
</tr>
<tr>
<td>Public sector workers</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Mining workers</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Live in district adjacent to mine pits</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Dwelling controls</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Household controls</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

Observations: 7738 6796 6668 6570 7738 7738
R-squared: 0.521 0.484 0.478 0.479 0.621 0.627

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects and control variables. Columns (5)-(6) are hedonic regressions that include dwelling characteristics such as type of urban settlement, wall and floor materials, number of rooms, and access to utilities (water, sewage, electricity and telephone), and household controls like schooling, age and gender of the household head and number of members and income earners.

5.3 Compensating Differentials

An alternative explanation of main results is that real wage, and income, might have increased just to compensate local workers for any negative spillover of living closer to the mine. These possible side-effects may have not been captured in the evaluation of short-run health and crime outcomes in Section 4.

In that sense, the operation of Yanacocha has not been exempt of environmental concerns. The most serious incident occurred in 2000 with the spill of 150 kg of mercury on the road near Choropampa, a small town 85 km from the mine. There is also anecdotal evidence of concerns among the population about the risk of water pollution, due to the use of toxic chemicals in the mine, and discomfort associated to the perceived increase in prostitution and crime (Pascó-Font et al., 2001, p. 156).

The increase in income, then, could not be interpreted as an improvement in the living standards of the local population. To explore this issue, we use self-reported house rental.

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36We are unable to evaluate in a reliable manner the effect among direct beneficiaries due to the small size of the sample.
prices as a measure of willingness to pay for living in a particular location.\textsuperscript{37} This approach is related to the literature of contingent valuation widely used to value environmental amenities (Hanemann, 1994).

In this case, we can think of each location near Cajamarca city as exposed to two amenities: a job market with better wages, and the negative spill-overs from the mine. If the increase in income was just compensating for the negative spillovers, we should observe no changes on the willingness to pay for living close to the city. On the contrary, an increase on the willingness to pay would be indicative that residents actually benefit from the mine activity. We use self-reported values, instead of actual land and rental prices, due to lack of data. The main limitation of using this measure is that open-ended stated preferences, like the self reported prices, may underestimate the true willingness to pay in a given location.

We construct the measure of willingness to pay by dividing the self-reported minimum rents by the value of the poverty line, our proxy of the price index. Then, we estimate a hedonic regression with the log of the willingness to pay as dependent variable and the measure of the mine expansion and distance as explanatory variables.

Columns (5) and (6) in Table 8 display the results. Column (5) includes as control variables year and district fixed effect and dwelling characteristics that may affect the rental price such as type of urban settlement, construction materials (walls and floor), number of rooms and access to utilities (water, sewage, electricity and telephone). Column (6) adds household characteristics to account for systematic biases in the report of rental price. In both cases, the expansion of mine’s demand of local inputs is associated to an increase in the self-reported rental price in areas close to Cajamarca city. We interpret these results as indirect evidence that there is no apparent decrease in the willingness to pay for living in locations closer to the city. This finding weakens the case for compensating differentials as a leading explanation of the observed increase in real income.

5.4 Urbanization

There are some systematic differences between areas close and far to Cajamarca. Areas closer to the city are relatively more urbanized, more densely populated and less agricultural. A relevant concern is that, simultaneous to the expansion of the mine, there may be other phenomena\textsuperscript{37}.

\textsuperscript{37} The survey question is: What is the minimum amount you would require for renting this property?
happening in the region that affected differently areas close and far from the city. This would violate our identification assumption and imply that the estimated effect on real income could not be attributed to the mine expansion.

In the main specification, this is dealt with by using district fixed effects and controlling for household characteristics. These different initial conditions, however, may also lead to different trends of income or prices which we may be mistakenly attributing to the mine expansion.

To address this concern we include a non-parametric trend interacted with dummies related to observable characteristics. In particular we use an indicator of urbanization (a dummy equal to 1 if the household is located in an urban area), agricultural activity (1 if the household reports any agricultural production) and population density (1 if the population density of the district where the household lives is above the median).

Table 9 shows the results of this robustness check using real income as dependent variable.\(^{38}\) In all cases, the estimates of the effect of the mine on real income are similar to those found in the baseline regression.

<table>
<thead>
<tr>
<th></th>
<th>ln (real income per capita)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Demand of local inputs (\times) distance &lt; 100 km</td>
<td>0.168**</td>
<td>0.177**</td>
<td>0.184**</td>
</tr>
<tr>
<td></td>
<td>(0.079)</td>
<td>(0.080)</td>
<td>(0.075)</td>
</tr>
<tr>
<td>Year dummies (\times) urban</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Year dummies (\times) farmer</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Year dummies (\times) high density</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Observations</td>
<td>7738</td>
<td>7738</td>
<td>7738</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.526</td>
<td>0.532</td>
<td>0.537</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects and control variables. Urban is a dummy equal to 1 if household resides in an urban area. Farmer is equal to 1 if household reports agricultural production. High density is equal to 1 if density of the district of residence is above the median in the sample.

The previous checks suggest that our results are not driven by different trends based on some observable characteristics. There might be, however, unobservable shocks contemporaneous to\(^{38}\) The results are similar using other dependent variables studied in the main results.
the mine expansion that affect differently areas close or far from any city.

To address this concern, we perform a falsification test replicating the estimates of the effect of the mine on real income but using as reference points other cities instead of Cajamarca. Finding a similar effect of the mine expansion on other cities would suggest that the observed effect on real income observed in areas closer to Cajamarca city is just reflecting a broader urban-rural phenomenon and would raise concerns about the validity of the identification assumption.

We select the other main cities around the North Highlands region: Chachapoyas, Chiclayo and Trujillo (see Figure 1 for a localization map of the cities). All these cities are department’s capitals, as Cajamarca, and have a similar governmental status. Chachapoyas is located in the highlands and have a similar size as Cajamarca. In contrast, Chiclayo and Trujillo are much larger cities located on the coast. For each city, we calculate proximity using the same algorithm as in the baseline results.

Table 10 presents the estimates of the baseline regression with real income as the dependent variable and including the mine wage bill and local purchases interacted with distance to other cities. In all cases, the mine expansion only affects areas closer to Cajamarca city, not to other urban centers.

Table 11 displays the results of the falsification test estimating the baseline regression with distance to the alternative city instead of Cajamarca and using two alternative samples. Panel A uses the same sample as in the baseline results: households in the North Highland region. Panel B includes households within 200 km of the cities, regardless of the geographical region. In all cases the effect of mine wages and purchases becomes insignificant or even negative. Note that results in Panel A show that the main results presented in Table 3 are only explained by proximity to Cajamarca (and not other cities). Results in Panel B, using households closer to each of the other cities, show that there are no contemporaneous positive effects in areas surrounding other cities. The lack of effect on this falsification exercise weakens the case of some confounding factor that affects large cities and that is driving the results.

5.5 Selective Migration

Empirically, a main concern with migration is that the observed increment on real income may be just reflecting compositional changes on the labor force. For example, if only the most

\[ \text{The results are similar using larger areas of influence, e.g. 400 km} \]
Table 10: Effect of the mine on real income, controlling by proximity to other cities

<table>
<thead>
<tr>
<th></th>
<th>Ln(real income per capita)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand of local inputs ×</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to Cajamarca</td>
<td></td>
<td>0.160*</td>
<td>0.160*</td>
<td>0.144*</td>
</tr>
<tr>
<td>&lt; 100 km</td>
<td></td>
<td>(0.083)</td>
<td>(0.083)</td>
<td>(0.082)</td>
</tr>
<tr>
<td>distance to Chachapoyas</td>
<td></td>
<td>-0.088</td>
<td>-0.088</td>
<td>-0.103</td>
</tr>
<tr>
<td>&lt; 100 km</td>
<td></td>
<td>(0.154)</td>
<td>(0.155)</td>
<td>(0.153)</td>
</tr>
<tr>
<td>distance to Chiclayo</td>
<td></td>
<td>0.014</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>&lt; 100 km</td>
<td></td>
<td>(0.179)</td>
<td>(0.179)</td>
<td></td>
</tr>
<tr>
<td>distance to Trujillo</td>
<td></td>
<td></td>
<td></td>
<td>-0.042</td>
</tr>
<tr>
<td>&lt; 100 km</td>
<td></td>
<td></td>
<td></td>
<td>(0.170)</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td>7738</td>
<td>7738</td>
<td>7738</td>
</tr>
<tr>
<td>R-squared</td>
<td></td>
<td>0.520</td>
<td>0.520</td>
<td>0.520</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects and control variables. Distance to all cities is calculated as the shortest path between the main town in the district where the household lives and the city.
Table 11: Falsification test using distance to other cities

<table>
<thead>
<tr>
<th></th>
<th>Ln(real income per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Panel A: North Highlands sample</td>
<td></td>
</tr>
<tr>
<td>Demand of local inputs</td>
<td>-0.188</td>
</tr>
<tr>
<td>× distance &lt; 100 km</td>
<td>(0.142)</td>
</tr>
<tr>
<td>Observations</td>
<td>7738</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.521</td>
</tr>
<tr>
<td>Panel B: Households within 200 km</td>
<td></td>
</tr>
<tr>
<td>Demand of local inputs</td>
<td>-0.058</td>
</tr>
<tr>
<td>× distance &lt; 100 km</td>
<td>(0.063)</td>
</tr>
<tr>
<td>Observations</td>
<td>6978</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.552</td>
</tr>
</tbody>
</table>

City: Chachapoyas  Chiclayo  Trujillo

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects and the same control variables of the baseline regression (see notes of Table 3).
productive agricultural workers migrate to the city, the increase in real income would be driven by higher productivity not by the demand shock from the mine.

Ideally we would like to identify migrants in the sample and check whether the results are driven by this sub-population. Unfortunately, that information is not available. Instead we address this concern indirectly by evaluating whether the expansion of the mine has lead to changes on observable characteristics of the labor force in areas closer and farther from the city. In particular we focus on different measures of human capital such as years of education, an indicator of having completed primary school, and an indicator of the worker being a male in prime age (between 20 and 40 years old). We also explore characteristics of the agricultural unit such as number and concentration of crops. In all cases, we estimate the baseline regression \(^{(1)}\) with year and district fixed effects as the only control variables.

Table 12 shows the results. Note that there are not significant changes in observable characteristics, except for the worsening of measures of education (columns 1 and 2). If we take into account that educational attainment in areas far from the city was lower before the mine expansion, these results suggest a reduction on the gap between both areas. This convergence may be due to the migration of relatively less educated workers from the rural hinterland to the city.\(^{41}\)

Taken together, these results reduce concerns that the increase in real income is driven by migration of more productive workers or farmers to the city.

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\(^{40}\) In the baseline regressions we control for education and age. However, these controls may be insufficient to account for compositional changes in the presence of human capital spillovers or complementarities.

\(^{41}\) In 1997 the average worker located more than 100 km from the city had 3 years of education while the average worker closer to the city had 3.6 years of education. In 2006, the years of education of both type of workers were 4.6 and 4.7, respectively.
Table 12: Changes on characteristics of labor force and agricultural activity

<table>
<thead>
<tr>
<th></th>
<th>Years of education</th>
<th>Complete primary</th>
<th>Male in prime age</th>
<th>Number of crops</th>
<th>Crop HH index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Demand of local inputs</td>
<td>-0.684**</td>
<td>-0.059*</td>
<td>-0.009</td>
<td>-0.153</td>
<td>0.015</td>
</tr>
<tr>
<td>× distance &lt; 100 km</td>
<td>(0.322)</td>
<td>(0.031)</td>
<td>(0.390)</td>
<td>(0.287)</td>
<td>(0.036)</td>
</tr>
<tr>
<td>Observations</td>
<td>31255</td>
<td>31255</td>
<td>34159</td>
<td>5582</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.106</td>
<td>0.064</td>
<td>0.011</td>
<td>0.311</td>
<td>0.228</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects. Regressions in Columns (1) to (3) use the sample of individuals in working age, while columns (4) to (5) use the sample of households with some agricultural production. Complete primary is equal to 1 if individual completed primary school. Prime age is equal to one if worker is a male between 20 and 40 years old. Crop HH index is the Herfindahl-Hirschman concentration index of the value of agricultural production.

6 Conclusion

This paper investigates the effects of a large mine’s interactions with a regional economy. We find robust evidence that the mine has generated a positive effect on real income for residents in the city and in the surrounding rural hinterland. These results are generated by the expansion of local procurement.

The main contribution of the paper is to improve the understanding of the mechanisms through which natural resource extraction can foster local development. In particular it shows that, in the presence of backward linkages, the expansion of extractive industries can generate a positive demand shock and increase the real return to local factors of production, such as land and labor. In turn, this translates into better living conditions for local residents.

A main limitation of the paper is that we only observe events occurring over the span of a decade during the mine operation. This means that we are unable to explore whether the welfare gains are a short-term effect or part of sustainable development that would persist after the mine closure. For the same reason, we can say little about relevant long-run phenomena such as specialization, technological progress, or agglomeration economies. Though beyond the scope of this paper, these phenomena warrant further research.

In the case we study, the positive effects come from a market channel rather than from the revenue windfall to local governments. This suggests that, in a context of weak governments,
policies that promote local procurement and employment could be more beneficial to local residents than increased public spending, at least in the short run.

This policy implication, however, depends on the pre-existence of goods and labor markets able to supply local inputs to the mine, and the extent of economic integration of the region where the mine is located. In the absence of migration costs or inter-regional trade, the benefits could disappear since the increase in real income could be offset by increasing labor supply or consumption goods’ prices.

The availability of natural resources in the developing world is often seen as a hindrance to economic development. In most cases, institutional failure (e.g. conflict, mismanagement or corruption) is at the heart of this inability to transform natural wealth into better standards of living. This paper suggests, however, that in the presence of strong enough backward linkages natural resources have the potential to be more of a blessing than a curse.
References


A Additional empirical results

A.1 Alternative Measures of Distance

In the baseline regressions, we use the shortest path by road and the average (i.e. 100 km) as the threshold. We check the robustness of our results to alternative measures of distance. In column 1 of Table 13 we show that results hold when the threshold is defined by the median, i.e. 90 km.

Additionally, we obtain two alternative measures of distance: a topographic measure and a straight line. The topographic measure is calculated using the ArcGIS package by minimizing the sum of the normalized values of altitude and gradient, regardless of the existence of a road. It can be interpreted as a proxy for where a road may be located or alternative transportation routes in the absence of roads. The straight line measure is calculated as the Euclidean distance between the district capital town and the city of Cajamarca. In order to distinguish district closer and farther from the city, we use as a threshold the median value of the measure of distance. Columns 2 and 3 show that the effects are similar, irrespective of the measure of distance used to tell apart districts that are far and close to Cajamarca.

Finally, we explore in more detail the monotonic decline of the effect by distance, which is a crucial feature of our identification strategy. To do that we estimate the baseline regression including the interaction between the mine wage bill and local purchases and different functions of distance. Column 1 in Table 14 displays the results with the linear measure of distance as a benchmark. Columns 2 and 3 allow for non-linearities by including the logarithm and inverse of distance. In all cases, the results support the claim that the effect of the mine expansion on real income declines with distance to the city.

A.2 Alternative price deflators

The model suggests that the increase in rural income is driven by the increase of local food prices. Hence, we should expect the rural income relative to local food prices to remain stable.

We test this prediction by estimating baseline regression (1), and using the unit value of potatoes and maize as deflators of nominal income. In both cases, we take the mean unit value
Table 13: Alternative measures of distance

<table>
<thead>
<tr>
<th>Measure of distance</th>
<th>Shortest path by road</th>
<th>Topographic</th>
<th>Straight line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median distance (km)</td>
<td>90</td>
<td>75</td>
<td>65</td>
</tr>
<tr>
<td>Observations</td>
<td>7738</td>
<td>7738</td>
<td>7738</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.521</td>
<td>0.521</td>
<td>0.521</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects and control variables. Topographic distance is calculated as the length of the shortest path that minimizes the normalized sum of altitude and gradient. Straight line distance is the Euclidean distance between two points.

Table 14: Exploring the decrease in the effect by distance

<table>
<thead>
<tr>
<th>Real income</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand of local inputs ( \times ) distance</td>
<td>-0.128**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.062)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand of local inputs ( \times ) Ln(distance)</td>
<td>-0.034**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.016)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand of local inputs ( \times ) distance(^{-1})</td>
<td>0.002*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>7738</td>
<td>7738</td>
<td>7738</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.521</td>
<td>0.521</td>
<td>0.521</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects. Distance is equal to the length of the shortest path by road from the main town of the district where the household lives to Cajamarca city, expressed in hundreds kilometers.
in each primary sampling unit to reduce measurement errors and obtain better proxies of the underlying prices.

Table 15 displays the results. Columns (1) and (2) use as dependent variable the log of the income divided by the unit value of potatoes or maize. As comparison, column (3) displays the baseline result using the poverty line as deflator. Note that the estimated effect of the mine expansion is positive but insignificant when using the unit values of local crops as deflators. The point estimates are also smaller than the one obtained using poverty line as a deflator.

Table 15: Effect of mine expansion on real income, using alternative price deflators

<table>
<thead>
<tr>
<th>Relative income</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand of local inputs × distance &lt; 100 km</td>
<td>0.137</td>
<td>0.115</td>
<td>0.174**</td>
</tr>
<tr>
<td>Deflator of nominal income</td>
<td>unit value</td>
<td>unit value</td>
<td>poverty</td>
</tr>
<tr>
<td>of potatoes</td>
<td>of maize</td>
<td>line</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>7132</td>
<td>7089</td>
<td>7738</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.562</td>
<td>0.525</td>
<td>0.521</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors in parentheses. Standard errors are adjusted for clustering at primary sampling unit level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include year and district fixed effects, and control variables as in Table 3.

B  A Model of an Export Enclave

This section presents a model to illustrate some of the local economic effects of an export enclave. We define an export enclave as a foreign-owned firm, that export most of its production and uses few local inputs. These features are characteristic of many large modern mines operating in less developed regions, such as Yanacocha.

The model is based in the mono-centric city model developed by Fujita and Krugman (1995). We extend this basic framework by including an export sector and inter-regional trade. The model treats the expansion of the export enclave as a (potential) increase in the demand of local inputs. The magnitude of the demand shock depends of the extend of backward linkages.

This setup allows us to explore the general equilibrium effects of an export enclave such as change in relative prices, migration and displacement of other economic activities. Moreover,
it clarifies the spatial distribution of the effects and how they could be transmitted from urban to rural areas.

B.1 Environment

Consider a spatial structure where the regional economy is a long narrow line, and each location is denoted by \( r \) (Figure 10). There is a single city, located at \( r = 0 \), surrounded by a rural hinterland that extends from \(-f \) to \( f \). At each location there is one unit of land of homogeneous quality.

![Figure 10: The mono-centric economy](image)

There is a given population of \( N \) workers who supply inelastically one unit of labor. \( L \) workers live in the city, while the remaining lives in the rural hinterland. There is free mobility of labor within the region, but no inter-regional migration.

The economy has four productive sectors: agriculture, services, manufacturing and a mine that produces a commodity. The rural hinterland specializes in agriculture, while the rest of economic activity takes place in the city. Only the output of the agriculture and service sector are for domestic consumption, the manufactured good and the export commodity are exported to inter-regional markets. The economy also imports a consumption good through importers located in the city. All import and export prices are given.

There is intra-regional trade. The city and rural hinterland exchange food, services and the import good. Intra-regional trade, however, is costly due to transportation costs. In particular, if one unit of a good is transported over a distance \( d \), only \( e^{-\tau d} \) units arrive. The parameter \( \tau \) represents the transportation cost and is the same for all types of goods. Costly transportation implies that there are (potentially) different factor and good prices in each location \( r \).

\[ ^{42} \] For simplicity, we drop the label when referring to the city \((r = 0)\).

\[ ^{43} \] This assumption is important for tractability of the model, and not unreasonable in the case we study. According to the 2007 Population Census, more than 96 percent of the population in the region where the mine is located (i.e. Cajamarca) had been living there for at least 5 years.

\[ ^{44} \] We normalize the transportation cost of inter-regional trade to zero.

\[ ^{45} \] For the case of services, a more intuitive interpretation of \( \tau \) is the cost of travelling to the city to receive the service. The model predictions are similar if we assume heterogeneous transportation costs.
Consumers  All consumers share the same homothetic preferences \( U = X^{\alpha} A^{\alpha} M^{1-\alpha-\mu} \), where \( X \) is a composite index of a variety \( v \) of domestic services, \( A \) is the agricultural good and \( M \) is the import good. The quantity index \( X \) is a CES function of the consumption of each available variety:

\[
X = \left( \int_0^v c_i^\rho \, di \right)^{\frac{1}{\rho}}, \quad 0 < \rho < 1,
\]

where \( c_i \) is the consumption of each individual variety and \( v \) is the range of varieties. The parameter \( \rho \) denoted the taste for variety and \( \sigma = \frac{1}{1-\rho} \), the elasticity of substitution between varieties.

The representative consumer’s budget constraint in location \( r \) is given by

\[
Y(r) = p_a(r)A(r) + p_m(r)M(r) + \int_0^v p_i(r)c_i(r)\,di,
\]

where \( Y \) is the consumer’s income, \( p_a \) is the price of food, \( p_m \) is the price of the import good and \( p_i \) is the price of variety \( i \). Note that, due to transportation costs, prices and quantities are location-specific.

The consumer maximization problem produces standard results. The demand for the agricultural and import goods are \( \alpha \frac{Y(r)}{p_a(r)} \) and \( (1 - \alpha - \mu) \frac{Y(r)}{p_m(r)} \) respectively, while the demand of the composite \( X \) is \( \mu \frac{Y(r)}{G(r)} \), where \( G(r) = \left[ \int_0^v p_i(r)^{1-\sigma} \, di \right]^{\frac{1}{1-\sigma}} \) is the price index for the services composite. The uncompensated demand for each variety is

\[
c_i(r) = \mu Y(r) \frac{p_i(r)^{-\sigma}}{G(r)^{(\sigma-1)}}. \tag{3}
\]

Furthermore, from the indirect utility function we can obtain the cost of living in a specific location \( r \):

\[
P(r) = G(r)^\mu p_a(r)^\alpha p_m(r)^{1-\alpha-\mu}. \tag{4}
\]

Service providers  The service industry provides a large number of varieties \( v \) using an increasing returns to scale technology. In particular, a firm requires \( l_i = F + \beta x_i \) units of labor to provide \( x_i \) units of a variety. The presence of increasing returns to scale implies that each variety is provided by a single firm. There is free entry and exit to the industry; hence, in equilibrium, service firms make zero profits.
A firm’s profit is equal to \( p_i x_i - w l_i \), where \( x_i = c_i \) as in equation (3) and \( w \) is the wage in the city. The resulting profit-maximization price is \( p_i = \frac{\sigma}{\sigma-1} \beta w \).

Note that this result implies \( p_i = p \), i.e. all varieties have the same price, since they all share the same marginal cost \( \beta \). It follows that the composite price index is \( G = \rho \nu \frac{1}{1-\sigma} \) and that the demand for a variety in a given location \( c(r) = \frac{\mu(\nu(r))}{\rho(r)} \). From the zero-profit condition we obtain a firm’s individual supply \( x = \frac{F(\sigma - 1)}{\beta} \) and its labor demand \( l = F\sigma \).

Manufacture producers and the mine In contrast to service providers, manufacture producers export all its production and use a decreasing returns to scale technology. In particular, their production function is \( E(L_e) = L_e^{\varepsilon} \), where \( E \) is the quantity produced, \( L_e \) is the size of the workforce employed in the industry and \( \varepsilon < 1 \). The industry profit is \( p_e E(L_e) - w L_e \), where \( p_e \) is the external price of the manufactured good.\(^{46}\)

Solving for the profit maximization problem we obtain the unconditional labor demand function: \( L_e(w) = \left( \frac{\varepsilon p_e}{w} \right)^{\frac{1}{1-\varepsilon}} \). Note that \( \varepsilon p_e E \) is paid, as wages, to local workers; while the industry profits \( \pi_e = (1 - \varepsilon) p_e E \) are distributed among the firms’ shareholders. For simplicity, we assume that all shareholders reside outside the region.

We model the mine as an export enclave with few interaction with the local economy. The mine’s profits are remitted abroad and the production is not used for local consumption or production. The only interaction is through the use of local labor. The mine’s demand of local labor is exogenously determined and equal to \( \theta \). This parameter captures the extent of backward linkages. We can think of \( \theta \) as the number of workers employed directly by the mine or indirectly through contractors. Further, we assume that \( \frac{\theta}{N} < \frac{1-\alpha-\mu}{1-\alpha} \), thus the relative size of the mine’s workforce is not too large relative to the region’s population.\(^{47}\)

Agricultural production and rural hinterland Farming uses a fixed proportion technology. It requires one unit of land and \( c_a \) units of labor to produce one unit of food. Food is consumed locally and the surplus, a proportion \( 1 - \alpha \), is sold to the city. Landlords live in their landholdings, hence all the agricultural income is consumed locally. For a given frontier \( f \) the

\(^{46}\) We include this sector to create a link between local wage and the mine activities. Note that the labor demands of all other sectors are linear. Thus, without the manufacture sector, an increase in the labor demand of the mine would not affect wages but only reallocate workers between industries.

\(^{47}\) This assumption guarantees the existence of a unique equilibrium. We check empirically the plausibility of this assumption in the Yanacocha case. The results are available from the authors upon request.
total demand of labor from the agricultural sector is $2c_af$, implying that population in the city is $L = N - 2c_af$, and total food supply to the city is $2 (1 - \alpha) \int_0^f e^{-\tau r} dr$.

Food is traded in competitive markets in the city at a price $p_a$. The price of food received by farmers, however, decreases with distance to the city due to transportation costs. In particular, a farmer in location $r$ receives $p_a(r) = p_a e^{-\tau |r|}$.

In contrast, the price of services and import goods increase with distance because they are produced in the city. In particular, in location $r$ the price of the manufacture composite is $G(r) = Ge^{\tau |r|}$ and the price of imports, $p_m(r) = p_m e^{\tau |r|}$. Taken together, these results imply that the price index in location $r$ is $P(r) = Pe^{(1-2\alpha)\tau |r|}$.

Since landlords use $c_a$ units of labor to produce 1 unit of food, their rents are $R(r) = p_a e^{-\tau |r|} - c_a w(r)$, where $w(r)$ is the wage rate in location $r$. The hinterland extends around the city up to the point where rents are zero, or $w(f) = \frac{p_a e^{-\tau f}}{c_a}$. Costless migration implies that in equilibrium the real wage is the same in all locations. In particular, we compare the real wage in the city and in the agricultural frontier to obtain the following wage equalization condition $w = \frac{p_a e^{-2(1-\alpha)\tau f}}{c_a}$.

Finally, we derive total demand for manufactures and import goods from the rural hinterland. Note that the total rural income corresponds to the price of the agricultural output $p_a(r)$. The income is distributed between landlords and agricultural workers, however, since they have the same homothetic preferences, we can treat their demand as the one of a representative consumer. Replacing the values of local prices and income, we obtain the total demand of each services variety and import goods from the rural hinterland:

- **Service variety:** $2\mu \frac{p_a}{pm} \int_0^f e^{-2\tau r} dr$
- **Import good:** $2(1 - \alpha - \mu) \frac{p_a}{pm} \int_0^f e^{-2\tau r} dr$. 

47
B.2 Equilibrium

The instantaneous equilibrium is given by the solution of the following system of non-linear equations:

\[
\frac{F(\sigma - 1)}{\beta} = \frac{\mu}{pw} \left( Lw + 2p_a \int_0^f e^{-2\tau r} \, dr \right) \quad (5)
\]

\[
2 (1 - \alpha) \int_0^f e^{-\tau r} \, dr = \frac{\alpha}{p_a} (Lw) \quad (6)
\]

\[
L = \nu F \sigma + L_e(w) + \theta \quad (7)
\]

\[
w = \frac{p_a e^{-2(1-\alpha)fr}}{c_a} \quad (8)
\]

\[
p_e E(w) + w\theta = (1 - \alpha - \mu) \left( Lw + 2p_a \int_0^f e^{-2\tau r} \, dr \right) \quad (9)
\]

\[
N = L + 2c_a f. \quad (10)
\]

Equation (5) represents the market equilibrium of each variety of the local manufacture. The total demand on the right hand side is proportional to the regional income composed by the wages paid to city workers and the agricultural income. Equation (6) and (7) are the equilibrium conditions of the food and city labor market, respectively. Equation (8) is the wage equalization condition obtained from the assumption of costless migration. Equation (9) represents the current account’s balance: in equilibrium, the value of exports minus net factor payments equals the value of total imports. Finally, equation (10) is the population constraint.

This system reduces to two equations with a unique solution in the \((f, w)\) space:

\[
N - 2c_a f - \frac{(1 - \alpha - \mu) \varepsilon + \mu L_e(w) - \frac{1 - \alpha}{1 - \alpha - \mu} \theta}{(1 - \alpha - \mu) \varepsilon} = 0 \quad (AA)
\]

\[
2c_a \left[ \frac{(1 - \alpha)(1 - e^{-\tau f})}{\alpha e^{-2(1-\alpha)\tau f}} + f \right] - N - \frac{(1 - \varepsilon)}{\varepsilon} L_e(w) = 0. \quad (BB)
\]

Figure 11 depicts curves AA and BB, and the equilibrium \(Q\). Recall that \(w\) denotes the wage in the city and \(f\) is the extent of the rural hinterland. Intuitively, the curve AA is upward sloping because a larger rural hinterland implies a smaller city population and higher city wages. In contrast, curve BB is downward sloping because higher wages in the city increase agricultural production.

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48 We assume a fixed exchange rate equal to one.

49 The solution and proofs are available from the authors upon request.
wages (due to costless intra-regional migration). In turn, this means that the marginal farmer makes losses and the agricultural frontier shrinks.

![Figure 11: Model equilibrium and the expansion of the mine](image)

**B.3 Testable predictions**

We simulate the expansion of the mine as an increase in $\theta$, the mine’s demand of local labor. In the case of Yanacocha, this increase was driven both by the expansion of the mine operations and a policy to hire more local workers. The immediate effect of this shock is to increase demand of labor and shift the curve $AA$ upwards as depicted in Figure 11. In the new equilibrium $Q'$, $w$ is higher and $f$ smaller. This implies an increase in nominal wages, a shrinking of the agricultural frontier and migration of rural workers to the city. The increase in nominal wage, in turn, reduces output and employment in the manufacturing sector, a result similar in flavor to the Dutch disease (Corden and Neary, 1982)\(^{50}\).

The effect on the number of service firms, $v$, however, is ambiguous. $v$ is proportional to the number of service workers available in the city.\(^{51}\) Hence, $v$ increases due to the growth of city population and the reduction of manufacturing employment, but declines due to the increase in mine employment.

The key question is what happens with real income. To find that effect we first need to

\(^{50}\)In contrast to standard Dutch disease, however, the crowding out is driven by an increase in the price of an input not by the change in terms of trade.

\(^{51}\)To see this note that we can rewrite equation (7) as $v = \frac{L - L_e(w) - \theta}{P}\)
obtain an expression for the real income in different locations. The real income of city residents is equal to the real wage, while the real income of the average rural resident is proportional to the relative value of the agricultural product \( \frac{p_a(r)}{p_a} \). From equation (6) we can write \( \frac{p_a}{P} \) as a function of the real wage so that the average real income in location \( r \) is:

\[
y(r) = \begin{cases} 
\frac{w}{P} & \text{if } r = 0 \\
\frac{1}{k} \int_0^r e^{-\tau s} d\tau \alpha \frac{L}{P} & \text{if } r \neq 0,
\end{cases}
\]

where \( \frac{w}{P} \) is the real wage, which is the same in every location due to costless internal migration, and \( k \) is the unknown, but constant, population size in each rural locality.\(^{52}\)

In general, the effect of the mine expansion on real income is ambiguous. On the one hand it increases due to higher nominal wages, \( w \). On the other hand, it may decrease if the general price index \( P \) raises. The net effect, however, depends on the change in \( v \), the number of service firms. In particular,

**Proposition 1** if the mine expansion do not reduce the number of service firms \( \frac{dv}{d\theta} \geq 0 \), then the mine expansion:

1. Increases real income in the city and rural hinterland
2. Increases the relative price of food.
3. The effects decline monotonically with distance to the city.

Intuitively, the expansion of the mine’s demand of local labor increases the urban nominal wage, and income. The growth of urban income increases the demand for food and its relative price. In turn, the change in relative price of food transmits the income gains from the city to the rural hinterland, not directly supplying goods to the mine. The income increase in real terms due to the access to relatively cheaper imports, the smaller increase in food prices relative to wages and (potentially) the access to a larger variety of services.

The effects decline with distance because transportation costs reduce the land rents for farmers in farther locations, and absorb part of the income gains. In the extreme, beyond the agricultural frontier, the effect is nil since there is no trade with the city.

\(^{52}\)Recall that in each farm there are \( c_a \) workers and a landlord, but \( (c_a + 1) \) is not the total population since a landlord can also be a worker.
B.4 Proofs and Derivations

B.4.1 Derivation of equations (AA) and (BB)

Using (7) and the population constraint \( N = L + 2c_a f \) we write the number of manufacturing firms, \( v \), as:

\[
v(w, f) = N - 2c_a f - L_e(w) - \theta \frac{1}{F}.\]

Using this result, replacing (9) into (5) and re-arranging, we obtain equation (AA):

\[
N - 2c_a f - \left(1 - \alpha - \mu\right) \varepsilon + \mu \left(1 - \alpha - \mu\right) \varepsilon L_e(w) - 1 - \alpha - \mu \varepsilon L_e(w) = 0.
\]

Note that equation (AA) defines an upward sloping curve in the space \((f, w)\). This curve has a positive intercept and also an upper bound \( f \) on the values that \( f \) can adopt. To see this, note that \( f \equiv \lim_{w \to \infty} f = \frac{1}{2} N - \frac{1 - \alpha}{1 - \alpha - \mu} \theta \) and that \( \lim_{f \to 0} w = L_e^{-1} \left(2c_a f^\left(1 - \alpha - \mu \varepsilon + \mu \left(1 - \alpha - \mu \right) \varepsilon\right)\right) \), where \( L_e^{-1} \) is the inverse function of \( L_e(w) \).

Second, we can rewrite the equilibrium condition in the food market (6) using the expression for the manufacturing labor demand, \((w) = \left(\frac{2c_a}{w}\right)^{\frac{1}{1-\varepsilon}}\), the wage equalization condition (8) and the population constraint (10). Solving for the integral over \( f \) and rearranging, we obtain expression (BB):

\[
2c_a \left[\left(1 - \alpha\right)\left(1 - e^{-\tau f}\right)ight] \frac{1}{\alpha e^{-2(1-\alpha)\tau f}} + f\right] - N - \frac{1 - \varepsilon}{\varepsilon} L_e(w) = 0.
\]

This expression defines a downward sloping curve in the space \((f, w)\), with a lower bound \( f \) on the values of \( f \). Note that \( f \equiv \lim_{w \to \infty} f = g^{-1}(N) \), where \( g^{-1}(\cdot) \) is the inverse function of \( g(f) = 2c_a \left[\frac{(1-\alpha)(1-e^{-\tau f})}{\alpha e^{-2(1-\alpha)\tau f}} + f\right] \).

B.4.2 Existence of Equilibrium

Assumption 2 \( N > \frac{1 - \alpha - \mu}{1 - \alpha} \varepsilon \theta \)

This assumption means that the share of employment from the mine is small enough relative to the total population in the region.

Proposition 3 Under Assumption 2, there is a unique and positive pair \((f^*, w^*)\) that solves (AA) and (BB).
Proof. To see this, first note that we can re-write equilibrium condition (BB) as a function of \(L_c(w)\) and plug it in equilibrium condition (AA). We then obtain an expression of \(f\) only that can be expressed as

\[
H(f) = N - 2c_a f - \frac{1 - \alpha}{1 - \alpha - \mu} \theta - A(f)
\]

where \(A(f) = (1 + \frac{\mu}{1 - \alpha - \mu} \varepsilon) \frac{\varepsilon}{1 - \varepsilon} \{2c_a[(\frac{1 - \alpha}{\alpha c_e - 2(1 - \alpha)} + f) - N]\}, A'(f) > 0\) and \(H'(f) < 0\).

To find the equilibrium, we look for a value \(f^*\) such that \(H(f^*) = 0\).

First, recall that the values of \(f\) can adopt in equation (AA) have an upper bound \(\tilde{f} = \frac{1}{2c_a} \left( N - \frac{1 - \alpha}{1 - \alpha - \mu} \theta \right) \) with \(0 < \tilde{f} < \frac{N}{2c_a}\) under Assumption 2. Note that \(H(\tilde{f}) = -A(\tilde{f})\), which is negative only if \(2c_a[(\frac{1 - \alpha}{\alpha c_e - 2(1 - \alpha)} + \tilde{f}) - N] > 0\). From definition of \(\tilde{f}\), (3) and the population constraint \(N = L + 2c_a f\), this condition can be re-written as \(\frac{1 - \alpha}{1 - \alpha - \mu} \theta + \frac{\pi_e}{w} > \frac{1 - \alpha}{1 - \alpha - \mu} \frac{\theta}{2c_a}\), which is satisfied under Assumption 2 hence \(H(\tilde{f}) < 0\).

Second, recall that the values of \(f\) in equation (BB) have a lower bound \(\check{f} = \lim_{w \to \infty} f = g^{-1}(N)\), where \(g^{-1}(\cdot)\) is the inverse function of \(g(f) \equiv 2c_a[(\frac{1 - \alpha}{\alpha c_e - 2(1 - \alpha)} + f)]\). From this definition follows that \(A(\check{f}) = 0\). Combining this result with the previous observations that \(A(\tilde{f}) > 0\) and \(A'(f) > 0\), it follows that \(0 < f < \check{f} < \frac{N}{2c_a}\) and therefore \(H(f) = N - 2c_a f - \frac{1 - \alpha}{1 - \alpha - \mu} \theta > 0\).

Finally, since \(H(f)\) monotonically decreases in \(f\), \(H(f) > 0\) and \(H(\tilde{f}) < 0\) imply that there is a unique positive value \(f^* \in (\check{f}, \tilde{f})\), such that \(H(f^*) = 0\). From inspection of (6), values of \(f^* \in (\check{f}, \tilde{f})\) imply a value of \(L_c(w) > 0\) and thus that the equilibrium wage, namely \(w^*\), is also unique and positive.

The result depends of Assumption 2. To check how reasonable this assumption is, note that we can re-write it as \(\mu < (1 - \alpha) \left( 1 - \frac{\theta}{\pi_e} \right)\), where \(\alpha\) is the consumer’s budget share of locally produced food, \(\mu\) is the budget share of local manufactures and \(\frac{\theta S}{N}\) is the relative size of the mine’s workforce.

We calculate the budget share on food using the ENAHO survey and use it as a proxy for \(\alpha\). The estimated budget share is 0.6, however note that this measure may overestimate the true value of \(\alpha\) since some of the food is not locally produced. Regarding \(\frac{\theta S}{N}\), recall from Section 2 that Yanacocha’s direct and indirect employment in the analyzed period was between 12% and 20% of the active population of the city of Cajamarca. This proportion would be significantly lower if we include working population in the rest of the region. These figures imply that for Assumption 1 to be violated \(\mu\) should be, at least, greater than 0.32 or 0.35. In turn this
implies a very small budget share of imported goods \((1 - \alpha - \mu)\), with values at most between 0.05-0.08\(^{53}\).

### B.4.3 Proof of Proposition 1

Note that \(\frac{w}{p} = \left(\frac{w}{G}\right)^{\mu} \left(\frac{w}{p_a}\right)^{\alpha} \left(\frac{w}{p_m}\right)^{1-\alpha-\mu}\). From (8) we see that \(w/p_a\) is decreasing in \(f\) and hence increasing in \(\theta\). \(w/p_m\) is also increasing in \(\theta\) since \(p_m\) is fixed. Using the definition of \(G\) and \(p = \frac{\sigma-1}{\sigma} \beta w\), we obtain that \(w/G = \beta \frac{\sigma-1}{\sigma} v^{1/\sigma}\), which is increasing in \(v\).

Hence, \(dv/d\theta \geq 0\) implies that the real wage, and by extension the real income in the city and rural hinterland, are also increasing in \(\theta\). Since rural income is proportional to \(p_a(r)/P(r)\), the previous result implies that also the relative price of food is increasing in \(\theta\). Finally, from expression (11) we can see that \(dy(r)/drd\theta < 0\) for every \(r \neq 0\).

\(^{53}\)Note that the overestimation of \(\alpha\) and \(\frac{\nu}{\sigma}\) mean that the threshold that \(\mu\) should exceed to violate assumption 1 are understated. Hence, violation of assumption 1 requires an even higher \(\mu\), and smaller budget share of imported goods.