Discussion Paper Series

2010 – 03

Department of Economics
Royal Holloway College
University of London
Egham TW20 0EX

The Blessing of Natural Resources: Evidence from a Peruvian Gold Mine*

Fernando M. Aragón† Juan Pablo Rud‡

September 2010

Abstract

This paper studies the impact of Yanacocha, a large gold mine in Peru, on the local population. Using annual household data from 1997 to 2006, we find evidence of a positive effect of the mine's demand of local inputs on real income, household welfare and poverty reduction. The effects are only present in the mine's supply market and surrounding areas. We examine and rule out that the results are driven by the fiscal revenue windfall from mining levies. Using a spatial general equilibrium model, we interpret these results as evidence of welfare gains generated by the mine's backward linkages.

Keywords: Natural resources, mining, local development.

JEL classification: O13, O18, Q32, Q33, R20

*We are particularly grateful to Tim Besley for his support and advice during this research project. We also thank Nava Ashraf, Oriana Bandiera, Konrad Burchardi, Francesco Caselli, Dave Donaldson, Claudio Ferraz, Greg Fischer, Maitreesh Ghatak, Guy Michaels, Gerard Padró i Miquel, Torsten Persson and seminar participants at LSE, Royal Holloway, the Econometric Society, Oxcarre, Houston, Notre Dame, Pompeu Fabra, Alicante, SITE, Simon Fraser and the Royal Economic Society for useful comments and suggestions.

†Department of Economics, Simon Fraser University, Burnaby B.C., V5A 1S6, Canada; Email: faragons@sfu.ca

‡Department of Economics, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, United Kingdom; Email: juan.rud@rhul.ac.uk

> 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

Access to natural resources has hardly been associated with development. A body of theoretical and empirical literature suggests that natural resources may not translate into better living standards or may even hinder development (Sachs and Warner, 1999; Sachs and Warner, 2001). The current explanations for this "natural resource curse" focus on conflict, bad institutions, ineffective government or displacement of other productive sectors through changes in relative prices (Benjamin et al., 1989; Torvik, 2002; Caselli, 2006; Frankel, 2010). The available evidence, however, is scant in terms of analyzing alternative market channels such as backward linkages between the extractive industry and the rest of the economy, or effects at the local level where phenomena such as pollution or population displacement occur.

In this paper, we fill this gap in the literature by investigating the economic mechanisms through which natural resources can benefit local communities. We use the case of Yanacocha, a large gold mine in Peru, as a testing ground to evaluate the effect of the expansion of the mine on household income and welfare. In contrast to the existing literature, we focus on the general equilibrium effects of the mine's demand of local inputs as the main transmission channel.

In order to inform the empirical exercise, in Section 2 we first develop a spatial general equilibrium model based on Fujita and Krugman (1995). In this setup, there is a single city surrounded by a rural hinterland with endogenous boundaries, specialized in the production of manufactured goods and food, respectively. Both areas engage in costly intra-regional trade, and are also able to import goods from other regions. The model treats the expansion of the mine as a shock in the demand for labor in the city, the mine's input market, and delivers two testable predictions. First, if the mine expansion increases real income in the city, then agricultural real income also increases. Second, there is an increase on the relative price of locally produced food. The increase in agricultural prices channels the income gains to the rural population, who do not supply goods or services to the mine. The effects wane with greater distance to the city, due to transportation costs.

We subsequently test these predictions using household data, representative of the region where the mine is located, for the period 1997 to 2006. We exploit two sources of variation to identify the effects of the mine expansion (see Section 3). First, we use information on Yanacocha's wage bill and local purchases. This variable shows a significant increase from 2000 onwards, driven by the expansion of gold extraction and the implementation of a corporate policy directed at increasing local procurement. Second, we use distance from the household location to Cajamarca city -the mine's local supplying market- as a source of heterogeneous exposure to the mine's expansion.

We find a positive effect of the mine's activities on real income in the city and surrounding areas (section 4). The effect decreases monotonically with distance and becomes insignificant beyond 100 km from the city. Our estimates suggest that a 10 percent increase in the mine's wage bill and local purchases is associated with an increase in real income of around 1.7 percent. We also observe increments on the relative price of local food crops, such as potatoes and maize. This is consistent with the effect on real income being driven by a market mechanism and explains how the rural population benefited from a demand shock in the city. In these regressions the identifying assumption is that in the absence of the mine's expansion of local purchases, these changes in income and relative prices would not have happened. Results are robust to alternative explanations that would invalidate this assumption (see Section 6).

In the presence of locational externalities associated to the mine (such as pollution or crime), a greater real income does not imply an increase in welfare. Moreover, the average increase in income may hide negative re-distributional effects, for example if poor households are unable to benefit from the mine expansion. To explore these issues, we first follow Roback (1982) and use house prices as a measure of welfare.We find evidence of house rental prices in the area going up, which we interpret as evidence of net welfare gains due to the mine expansion. Second, we look at self-reported measures of health and crime, and do not find evidence that they have worsened with the expansion of the mine. Finally, we analyze the re-distributional impacts of the mine expansion. Using quantile regressions, we find that the average household income at the bottom of the income distribution has experienced an increase of real income similar to that observed for richer households. Furthermore, we find direct evidence of poverty reduction.

To discuss further the mechanism at play, in Section 5 we investigate whether the observed phenomena could be explained by the revenue windfall to local governments or by direct beneficiaries. The former is a relevant question because of the importance attached to the expansion of public expenditure, seen as one of the main benefits of natural resource exploitation. We show that local public spending increases due to the expansion of the mine. However, we find no evidence that this expansion of the public sector contributes to the observed increase in real income or welfare.[1] Instead, the observed phenomena seems to be driven entirely by the expansion of the mine's local purchases and employment. To the best of our knowledge, there is not previous empirical work contrasting the relative importance of these two mechanisms.

In sum, our empirical results suggest that the expansion of the mine increased both the real income and welfare of the local population. The effect seems to be driven by the demand shock and its multiplier effect, associated to the mine's backward linkages and not to the fiscal revenue windfall. The gains are transmitted to residents in the rural area, not directly selling inputs to the mine, due to the existence of trade within the economic region. The increase in the relative price of locally produced food crops is evidence of this transmission channel.

This paper contributes to the literature studying the effect of natural resources on economic development and to the literature examining how regional markets respond to demand shocks.[2] Three features distinguish our paper from previous work. First, we use a microeconomic approach where the household is the unit of observation, as opposed to counties or districts. The comprehensiveness of the data allows us to explore in more detail the mechanisms generating the spillover effects and to assess the net impact on resident's welfare. Second, we show the importance of backward linkages as a channel to improve local conditions. The mechanism we uncover hints at an alternative explanation for the failure of natural resources to promote de-

[1]Using the case of Brazil, Caselli and Michaels (2009) also find evidence suggesting that the oil revenue windfall to municipalities did not translate in increases to local income.

[2]There is not conclusive evidence of the effect of natural resources on development. Earlier studies use cross country data and find negative effects (Sachs and Warner, 1995; Sachs and Warner, 2001). However other papers using alternative measures of resource abundance fail to find a negative relation (Lederman and Maloney, 2003; Sala-i-Martin et al., 2004). Using a microeconomic approach, Michaels (2006) finds that oil abundance in U.S. counties caused specialization, but that these costs were offset by population growth and better education. In balance, oil-rich counties enjoyed higher income per capita without increase in inequality. Black et al. (2005) explore the effect of a coal boom in U.S. counties and find modest positive spillover effects on employment. More recently, Caselli and Michaels (2009) find no evidence of positive effect of oil extraction on income in Brazilian municipalities. In contrast, the literature on the impact of demand shocks (such as large industrial plants, construction works, casinos or military bases) find some evidence of positive regional effects on wage bill and employment (Carrington, 1996; Hooker and Knetter, 2001; Evans and Topoleski, 2002), and resident's welfare (Greenstone and Moretti, 2003).

velopment: few linkages with local markets. This explanation relates to a technological feature of extractive industries and contrasts to the political economy argument used to explain the natural resource curse. Finally, we embed the study of natural resources (and local demand shocks) in the analytical framework of a new economic geography model. This allows us to explicitly explore general equilibrium effects and to introduce transportation costs, agglomeration economies and migration which are relevant factors when studying a regional economy.

A main policy implication of our findings is that, even in the presence of weak governments, natural resources can benefit local populations if backward linkages between the extractive industry and the rest of the economy are strong enough. This recommendation, however, hinges on the existence of economic integration in the regional economy (labor mobility and trade) as well as the pre-existence of good and labor markets able to supply local inputs to the extractive industry.

The lessons to be drawn from this paper are not exclusive to extractive industries and could apply to any business venture that creates a strong demand shock in a relatively poor area. However, the case of large-scale mining might be different not just because the location of the venture is driven by resource location and not by other features (such as agglomeration economies, for example). There are at least two other features that make large-scale mining a different and interesting case to study. First, mining is a relevant industry for developing countries.[3] According to the World Bank, around 60 countries in the world have a mining sector large enough, in terms of GDP or exports, to be a main driver of economic growth and poverty reduction (World Bank, 2002). However, understanding how to transform mining wealth into better living standards remains an unsolved policy question. Second, there are well-documented negative local effects associated to mining. This increases the need to assess both direct and indirect benefits on local communities to inform industrial and development policies.

[3]Developing countries play an important role in global mining. They are the largest producers of key minerals like iron, copper and aluminium, and have almost three quarters of the world mineral resources. They account for most of the recent growth on mining production and attract an even increasing proportion of exploration spending (Humphreys, 2009).

2 Analytical framework

In this section we present a stylized model to shed light on the general equilibrium effects of the expansion of a mine on a regional economy. We use the mono-centric city model developed by Fujita and Krugman (1995) and extend it by including an export sector and interregional trade. In this framework, the mine is a foreign-owned net exporter that uses local labor as a production factor but sells all its output in international markets.[4]

The model stresses the role of backward linkages, by treating the expansion of the mine as a shock in the demand for local labor. We then explore the effect on factor and good prices, and ultimately on real income. The model allows us to analyze the spatial distribution of the effects as well as the interaction of different economic sectors.

2.1 Environment

We consider a mono-centric spatial structure where the regional economy is a long narrow line around a single city, located in the center. Each location along the line is denoted by r and normalize the city location to zero.[5] The rural hinterland extends from $-f$ to f, where f represents the endogenously determined agricultural frontier. The land is of homogenous quality with one unit of land per unit of distance.

The economy has three productive sectors: manufacturing, agriculture and an export sector. The manufacturing sector produces a large number of varieties with an increasing returns to scale technology and has a monopolistic competition structure. In contrast, the agricultural sector is perfectly competitive and produces a single homogeneous good, namely food. The export sector produces two goods: a manufactured commodity and the natural resource, which are not consumed locally. Consumers in the region can import consumption goods from other regions. Import and export goods are homogenous and their prices are set in external markets. All manufacturing, production of the export goods and import activity takes place in the city, while the rural hinterland specializes in food production. We take this spatial system as given.[6]

Transportation is costly. In particular, we use an iceberg transportation cost such that if one unit is transported over a distance d, only $e^{-\tau d}$ units arrive. The parameter τ represents

[4] This setup resembles the characteristics of the mining activities of Yanacocha and other large modern mines.
[5] For simplicity, we drop the label when referring to the city ($r = 0$).
[6] See Fujita and Krugman (1995) for conditions under which this configuration could be an equilibrium outcome.

the transportation cost and is the same for all types of goods.[7] Costly transportation implies that there are (potentially) different factor and good prices in each location r, .

The region has a given population of N workers who supply inelastically one unit of labor.[8] Intra-regional migration is costless and workers can freely move among locations, hence the population allocation within the region is endogenous. In particular, the size of the city L will depend on the spatial distribution of real wages.

Consumers All consumers share the same homothetic preferences $U = X^{\mu} A^{\alpha} M^{1-\alpha-\mu}$, where X is a composite index of the domestically produced manufactured goods, A is the agricultural good or food and M is the import good. The quantity index X is a CES function of the consumption of each available variety:

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

where c_i is the consumption of each individual variety and v is the range of varieties. The parameter ρ 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 transport costs, prices and quantities are location-specific.

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

[7]The model predictions are similar if we assume different transportation costs for agricultural, manufactured and import goods.

[8]This assumption is important, since it precludes the possibility of inter-regional migration, but not a very strong one for our purposes: 2007 census data show that more than 96 percent of the population had been living in the region where the mine is located, i.e. Cajamarca, for at least five years.

facturing composite. The uncompensated demand for each variety is

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

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

$$P(r) = G(r)^{\mu} p_a(r)^{\alpha} p_m(r)^{1-\alpha-\mu}. \tag{2}$$

Manufacture producers The local manufacturing industry uses an increasing returns to scale technology with labor as the only production factor. In particular a firm requires $l_i = F + \beta x_i$ units of labor to produce x_i units of a variety of the manufacturing good. The presence of increasing returns to scale implies that each variety is produced by a single firm. There is free entry and exit to the industry; hence. in equilibrium, manufacturing 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 (1) and w is the wage in the city. The resulting profit-maximization price is

$$p_i = \frac{\sigma}{\sigma - 1}\beta w. \tag{3}$$

Note that this result implies $p_i = p$, i.e. all varieties have the same price, since they all share the same marginal cost β. It follows that the manufacturing price index becomes $G = pv^{\frac{1}{1-\sigma}}$ and the location-specific individual demand for each variety (1) is $c(r) = \frac{\mu Y(r)}{p(r)v}$. From the zero-profit condition we obtain a firm's individual supply $x = \dfrac{F(\sigma-1)}{\beta}$ and its labor demand $l = F\sigma$.

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 total demand of labor from the agricultural sector is $2c_a f$, implying that population in the city is $L = N - 2c_a f$, and total food supply to the city is $2\,(1-\alpha)\int_0^f e^{-\tau r} d$.

Food is traded 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 $p_a(r) = p_a\ e^{-\tau|r|}$ where $|r|$ measures the distance to the city.

In contrast, the price of manufactured and import goods increase with distance because they need to be shipped from the city to rural areas. 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

$$P(r) = Pe^{(1-2\alpha)\tau|r|}. \tag{4}$$

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:[9]

$$w = \frac{p_a e^{-2(1-\alpha)\tau f}}{c_a}. \tag{5}$$

Finally, we derive total demand for manufactures and import goods from the rural hinterland. Note that a proportion μ of the local income is consumed in the manufactured good while the remaining $1 - \alpha - \mu$ is spent on imports. In the rural hinterland, the total income -distributed between landlord and workers- corresponds to the price of the agricultural output $p_{a(r)}$. Since landlords and agricultural workers share 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 manufactured good variety and import goods from the rural hinterland:

$$\text{Manufactured goods:} \quad 2\mu \frac{p_a}{pv} \int_0^f e^{-2\tau r} dr \tag{6}$$

$$\text{Imported goods:} \quad 2(1-\alpha-\mu) \frac{p_a}{p_m} \int_0^f e^{-2\tau r} dr. \tag{7}$$

Export sector There are two types of firms in the export sector: producers of a tradeable commodity and a mine that extracts the natural resource. Both use labor as their only input and sell their output in perfectly competitive external markets.

[9] Real wage equalization and the price index defined in (4), give us a nominal wage in location r equal to $w(r) = we^{(1-2\alpha)\tau|r|}$.

In contrast to the manufacturers supplying the domestic market, the commodity producers face decreasing returns to scale. In particular, their production function is $E(L_e) = L_e^{\varepsilon}$, where E is the amount produced of the commodity, L_e is the size of the workforce employed in the industry and $\varepsilon < 1$. The industry profit is $p_e E(L_e) - wL_e$, where p_e is the price of the commodity. Solving for the profit maximization problem we obtain the unconditional labor demand function:

$$\text{Labor demand: } L_e(w) = \left(\frac{\varepsilon p_e}{w}\right)^{\frac{1}{1-\varepsilon}}. \tag{8}$$

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 in the city and have similar preferences than workers.

The mine uses a fixed proportion of local labor in its production process. The demand of local labor is θS, where S is the mine's production and $\theta < 1$ is exogenously determined. Note that θ captures the extent of backward linkages between the mine and the local economy. The mine is foreign-owned and there are no taxes, hence all the profits are remitted abroad.

2.2 Equilibrium

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

$$\frac{F(\sigma-1)}{\beta} = \frac{\mu}{pv}\left(Lw + 2p_a \int_0^f e^{-2\tau r} dr + \pi_e\right) \tag{9}$$

$$2(1-\alpha)\int_0^f e^{-\tau r} dr = \frac{\alpha}{p_a}(Lw + \pi_e) \tag{10}$$

$$L = vF\sigma + L_e(w) + \theta S \tag{11}$$

$$p_e E(w) + w\theta S = (1-\alpha-\mu)\left(Lw + 2p_a \int_0^f e^{-2\tau r} dr + \pi_e\right) \tag{12}$$

Equation (9) 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 which is composed by the wages paid to city workers, agricultural income and the profits from the commodity export firms. Equation (10) is the food market equilibrium condition while equation (11) represents the equilibrium in the city's labor market. Note that the labor demand in the city comes from local manufacturers, commodity export firms and the mine. Equation (12) represents the current account's balance: in equilibrium the value of exports minus the net factor payments should be the same as the value of total imports.[10]

We solve the system analytically. First, using (11) and the population constraint $N = L + 2c_a f$ we write the number of manufacturing firms, v, as:

$$v(w,f) = \frac{N - 2c_a f - L_e(w) - \theta S}{F\sigma}. \tag{13}$$

Using this result, replacing (12) into (9) and re-arranging, we obtain:

$$N - 2c_a f - \frac{(1-\alpha-\mu)\varepsilon + \mu}{(1-\alpha-\mu)\varepsilon} L_e(w) - \frac{1-\alpha}{1-\alpha-\mu}\theta S = 0. \tag{AA}$$

Note that expression (AA) defines an upward sloping curve in the space (f, w). This curve has a positive intercept and also an upper bound $\overline{f}$ on the values that f can adopt.[11]

Second, we can rewrite the equilibrium condition in the food market (10) using (8), the wage equalization condition (5) and the population constraint. Solving for the integral over f and rearranging, we obtain:

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

This expression defines a downward sloping curve in the space (f, w), with a lower bound $\underline{f}$ on the values of f.[12]

Intuitively, the curve AA is upward sloping because with a larger rural hinterland (higher f), the city has a smaller population and hence the labor supply is smaller. This translates into higher wages in the city. In contrast, curve BB is downward sloping because higher wages in the city increase agricultural wages (due to costless intra-regional migration). In turn, this means that the marginal farmer makes losses and hence the agricultural frontier shrinks (smaller f).

To solve the model we plot curves AA and BB (see Figure 1). The intersection of both curves at point Q provides the unique pair (f^*, w^*) that solves the system and defines the equilibrium.

[10] We assume a fixed exchange rate equal to one.

[11] To see this, note that $\overline{f} \equiv \lim_{w\to\infty} f = \frac{1}{2c_a}\left(N - \frac{1-\alpha}{1-\alpha-\mu}\theta S\right)$ and that $\lim_{f\to 0} w = L_e^{-1}\left(2c_a\overline{f}\frac{(1-\alpha-\mu)\varepsilon+\mu}{(1-\alpha-\mu)\varepsilon}\right)$, where L_e^{-1} is the inverse function of $L_e(w)$.

[12] Note that $\underline{f} \equiv \lim_{w\to\infty} f = g^{-1}(N)$, where $g^{-1}(\cdot)$ is the inverse function of $g(f) \equiv 2c_a[\frac{(1-\alpha)(1-e^{-\tau f})}{\alpha e^{-2(1-\alpha)\tau f}} + f]$.

2.3 The Effects of the Mine's Expansion

We simulate the expansion of the mine as an increase on S, the amount of natural resources extracted by the mine. The immediate effect of this shock is to increase demand of labor and shift the curve AA upwards as depicted in Figure 1.

As a consequence, the equilibrium moves from point Q to $Q\prime$ with a higher wage in the city but smaller f. The reduction on f implies a smaller extension of agricultural frontier and a larger city population. Since N is assumed to be fixed, the growth of the city requires migration of agricultural workers to the city. In this model, the increase on wages -triggered by the mine expansion- is partially offset by migration to the city.

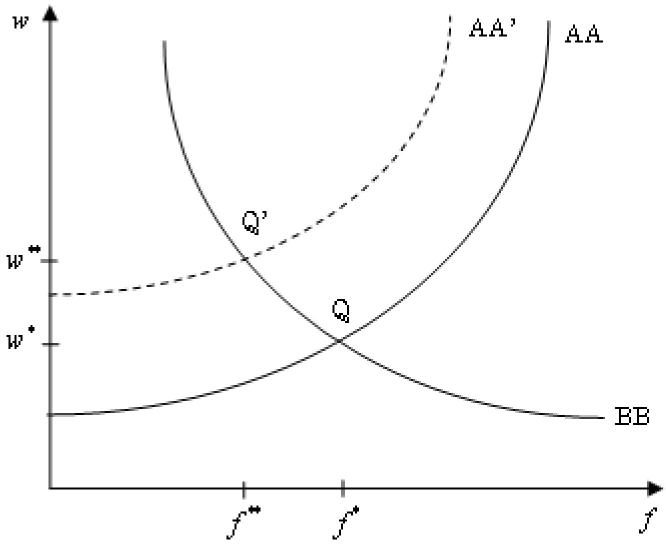

Figure 1: Model equilibrium and the expansion of the mine

Crowding out The expansion of the mine, and the subsequent wage increment, displaces other economic activities. First, the reduction on the agricultural frontier implies a smaller agricultural production. Second, the higher wage reduces the employment, output and profits of the export sector which uses labor as its only production factor. This result is similar in flavor to the "Dutch disease", commonly found in macroeconomic models of resource boom (Corden and Neary, 1982). In this case, the crowding out is driven by an increase on the relative price of a production factor.

Nonetheless, the net effect on the local manufacturing industry could be either positive or negative. On the one hand, the growth of the city population favors the increase on the number of firms, v, due to the increasing returns to scale. On the other hand, this positive effect is offset by the expansion of the mine's labor demand, which reduces the labor available for manufacturing firms.[13]

Effect on real wages From (2), we can obtain an expression for the real wage in the city:

$$\omega = \frac{w}{P} = \left(\frac{w}{G}\right)^{\mu} \left(\frac{w}{p_a}\right)^{\alpha} \left(\frac{w}{p_m}\right)^{1-\alpha-\mu}, \tag{14}$$

where $G = pv^{\frac{1}{1-\sigma}}$ and $\sigma > 1$.

Note that the wage relative to the price of food and import goods ($\frac{w}{p_a}$ and $\frac{w}{p_m}$) increases as a consequence of the expansion of the mine.[14] These results highlight two sources for real wages to increase: the increase on the payments to labor relative to land rents, due to the additional demand; and the access to relatively cheaper import goods. However, the effect on real wages is ambiguous, because these gains may be offset by higher price of manufactured goods (G), if the number of firms reduces.[15]

2.4 Testable Predictions

The previous results provide the basis for the two set of testable predictions of the model regarding the effect of the mine expansion on real income and relative prices.

2.4.1 Effect on Real Income

The income in the city and rural hinterland comes from different sources. In the city, the income is composed by wages and the dividends from export firms. In contrast, in the rural hinterland it is proportional to the value of the agricultural output $p_a(r)$. Taking that into account, we

[13]The net effect depends on the extent of the mine's backward linkages, θ. In particular, if θ is sufficiently high, v would increase, because the multiplier effect would make the city population grow enough to satisfy the additional labor demand from the mine without harming the manufacturing industry.

[14]To see this note, from (5), that $\frac{w}{p_a}$ is decreasing on f and hence increases with S. Additionally, given that the price of imports p_m is exogenously determined and w increases, $\frac{w}{p_m}$ also increases.

[15]We can, however, identify two plausible cases in which the real wage increases: when v increases, and when v decreases but local manufactures represent a small proportion of the budget (small μ).

can write the average real income in location r as:

$$y(r) = \begin{cases} \omega + \frac{\pi_e}{PL} & \text{if } r = 0 \\ \frac{1}{k}\frac{p_a}{P}\ e^{-2(1-\alpha)\tau|r|} & \text{if } r \neq 0, \end{cases} \tag{15}$$

where $y(r)$ is the average real income, P is the general price index in the city, and k is the unknown, but constant, population size in each rural locality.[16]

The effect of the mine expansion on the income of city residents is, a priori, unclear and remains an empirical question. On the one hand, it increases due to higher wages. On the other hand, it decreases due to reduction on the profit of export firms, crowded out by the mining sector, and the (potential) increase on the price of the manufactured good due to the smaller number of firms.

We focus on the case in which the real income in the city increases with the mine expansion. In this case, the model provides clear testable predictions regarding the relation between income in the city and rural hinterland, and relative prices.

Proposition 1 *If the real income of city residents increases, then the real income of rural inhabitants must also increase.*

Intuitively, the growth of urban income combined with the larger city population increases the demand for food. This demand shift, combined with the reduction on food supply due to the smaller agricultural frontier, necessarily results on an increase in the price of food and on higher income in rural locations.

To explore the effects on welfare, note that the indirect utility of a household in location r is $V(r) = \mu^\mu \alpha^\alpha (1-\mu-\alpha)^{1-\mu-\alpha} y(r)$. Hence, the real income becomes a sufficient statistic for welfare; this result, however, does not hold in presence of externalities from the mine. For that reason, in the empirical section we explore different measures of welfare in addition to real income.

In this model, the shock of demand created by the mine expansion directly affects the city's labor and goods markets. The effect is transmitted to the surrounding rural areas due to the trade links between the city and its rural hinterland. Since intra-regional trade is limited by the

[16] Recall that in each farm there are c_a workers and a landlord, but it does not correspond to the total population since a landlord can also be a worker.

existence of transportation costs, a relevant question is how the effects of the mine expansion are distributed spatially in the economic region.

Proposition 2 *When the mine expansion increases real income, the effect decreases monotonically with distance to the city.*

The model predicts heterogeneous effects by distance, because transportation costs reduce the land rents for farmers in farther locations and absorb part of the gains on real income. In the extreme, beyond the agricultural frontier, the effect is nil since there is no trade with the city. In the empirical section, we use this insight as a key element of the identification strategy. In particular, we obtain the distance from a locality to the city, and use it as a measure of different exposure of households to the mine expansion.

2.4.2 Effect on Relative Prices

The increase of real income and its transmission to agents not directly employed by the mine are driven by changes in the relative prices of labor and food. To explore this mechanism further, we use the model to obtain predictions regarding the effect of the mine expansion on relative prices within the economic region. We focus on two types of goods that are possible to identify in the data: the agricultural good and the import good.

Proposition 3 *If the real income of city residents increases due to the mine expansion, then* $\frac{p_a(r)}{P(r)}$ *also increases. The effect on* $\frac{p_m(r)}{P(r)}$ *is ambiguous.*

The relative price of food in the region increases because it is proportional to the real agricultural income. In contrast, the effect on the relative price of the import good is ambiguous since G, one of the components of the price index may increase or decrease. However, if local manufactures represent a small proportion of the consumption basket, then the relative price of imports would actually decrease due to the increase on price of food.

A corollary of Proposition 3 is:

Proposition 4 *if the real income of city residents increases due to the mine expansion, then the increase on* $y(r)$ *is greater than the increase on* $\frac{Y(r)}{p_a(r)}$*, where* $Y(r)$ *is the nominal income in location* r*.*

Note that $\frac{Y(r)}{p_a(r)} = \frac{y(r)}{p_a(r)/P(r)}$. It is straightforward to see that the change on $\frac{Y(r)}{p_a(r)}$ is smaller than the change on $y(r)$ since $\frac{p_a(r)}{P(r)}$ also increases due to the mine expansion.

This result sheds light on the transmission channel of the effect from the city to the rural hinterland. Since rural income increments are driven for higher food prices, the income relative to the price of food should not vary as consequence of the mine expansion. In the city, the increment may be positive, but still smaller than the increase on y.

3 Background

3.1 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.[17] In the late 1990s, it experienced a mining boom and the sector expanded significantly, driven by the opening and expansion of large mining operations in gold, copper and silver.

One of the largest new mines is Yanacocha, the second largest gold mine in the world, and producer of around 45 percent of Peruvian gold. The mine extracts gold from open pits and uses a capital intensive technology. All production is exported as gold lingots, with no other processing or added value. This feature precludes the creation of forward linkages. In addition, Yanacocha is privately owned and none of the investors resides locally.[18]

The mine is located in the department of Cajamarca in the North Highlands of Peru. This department is mostly rural and relatively poor.[19] The mine site is almost 50 km away from Cajamarca city, the department's capital and largest urban settlement (see Figure 3 for a map of the spatial configuration). Due to the proximity to the city, most 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. There are also other three major cities in the surroundings (Trujillo, Chiclayo and Chachapoyas) and some small and medium mines in the south of Cajamarca.[20]

[17] 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).

[18] 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.

[19] In 2006, Cajamarca was the eighth poorest department (among 24), with 63.8 percent of the population living below the poverty line (INEI, 2007).

[20] These mines use more traditional technologies, have smaller scale and are more labor intensive than Yana-

Yanacocha started operations in 1993, and its production has increased steadily over time due to the opening of new pits and the expansion of productive capacity (see Figure 2). This continuous growth has required an increasing amount of production inputs. Yanacocha procures its inputs in two ways: purchasing goods and services to suppliers, or directly hiring workers. In terms of origin, Yanacocha classifies the supplying firms as local and non-local depending of where they are registered for tax purposes and the origin of their shareholders.[21] In particular, for a firm to be considered local it has to pay taxes in Cajamarca and have at least 50 percent of Cajamarquinos among their shareholders.

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 on this trend. The mine increased employment and local procurement. As a consequence, the wage bill and amount spent on local purchases increased significantly (see Figure 2).

The increase on employment and local procurement 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.[22] 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 mine's workforce is composed by workers hired by the mine and workers employed by contractors who provide services to the mine. Workers that are hired directly by Yanacocha tend to be skilled (engineers, accountants, technicians, secretaries, assistants, supervisors) as opposed to low-skilled workers employed by contractors. The workforce size raised from 4,000 in 1997 to almost 14,000 in 2006 and represents an increasing proportion of the city workforce.[23]

Local purchases consist of relatively simple goods and services, with low quality requirements and not considered vital to the operations of the mine. The expenditure on services is larger

cocha.

[21]The non-local category includes Lima, rest of Peru, and other countries.

[22]The most important features of the mine procurement policy were: to give priority to local suppliers and workers in competitive bids and to encourage hiring o local workers.

[23]The mine's workforce represented around 12 percent of the active population of the city of Cajamarca in 2001 and 20 percent in 2005.

that the expenditure on goods.[24] The main local services contracted locally include demolition, haulage and transport of material to leach pads, and cleaning and reforestation activities. More specialized services such as transport of dangerous materials, consulting, engineering, laboratory analysis, etc., are supplied by firms located in Lima or abroad. In the case of goods, local purchases consists mostly of construction materials, basic hardware, cleaning materials, vehicles spare parts, chemical products, office furniture, etc.

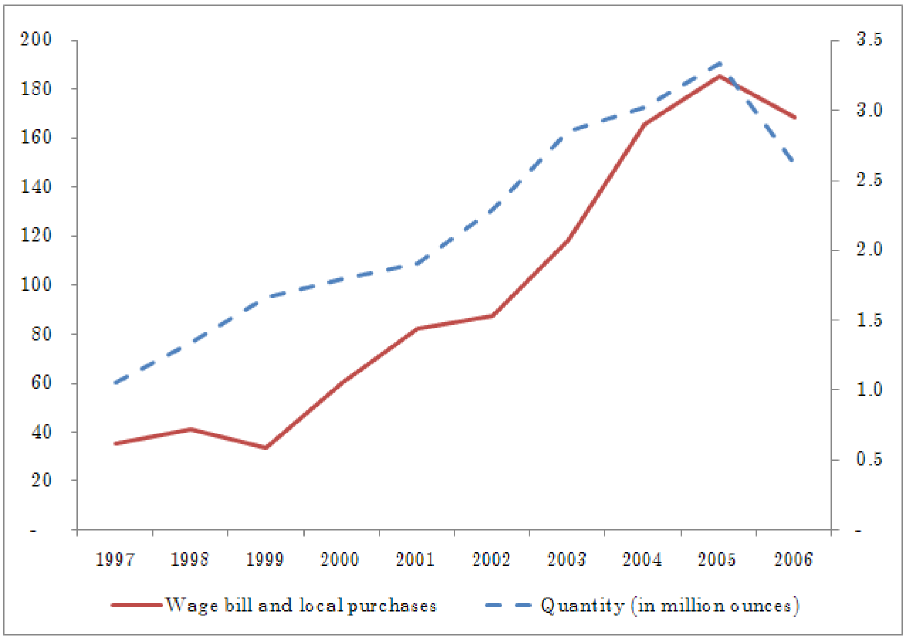

Figure 2: Evolution of Yanacocha's local procurement and production

3.2 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 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 region where the mine is located. Figure 3 shows the area of study and the spatial distribution of the sample. The darker shaded areas correspond to districts sampled at least one year, while lighter shaded ones are districts for which there are no available observations. We can see that the sample is evenly distributed

[24]For example, in 2004 the expenditure on services was around nine times greater than the expenditure on goods.

over the area of study. The data set covers 10 years, between 1997 and 2006, and includes more than 7,700 households.

Additionally, we obtain a measure of the distance from the household's location to the city. We measure distance as the length of the shortest path between the main town of the household's district and Cajamarca city using the existing road network. We performed 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.

Table 1 shows the mean of the main variables at household level. Since we use an stratified sample, the means are estimated using sampling weights. In the second column we report the standard errors of the mean estimates, which are calculated using sampling weights and clustering by primary sampling unit.

Table 1: Mean of main variables at household level

Variables	Mean N=7738	Standard error
Household head		
Years of education	4.1	0.2
Age	48.4	0.7
% female	0.129	0.021
Household		
Income per capita	143.7	10.8
Expenditure per capita	149.0	8.8
Poverty line	155.9	1.6
% poor	0.651	0.048
% extreme poor	0.374	0.040
% access to electricity	0.163	0.031
% access to water	0.616	0.054
% victim of crime	0.014	0.005
Nr. Household members	4.8	0.2
Nr. Income earners	2.0	0.1
Distance to Cajamarca city (km)	108.2	7.9

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

Firm data To measure the expansion of the mine activities, we collected data from the Yanacocha reports on the mine wage bill, value of local purchases and quantity of gold produced (Minera Yanacocha, 2006). The frequency of this data is annual and covers the period 1993 to

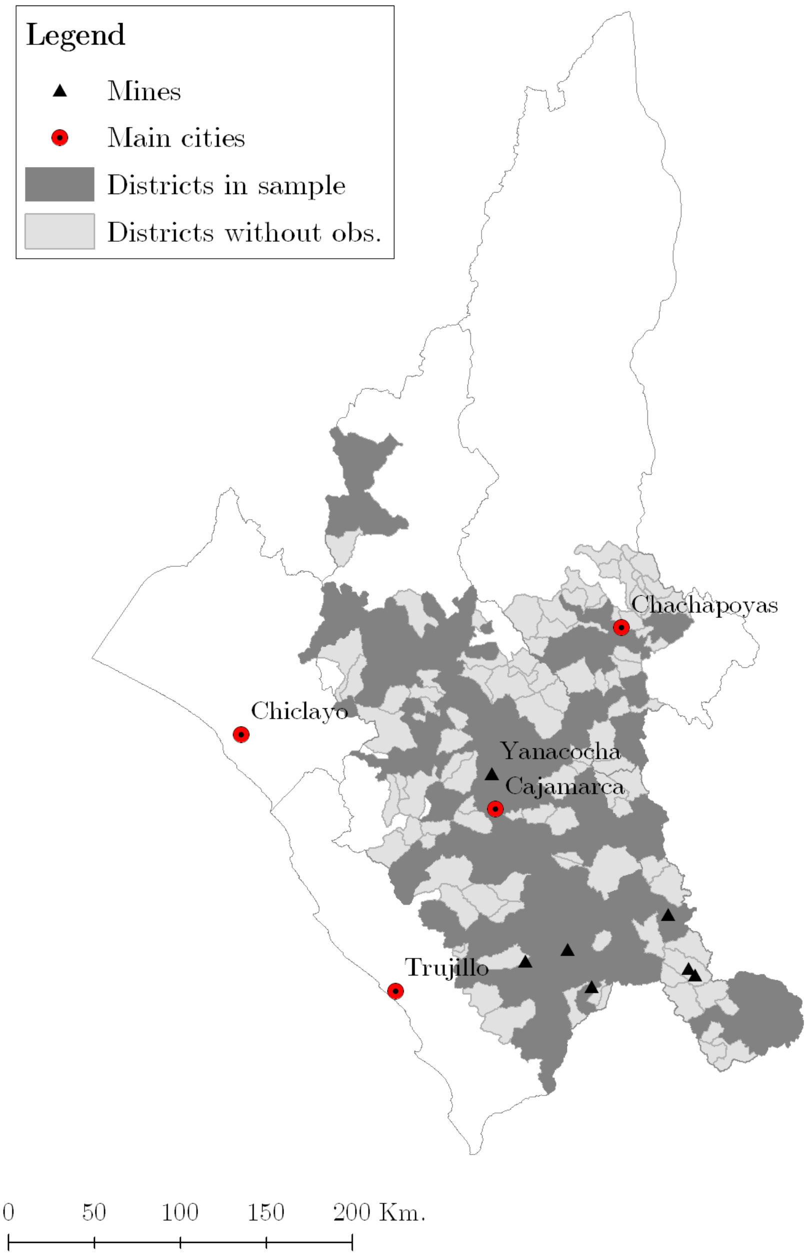

Figure 3: Area of study and spatial distribution of sample

2006. Local purchases include both 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 net wages and bonuses paid to workers directly employed by Yanacocha. 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.

Municipality data We complement the household and firm data with data at municipality level.[25] Municipalities are the lowest tier of autonomous local government with jurisdiction over districts. We use this administrative unit to calculate the distance from the city to the households.

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 dataset includes information on 179 municipalities over the period 1998 to 2006.

Our dataset 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. The expenditure is also divided between capital and current expenditures. This is a relevant distinction since the mining transfers are earmarked to capital expenditures, and hence we can expect a relative increase of this category of expenditure.[26]

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 next periods. In the period of analysis, capital expenditures represented around 40 percent of total expenditures, while mining transfers represented 12 percent of total revenue.

[25]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.

[26]Capital expenditures include mainly the investment on infrastructure projects.

Table 2: Summary statistics of firm and municipality data

Variables	Mean	Standard deviation
A. Firm data		
Wage bill	55.5	33.9
Local purchases	42.3	27.7
Gold production	2.18	0.76
% local purchases	0.12	0.05
B. Municipality data		
Total revenue	3.53	8.20
Mining transfer	0.41	2.08
Total expenditure	2.96	6.52
Capital expenditure	1.26	2.42

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.

3.3 Identification strategy

The aim of the empirical exercise is to evaluate the effect of the mine expansion on real income, relative prices and measures of welfare.[27] To do that, we exploit two sources of variation. First, we use the significant increase on Yanacocha's wage bill and local purchases 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 use distance to the city as a measure of heterogeneous exposure to the mine expansion. As predicted by the model, we expect the effect on real income, if positive, to decrease with distance to the city due to transportation costs. At a large enough distance, the effect should become insignificant because there is no economic interaction between those locations and the city. This prediction suggest that we could use households living in areas farther from the city as a control group of households living in areas closer to it. In the sample, the distance ranges from 0 to 400 km with an average value of around 100 km. In the main specification, we use this threshold to divide the districts in two categories (far and close to the city).

Our identification strategy is basically a difference in difference, with the expansion of the mine being the treatment and the distance to the city defining the exposure to that treatment.

[27] We provide more details about the measures of welfare and the rationale for using them in the next section.

The underlying identification assumption is that the evolution of the outcome variables in areas close and far from the city would have been similar in the absence of the mine expansion.

Figure 4 illustrates the basic idea behind the identification strategy. It plots the conditional mean of real income per capita for households located in districts within 100 km from the city and those further away.[28] 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 6.

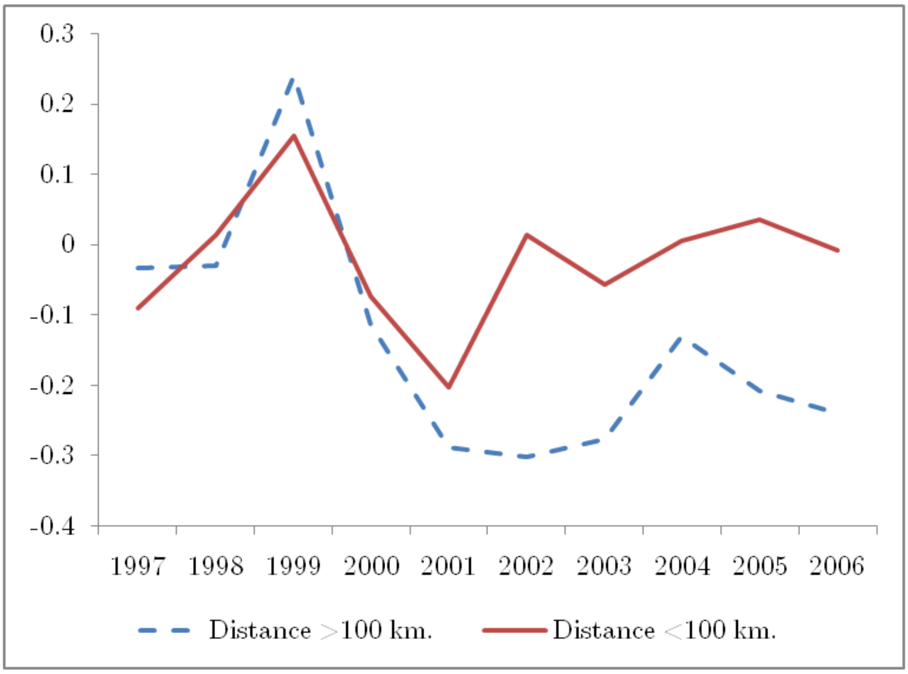

Figure 4: Conditional mean of real income

To formally evaluate the effect of the mine expansion on real income, relative prices and

[28]The mean is conditional on schooling, age and gender of the household head, access to water and electricity, number of household members and number of income earners.

measures of welfare, we estimate the following regression:

$$\ln y_{hdt} = \alpha_d + \eta_t + \beta(\ln M_t \times D_d) + \mathbf{X}_{hdt}\gamma + \varepsilon_{hdt}, \tag{16}$$

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 a measure of welfare. To obtain relatives values we use as a deflator the value of the poverty line.[29] 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 value of the mine's wage bill and local purchases, but we also check the robustness of the results using alternative measures such as the value of local purchases or quantity of gold produced. D_d is the measure of distance. In most specifications it is a dummy equal to one if the district where the household lives is within 100 km of Cajamarca city, and zero otherwise. However, we also use more flexible definitions, such as an spline or the continuous measure. In this specification, the parameter of interest is β which captures the effect of the mine expansion.

All regressions include year (η_t) and district (α_d) fixed effects, and a vector of time-varying control variables, $\mathbf{X}_{hdt}$. 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.[30] We cluster the errors at this level to account for spatial correlation of households exposed to similar shocks and market conditions, or surveyed simultaneously.

4 Main Results

The model highlights a market channel for an extractive industry to affect a regional economy. The mechanism resembles the classical multiplier effect, with growth in the mining industry creating ripple effects in other sectors of the economy. In this view, the mine expansion increases the demand for local labor. This demand shock increases wages and may also increase real income in the city. In turn, this income effect increases demand, and price, of local food which translates into higher rural income. The effect, however, decreases with distance to the city due

[29]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.

[30]See Magee et al. (1998) for a discussion on the use of sample weights with complex survey data.

to transportation costs.

In this section, we first evaluate the model predictions regarding the effect on real income and relative price of local food crops. Then, we explore the effect on welfare and the re-distributional effects of the mine expansion.

4.1 Effect on Real Income

Columns (1) and (2) of Table 3 show the estimates of β using the baseline specification (16) with different measures of the mine activity. Panel A uses the value of the mine wage bill and local purchases as a measure of mine activity, while panel B uses the value of the mine local purchases only. In column (1) we use the full set of control variables including characteristics of the household head such as education, age, gender and dummies indicating the industry of occupation and type of job (e.g. independent worker, employee, wage worker, etc.). It also includes household characteristics like access to water, electricity and number of household members and income earners. In column (2) we use a more parsimonious specification with only the household head's schooling, age and industry of occupation.

In all the cases, the estimates of β, the change on real income associated to the mine expansion, are positive and significant. The results are not sensitive to different measures of the mine activity or alternative set of control variables.[31] In what follows, we use the mine wage bill and local purchases as our preferred measure of the mine activity because it relates, more closely, to the mine's demand of local inputs.[32]

Under the assumption that the evolution of income in locations far and closer to the city would have been similar in the absence of Yanacocha, we can interpret these results as the evidence of a positive effect of the mine on real income. The magnitude of the effect is economically significant: the smallest estimate using the full specification 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.

The model predicts that the effect of the mine expansion on real income decreases with

[31] We also use real expenditure per capita as a dependent variable. The results, not reported, are similar.

[32] We also estimated the baseline regression using the quantity of gold produced as an instrument for the mine's wage bill and local purchases and obtained similar results. The results are available upon request.

Table 3: Effect of Yanacocha's expansion on real income per capita

	Ln(real income per capita)			
	(1)	(2)	(3)	(4)
A. Measure of mine activity = mine's wage bill and local purchases				
Mine activity	0.174**	0.161*		
× distance < 100 km	(0.078)	(0.088)		
Mine activity			-0.128**	-0.102
× continuous distance			(0.062)	(0.064)
R-squared	0.521	0.349	0.521	0.348
B. Measure of mine activity = mine's local purchases				
Mine activity	0.215**	0.188*		
× distance < 100 km	(0.091)	(0.101)		
Mine activity			-0.151**	-0.119*
× continuous distance			(0.060)	(0.064)
R-squared	0.523	0.35	0.522	0.349
Observations	7738	7738	7738	7738
Full set of controls	yes	no	yes	no

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 full set of control variables includes: 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. Columns (2) and (4) use a smaller set of controls: household heads' schooling, age and dummies of her industry of occupation. Columns (3) and (4) use a measure of continuous distance expressed in hundreds of kilometers.

distance. This heterogenous response justifies the use of households far from the city as controls for households closer to the city. To test this hypothesis, we present two additional specifications. 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 (16) with the full set of controls, using the mine wage bill and local purchases as measure of the mine activity interacted with each of the distance dummies.

Figure 5 shows the estimates of β 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 provide the basis for using a dummy variable of distance and reduces concerns about the observed average effect being driven exclusively by city residents.[33]

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 columns (3) and (4) of Table 3. Note that in almost all the cases, the estimated parameter is negative and significant. Taken together, these results are consistent with the model prediction that the effect decreases with distance.[34]

4.2 Effect on Relative Prices

The model predicts an increase in the relative price of locally produced food as a consequence of the demand shock initiated by the mine activities. This price increment transmits the effect to rural agricultural producers, who do not participate directly in the city's labor market. In contrast, the model is mute regarding the effect on the relative price of imported goods. Their relative price may increase or decrease (see Proposition 3).

To test this prediction, 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

[33]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.

[34]Results are robust to the use of alternative measures of distance and non-linearities.

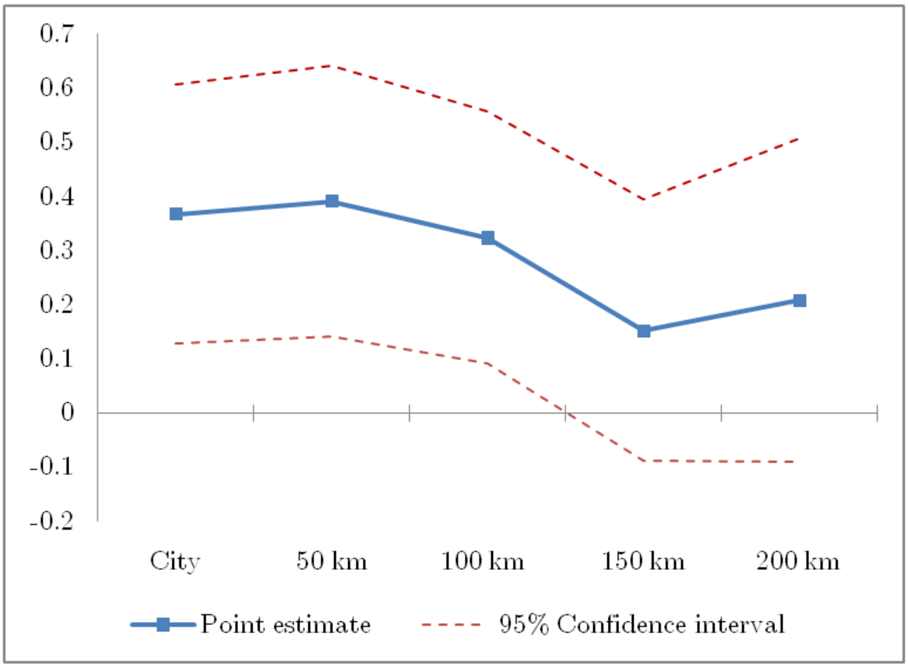

Figure 5: Effect of Yanacocha's wage bill and local purchases on household income, by distance to Cajamarca city

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.[35]

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.[36] The producer prices and unit values are then divided by the value of the poverty line to obtain measures of relative prices. Then, we estimate the baseline regression (16) 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).

Table 4 presents 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

[35]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.

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

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.[37]

Table 4: Effect of mine expansion on price of local goods

	Ln relative price of:			
	Potatoes		Maize	
	(1)	(2)	(3)	(4)
Mine's wage bill and local purchases × distance < 100 km	0.128*	0.084*	-0.026	0.110***
	(0.074)	(0.050)	(0.082)	(0.038)
Prices reported by:	producer	consumer	producer	consumer
Real income per capita	no	yes	no	yes
Observations	3407	4072	4253	4000
R-squared	0.417	0.524	0.374	0.19

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. Columns (1) and (3) do not include any additional control variable. Columns (2) and (4) include ln(real income per capita) as control variable.

The model provides an alternative way to evaluate this change on relative prices. In particular, it predicts that the increase on income deflated by the price of local crops is smaller than the increase on income deflated by a more general price index (Proposition 4). The main reason is that the increase on rural income is mostly driven by changes on food prices. Hence, there should be a small or negligible increase of the purchasing power in term of local food.

To test this prediction, we re-estimate the baseline regression (16), using the unit value of potatoes and maize as deflators of nominal income. In both cases, we take the mean unit value in each primary sampling unit to reduce measurement errors and obtain better proxies of the underlying prices.

Table 5 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. Column (3) displays the baseline

[37] We replicated this exercise using unit values of food stuff less likely to be locally produced such as rice, sugar, cooking oil and canned fish. In contrast to the case of local crops, the effect of the mine on relative prices is negative or insignificant.

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.

Taken together, these results support the argument that the change of relative prices is a channel to transmit the effect of the mine from the city to the surrounding areas.

Table 5: Effect of mine expansion on real income, using alternative price deflators

	Ln(relative income per capita)		
	(1)	(2)	(3)
Mine's wage bill and local purchases × distance <100 km	0.137 (0.091)	0.115 (0.091)	0.174** (0.078)
Deflator of nominal income	unit value of potatoes	unit value of maize	poverty line
Observations	7132	7089	7738
R-squared	0.562	0.525	0.521

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.

4.3 Effect on Welfare

We have shown that the mine has had a positive effect on real income. In the presence of negative externalities, however, higher income may not necessarily increase household welfare. The negative effects of the mine may offset the benefits of having a higher income and leave households neither better or worse off. In that case, higher wages would just compensate for the mine negative externalities.[38]

We evaluate the effect on household welfare in two steps. First, we treat the mine as an amenity and apply the analytical framework developed by Roback (1982) that suggests using changes on housing prices as a measure of net welfare effects. Second, we evaluate changes on indicators of negative spillovers -such as incidence of health problems and crime.

[38] For example, the mine may have increased the actual, or expected, levels of pollution or environmental degradation with negative effects on health. Similarly, the influx of new population and growth of the city may be linked to increase on criminal activity or anti-social behavior. There is anecdotal evidence of concerns among the population about the risk of water pollution due to the use of highly toxic chemicals in the mine, and discomfort associated to the perceived increase on prostitution and crime (Pascó-Font et al., 2001, p. 156).

4.3.1 The Mine as an Amenity

Using the simplest version of the model in Roback (1982), the mine can be studied as an amenity that generates locational externalities (positive or negative). In this setup, the economy has a fixed supply of land and costless migration. These features guarantee that workers move to locations where they can obtain higher utility and that the price of land captures the welfare gains. A particularly useful implication of this model is that property prices become sufficient statistics for household welfare. In particular, higher property prices would suggest an increase of welfare for landowners.[39]

To explore these questions, we use data from the household survey on self-reported house rents. This variable was obtained asking home owners about the minimum price they would require for renting their property.[40] We calculate a proxy for relative land rents dividing the reported house rents by the value of the poverty line.

Then, we estimate the baseline regression (16) with the logarithm of the relative house rent as dependent variable. In addition to year and fixed effects, the regression includes controls for observable house characteristics that may affect the property value such as type of urban settlement, construction materials (walls and floor), number of rooms and access to utilities (water, sewage, electricity and telephone). We also include household socioeconomic variables - like schooling, age and gender of the household head and number of members and income earners - to account for systematic biases in the report of rental price.[41]

Table 6 displays the results using different sets of control variables. Column (1) includes only house characteristics while column (2) runs the complete specification with socio-economic controls. In both cases, we find evidence of a positive relation between the mine activity and house rents. The magnitude of the effect is significant, with an estimated elasticity of 0.24. This evidence is consistent with the mine activities having a positive net effect on household welfare.

[39] For an example of an empirical application see Greenstone and Moretti (2003).

[40] We did no use actual rent prices due to the small number of observations. In the sample, only 6 percent of households live in rented accommodation.

[41] This empirical specification corresponds to the hedonic regression, a widely used method to assess the value of environmental amenities. See Black (1999) and Greenstone and Gallagher (2008) for examples of empirical applications.

Table 6: Effect of mine expansion on house rents

	Ln (relative value of house rent)	
	(1)	(2)
Mine's wage bill and local purchases × distance < 100 km	0.250**	0.238**
	(0.095)	(0.092)
House characteristics	yes	yes
Socio-economic controls	no	yes
Observations	7699	7696
R-squared	0.635	0.650

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. Column (1) include as additional controls only house characteristics such as type of urban settlement, construction materials (walls and floor), number of rooms and access to utilities (water, sewage, electricity and phone landline). Column (2) adds socio-economic characteristics of the household such as schooling, age and gender of the household head and number of household members and income earners.

4.3.2 Health and Crime

A main limitation of the previous analysis is that the self-reported rental prices may fail to fully capture the net effect on household welfare. This may happen, for example, if self-reported rental prices are biased or if individuals lack information regarding the negative effects associated to the mine.

To address this issue, we test directly for the presence of some negative effects on health or crime 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.[42] Then, we use these dummies as the dependent variables in the baseline regression (16) 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.

Table 7 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

[42]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?".

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 us about the perceived level of crime but may fail to account for other forms of social disorder or crimes within the household.

Table 7: Yanacocha's expansion and measures of health, crime and poverty

	Health problems		Crime	Poor	Extreme poor
	(1)	(2)	(3)	(4)	(5)
Mine's wage bill and local purchases × distance < 100 km	-0.087***	-0.008	0.001	-0.107***	-0.075**
	(0.039)	(0.057)	(0.008)	(0.036)	(0.056)
Sample	all individuals	children age <5	households	households	households
Observations	39674	4189	6663	7738	7738
R-squared	0.076	0.157	0.048	0.406	0.3572

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. Columns (3) to (5) use similar controls but exclude individuals' age and sex.

4.4 Distributional Impacts

The previous results are only informative of the effect of the mine expansion on the income, and welfare, of the average household. They do not tell us, however, whether the operations of the mine have reduced poverty or whether the effects were distributed evenly across different income groups.

We address these questions in two steps. First, we evaluate the effect of the mine expansion on measures of poverty. To do so, we estimate the baseline regression (16) using as dependent variables dummies indicating whether a household is poor or extreme poor.[43] Columns (4) and (5) in Table 7 displays the results using a linear probability model. Note that the mine expansion is associated to reductions on the probability of being poor or extreme poor.

Second, we explore the distributional impact of the mine expansion using quantile regressions to estimate the effect of the mine on real income at different points of the conditional income distribution.[44] The model specification is the same as the baseline regression (16), but the estimator does not use the sampling weights nor cluster the errors by primary sampling unit.

Figure 6 plots the estimates of β -the effect of the mine expansion on real income- and the confidence interval at 95 percent at different quantile values. The estimated parameter is positive and significant for all quantiles except for the top 20 percent. These results suggest 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.[45]

Taken together, these results support the argument that the increase of income associated to the mine expansion did not have a negative redistributive effect. Most of the beneficiaries are households with low and middle income. Moreover, the increase of income was large enough to reduce poverty.

[43]The difference between these two categories is the definition of the minimum consumption basket, which is more restrictive for the case of extreme poor. In the sample, 65.2 percent of households are poor, while 37.4 percent are classified as extreme poor.

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

[45]There are several possible explanations for the lack of effect among top earners: use of poverty line as a price deflator, lower migration cost of skilled workers or labor demand biased toward low skilled workers.

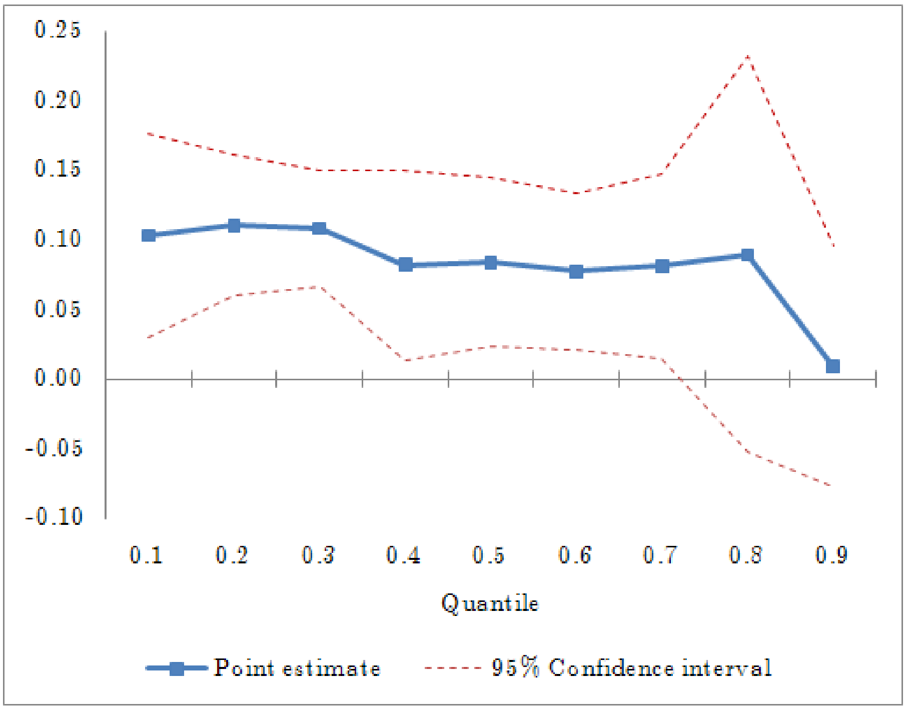

Figure 6: Effect of Yanacocha's wage bill and local purchases on household income, by quantile

5 Alternative explanations

In addition to local purchases and employment, there are at least two other channels through which Yanacocha's activities might have affected the regional economy: a revenue windfall to local governments and direct transfers to local groups such as miners, public workers or residents of communities in the mine surroundings.

5.1 Fiscal Revenue Windfall

Local governments receive a transfer from the central government, funded with the taxes paid by the mine. In particular, 50 percent of the corporate tax paid by the mine is distributed to local governments in the region.[46] This mining transfer (called *canon minero*) is allocated according to a formula established by law, that takes into account location of the mine pits, population, density and poverty incidence.

This source of local revenue grew in the last years following the expansion of the mine operations and represented a substantial revenue windfall for local governments. For example,

[46]Mining firms also pay fees for operational rights (derecho de vigencia) which is distributed to the local government where the mine pits are. The total fee is proportional to the extension of the mining operation, regardless of actual production. Its magnitude is much smaller than the *canon minero*.

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 percent to 25 percent.

This revenue windfall may explain the observed relation between the mine expansion and real income. For example, the additional revenue could have increased public spending and demand of local inputs. Similarly, better public good provision could have enhanced household welfare, and contributed to the increase in housing rents.[47]

In order to understand the mechanism driving the results, we evaluate whether the effects on real income and welfare are driven by a fiscal channel (additional public spending) or by a market channel (mine's demand of local inputs). To do so, we re-estimate the baseline results on the effect on real income including, as an additional control, the logarithm of the municipal revenue or expenditure of the district 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.

Table 8 reports the results. Columns (1) and (2) use two measures of municipal revenue: the amount received as mining transfer and the total revenue. Columns (3) and (4) uses instead measures of total expenditure and capital expenditures. The difference in the sample size respect to the baseline regressions is due to the lack of observations on municipal budgets for 1997.

Note that in all cases the effect of the mine expansion on real income remains positive and significant. The estimates are similar in magnitude to the results without municipality control variables. In contrast, the effect of municipality's revenue or expenditure is insignificant or even negative.[48] 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 and welfare 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.[49] An alternative explanation is that public spending increased well being (through better public good provision) but did not affect income.

[47] We check that the expansion of the mining transfer is associated with an increased of total revenue and total spending.

[48] We also replicate this exercise using relative value of house rents as dependant variable, and including the measure of mine expansion interacted with distance. The results, not reported, are similar.

[49] 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.

However, the lack of positive effect on house rents does not support this argument. Finally, it could be that the additional public spending had very small social returns.[50] 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. However they find no evidence of a positive effect on local income. They interpret this result as suggestive that the additional revenue was wasted if not stolen.

Table 8: Effect of the mine on real income, controlling for municipal revenue or expenditure

	Ln(real income per capita)			
	(1)	(2)	(3)	(4)
Mine's wage bill and local purchases × distance < 100 km	0.175**	0.180*	0.164*	0.164*
	(0.083)	(0.094)	(0.089)	(0.089)
Municipal revenue or expenditure	-0.025	-0.142	0.045	0.045
	(0.209)	(0.093)	(0.126)	(0.126)
Observations	7738	6305	6305	6305
R-squared	0.521	0.536	0.536	0.536
Municipal revenue or expenditure	Mining transfers	Total revenue	Total expenditure	Capital expenditure

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 expenditure or revenue and mine wage bill and local purchases are expressed as logarithms of the total amount.

5.2 Direct Beneficiaries

There are three groups of individuals that might have benefited directly from the mine expansion: residents of communities located around the mine pits, mine workers, and public sector workers.[51]

[50] Anecdotal evidence suggests that some recipients of mining transfers embarked in unproductive projects such as refurbishing the town main square or erecting monuments.

[51] Local residents may have benefitted from development projects funded by the mine. Mine workers receive a salary higher than the average in the region. Finally, public workers may have benefitted if the revenue windfall from the mine was redistributed as in-kind benefits or higher wages.

A relevant concern is that the observed effect on the average real income may be just driven by the positive effect of local development projects or higher wages received by mine workers or public servants, not by the multiplier effect highlighted in the model.

To check this possibility, we use data on the industry of occupation reported by employed individuals and identify workers in mining and public service.[52] We classify education workers as part of the public sector given that most teachers are in the government payroll. Additionally, we identify households living in the same districts where the towns targeted by Yanacocha's development projects are located. We consider these groups to be a broader definition of potential direct beneficiaries of the mine activities. In our sample, these households represent around 15 percent of total observations. Then we re-estimate the regressions of the effect on real income and welfare excluding these three groups of households.

Table 9 displays the results using real income as the dependent variable. Column (1) presents the baseline results with the whole sample. Columns (2) to (4) gradually reduce the sample excluding public sector workers, mining workers and households living adjacent to the mine. Note that in all the cases the results are similar to the obtained with the whole sample. This evidence suggests that the observed effects on income and welfare are not driven by groups that may receive direct benefits from the mine, and supports the claim that the main driver is the multiplier effect from the mine's demand shock.[53]

[52]The survey reports the 2-digit International Standard Industry Code of the main activity of working individuals.

[53]We are unable to evaluate in a reliable manner the effect among direct beneficiaries due to the small size of the sample.

Table 9: Effect on households not directly employed by public sector, mining industry or living adjacent to the mine

	Ln(real income per capita)			
	(1)	(2)	(3)	(4)
Mine's wage bill and local purchases × distance < 100 km	0.174**	0.198**	0.186**	0.187**
	(0.078)	(0.085)	(0.086)	(0.087)
Observations	7738	6796	6668	6570
R-squared	0.521	0.484	0.478	0.479
Public sector workers	yes	no	no	no
Mining workers	yes	yes	no	no
Live in district adjacent to mine pits	yes	yes	yes	no

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).

6 Additional Checks

In this section we present additional checks on the validity of the previous results. We are particularly interested on confounding factors that may violate the identification assumption, compositional effects driven by migration within the region and the sensitivity of the results to alternative measures of distance.

We focus on the baseline regression exploring the effect of the mine on real income. We also perform similar checks on the set of results on local crop prices and house rents and reach similar conclusions. These additional checks are not reported, but are available from the authors upon request.

6.1 Confounding Factors

A main concern is that, simultaneous to the expansion of the mine, there may be other phenomena 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. We are particularly concerned with heterogenous trends driven by different initial conditions or by proximity to a city.

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. In the main specification, this is dealt with by using district fixed effects and controlling for household characteristics. However, these different initial conditions 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), population density (1 if the population density of the district where the household lives is above the median).

Table 10 shows the results of this robustness check using real income as dependant variable.[54] In all cases, the estimates of the effect of the mine on real income are similar to those found in the baseline regression.

Table 10: Effect of the mine on real income, controlling by heterogenous trends

	Ln (real income per capita)		
	(1)	(2)	(3))
Mine's wage bill and local purchases × distance < 100 km	0.168** (0.079)	0.177** (0.080)	0.184** (0.075)
Year dummies × urban	yes	yes	yes
Year dummies × farmer	no	yes	yes
Year dummies × high density	no	no	yes
Observations	7738	7738	7738
R-squared	0.526	0.532	0.537

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 may be, however, unobservable shocks contemporaneous to

[54]The results are similar using other dependant variables studied in the main results.

the mine expansion that affect differently areas close or far from the 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.[55] 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 city-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 3 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 11 displays the results of the falsification test 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.[56] In all cases the effect of mine wages and purchases becomes insignificant or even negative. The lack of effect on this falsification exercise weakens the case of some confounding factor driving the results.

6.2 Migration and Compositional Effects

The model predicts an increase on city size due to intra-regional migration. In the model, the increase on labor demand and wages in the city attracts agricultural workers. To explore this model prediction, 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.[57]

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

[55] We also estimate the baseline regressions with distance to Cajamarca city adding proximity to other cities as additional control variables. The results, not reported, are similar to the baseline regressions.

[56] The results are similar using larger areas of influence, e.g. 400 km

[57] This extension corresponds to the range of distances observed in the data.

Table 11: Falsification test using distance to other cities

	Ln(real income per capita)		
	(1)	(2)	(3)
Panel A: North Highlands sample			
Mine's wage bill and local purchases × distance < 100 km	-0.188	-0.066	-0.136
	(0.142)	(0.169)	(0.157)
Observations	7738	7738	7738
R-squared	0.521	0.521	0.521
Panel B: Households within 200 km			
Mine's wage bill and local purchases × distance < 100 km	-0.058	0.000	-0.077*
	(0.063)	(0.050)	(0.044)
Observations	6978	10801	12073
R-squared	0.552	0.536	0.604
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) grew at a much slower pace, below the regional average. Interestingly, the growth rate decreases with distance to the city.[58]

Taken together, this evidence is suggestive of migration from the rural hinterland to the city, as predicted by the model.[59] 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 productive agricultural workers migrate to the city, the increase on real income would be driven by higher productivity not by the demand shock from the mine.

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.[60] In particular we focus on different measures of human capital such as years of education, an indicator of having completed primary school and age.[61] We also explore characteristics of the agricultural unit such number and concentration of crops. In all cases, we estimate the baseline regression (16) with year and district fixed effect as the only control variables.

Table 12 shows the results. The parameter associated to the interaction term captures the changes on the measure of human capital or agricultural activity in areas closer to the city associated to the expansion of the mine. Note that all the measures of education (columns 1 to 2) worsen in areas closer to the city, but there are not significant changes in the other observable characteristics. 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 due to the migration of relatively less educated workers from the rural hinterland to the city.[62]

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

[58]A possible explanation consistent with this observation is that migration costs are increasing with distance.

[59]Nonetheless, we cannot interpret it as evidence of the mine expansion causing migration because, among other reasons, we do not know whether migration occurred before or after the expansion of the mine.

[60]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.

[61]In the baseline regressions we control for education. However, this control may be insufficient to account for compositional changes in the presence of human capital spillovers or complementarities.

[62]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

	Years of education (1)	Complete primary (2)	Age (1)	Number of crops (2)	Crop HH index (3)
Mine wage bill and local purchases × distance 100 km	-0.684**	-0.059*	-0.648	-0.153	0.015
	(0.322)	(0.031)	(0.835)	(0.287)	(0.036)
Observations	31255	31255	34507	5582	5582
R-squared	0.106	0.064	0.023	0.311	0.228

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 a dummy equal to 1 if individual completed primary school. Crop concentration is the Herfindahl-Hirschman concentration index calculated as the sum of squares of the contribution of a crop to total agricultural production.

7 Conclusion

This paper investigates the effect of a large mine on a regional economy using the analytical framework provided by a spatial general equilibrium model. We find robust evidence that the mine has generated positive income and net welfare gains for residents in the city and in the surrounding rural hinterland.

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 city formation. Though beyond the scope of this paper, these phenomena warrants 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 of the pre-existence of good and labor markets o 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 inter-regional trade, the benefits would disappear since the increase on good prices could offset the gains on nominal income or could be restricted to the place where the mine is located.

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. However, as this paper suggests, in the presence of strong enough backward linkages natural resources can be more a blessing than a curse.

References

Benjamin, Nancy C., Shantayanan Devarajan, and Robert J. Weiner, "The 'Dutch' disease in a developing country : Oil reserves in Cameroon," *Journal of Development Economics*, January 1989, *30* (1), 71–92.

Black, Dan, Terra McKinnish, and Seth Sanders, "The Economic Impact of the Coal Boom and Bust," *Economic Journal*, April 2005, *115* (503), 449–476.

Black, Sandra E., "Do Better Schools Matter? Parental Valuation of Elementary Education," *Quarterly Journal of Economics*, 1999, *114* (2), 577–599.

Carrington, William J, "The Alaskan Labor Market during the Pipeline Era," *Journal of Political Economy*, February 1996, *104* (1), 186–218.

Caselli, Francesco, "Power Struggles and the Natural Resource Curse," 2006.

——— **and Guy Michaels**, "Do Oil Windfalls Improve Living Standards? Evidence from Brazil," June 2009.

Corden, W. Max and J. Peter Neary, "Booming Sector and De-Industrialisation in a Small Open Economy," *The Economic Journal*, 1982, *92* (368), 825–848.

Deaton, Angus, *The Analysis of Household Surveys: A Microeconometric Approach to Development Policy*, John Hopkins University Press for The World Bank, 1997.

Evans, William N. and Julie H. Topoleski, "The Social and Economic Impact of Native American Casinos," NBER Working Papers 9198, National Bureau of Economic Research September 2002.

Frankel, Jeffrey A., "The Natural Resource Curse: A Survey," NBER Working Paper 15836, NBER 2010.

Fujita, Masahisa and Paul Krugman, "When is the economy monocentric?: von Thünen and Chamberlin unified," *Regional Science and Urban Economics*, August 1995, *25* (4), 505–528.

Greenstone, Michael and Enrico Moretti, "Bidding for Industrial Plants: Does Winning a 'Million Dollar Plant' Increase Welfare?," NBER Working Papers 9844, National Bureau of Economic Research, Inc July 2003.

—— **and Justin Gallagher**, "Does Hazardous Waste Matter? Evidence from the Housing Market and the Superfund Program," *Quarterly Journal of Economics*, 2008, *123* (3), 951–1003.

Hirschman, Albert O., *The Strategy of Economic Development*, Yale University Press, 1958.

Hooker, Mark A and Michael M Knetter, "Measuring the Economic Effects of Military Base Closures," *Economic Inquiry*, October 2001, *39* (4), 583–98.

Humphreys, David, "Emerging Players in Global Mining," Extractive Industries and Development Series 5, The World Bank June 2009.

INEI, "Perú: Perfil de la Pobreza según departamentos 2004-2006," 2007.

Jenkins, Beth, Anna Akhalkatsi, Brad Roberts, and Amanda Gardiner, "Business Linkages: Lessons, Opportunities and Challenges," Technical Report, IFC, International Business Leaders Forum, and the Fellows of Harvard College 2007.

Koenker, Roger and Kevin F. Hallock, "Quantile Regression," *Journal of Economic Perspectives*, Fall 2001, *15* (4), 143–156.

Kuramoto, Juana R., "Las aglomeraciones productivas alrededor de la minera: el caso de la minera Yanacocha S.A," Documentos de Trabajo 27, Grupo de Análisis para el Desarrollo (GRADE) July 1999.

Lederman, Daniel and William F. Maloney, "Trade structure and growth," Policy Research Working Paper Series 3025, The World Bank April 2003.

Magee, L., A. L. Robb, and J. B. Burbidge, "On the use of sampling weights when estimating regression models with survey data," *Journal of Econometrics*, June 1998, *84* (2), 251–271.

Michaels, Guy, "The Long-Term Consequences of Regional Specialization," CEPR Discussion Papers 6028, CEPR Discussion Papers December 2006.

Minera Yanacocha, "Balance Social y Ambiental," 2006.

Ministerio de Energía y Minas, "Anuario Minero," 2006.

Pascó-Font, Alberto, Alejandro Diez Hurtado, Gerardo Damonte, Ricardo Fort, and Guillermo Salas, "Chapter 4. Peru: Learning by Doing," in Gary McMahon and Felix Remy, eds., *Large Mines and the Community: Socioeconomic and Environmental Effects in Latin America, Canada and Spain*, The World Bank, 2001.

Roback, Jennifer, "Wages, Rents, and the Quality of Life," *Journal of Political Economy*, December 1982, *90* (6), 1257–78.

Sachs, Jeffrey D. and Andrew M. Warner, "Natural Resource Abundance and Economic Growth," NBER Working Papers 5398, National Bureau of Economic Research, Inc December 1995.

___ **and** ___ , "The big push, natural resource booms and growth," *Journal of Development Economics*, June 1999, *59* (1), 43–76.

___ **and** ___ , "The curse of natural resources," *European Economic Review*, May 2001, *45* (4-6), 827–838.

Sala-i-Martin, Xavier, Gernot Doppelhofer, and Ronald I. Miller, "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review*, September 2004, *94* (4), 813–835.

Torvik, Ragnar, "Natural resources, rent seeking and welfare," *Journal of Development Economics*, April 2002, *67* (2), 455–470.

World Bank, "A Sourcebook for Poverty Reduction Strategies: Mining," 2002.

NOT FOR PUBLICATION

A Proofs

A.1 Existence of equilibrium

Assumption 5 $N > \frac{1-\alpha}{1-\alpha-\mu}\theta S$

This assumption means that the share of employment from the mine is small enough relative to the total population in the region. To check how reasonable this assumption is, note that we can re-write it as $\mu < (1-\alpha)\left(1-\frac{\theta S}{N}\right)$, where α is the consumer's budget share of locally produced food, μ 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 α.The estimated budget share is 0.6, however note that this measure may overestimate the true value of α since some of the food is not locally produced. Regarding $\frac{\theta S}{N}$, recall from Section 3 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 μ 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.[63]

Proposition 6 *Under Assumption 5, 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 $L_e(w)$ and plug it in equilibrium condition (AA). We then obtain an expression of f only that can be expressed as

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

[63] Note that the overestimation of α and $\frac{\theta S}{N}$ mean that the threshold that μ should exceed to violate assumption 1 are understated. Hence, violation of assumption 1 requires an even higher μ, and smaller budget share of imported goods.

,where $A(f) = (1 + \frac{\mu}{1-\alpha-\mu}\frac{1}{\varepsilon})\frac{\varepsilon}{1-\varepsilon}\{2c_a[\frac{(1-\alpha)(1-e^{-\tau f})}{\alpha e^{-2(1-\alpha)\tau f}} + f] - N\}$, $A'(f) > 0$ and $H'(f) < 0$. To find the equilibrium, we look for a value f^* such that $H(f^*) = 0$.

First, recall that the values that f can adopt in equation (AA) have an upper bound $\overline{f} = \frac{1}{2c_a}\left(N - \frac{1-\alpha}{1-\alpha-\mu}\theta S\right)$ with $0 < \overline{f} < \frac{N}{2c_a}$ under Assumption 5. Note that $H(\overline{f}) = -A(\overline{f})$, which is negative only if $2c_a[\frac{(1-\alpha)(1-e^{-\tau\overline{f}})}{\alpha e^{-2(1-\alpha)\tau\overline{f}}} + \overline{f}] - N > 0$. From definition of $\overline{f}$, (10) and (**??**), this condition can be re-written as $\frac{1-\alpha}{1-\alpha-\mu}\theta S + \frac{\pi_e}{w} > \frac{1-\alpha}{1-\alpha-\mu}\frac{\theta S}{2c_a}$, which is satisfied under Assumption 5, hence $H(\overline{f}) < 0$.

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

Finally, since $H(f)$ monotonically decreases in f, $H(\underline{f}) > 0$ and $H(\overline{f}) < 0$ imply that there is a unique positive value $f^* \in (\underline{f}, \overline{f})$, such that $H(f^*) = 0$. From inspection of either (10) or (**??**), values of $f^* \in (\underline{f}, \overline{f})$ imply a value of $L_e(w) > 0$ and thus that the equilibrium wage, namely w^*, is also unique and positive. ■

A.2 Effect on number of manufacturing firms

Proposition 7 *the number of manufacturing firms, v increases with the expansion of the mine, $\frac{dv}{dS} > 0$, if and only if $\theta > -\frac{1}{\varepsilon}\frac{dL_e}{dw}\frac{dw}{dS}$.*

Proof. Taking total derivatives to (AA) we obtain that:

$$-2c_a\frac{df}{dS} - \frac{(1-\alpha-\mu)\varepsilon + \mu}{(1-\alpha-\mu)\varepsilon}\frac{dL_e}{dw}\frac{dw}{dS} = \frac{1-\alpha}{1-\alpha-\mu}\theta. \tag{17}$$

Similarly taking total derivatives to (13) we obtain

$$\frac{dv}{dS} = -2c_a\frac{df}{dS} - \frac{dL_e}{dw}\frac{dw}{dS} - \theta \tag{18}$$

and thus $\frac{dv}{dS} > 0$ if and only if:

$$-2c_a\frac{df}{dS} - \frac{dL_e}{dw}\frac{dw}{dS} > \theta. \tag{19}$$

Using (17) and (8) we can re-write condition (19) as $\theta > -\frac{1}{\varepsilon}\frac{dL_e}{dw}\frac{dw}{dS}$. ■

A.3 Effect on real wage

Proposition 8 *if the number of manufacturing firms increase with expansion of the mine, then* $\frac{d\omega}{dS} > 0$*. Otherwise, the effect is more likely to be positive for low values of* μ*,* θ *or high values of* ε*.*

Proof. Taking total derivatives to (14) and using (**??**) we obtain:

$$\begin{aligned}\frac{d\omega}{dS} = \frac{\mu}{\sigma-1}(\frac{w}{G})^{\mu}v^{-1}\frac{dv}{dS} + 2(1-\alpha)\alpha\tau(\frac{w}{p_a})^{\alpha}(-\frac{df}{dS})+ \\ (1-\alpha-\mu)(\frac{w}{p_a})^{1-\alpha-\mu}w^{-1}\frac{dw}{dS},\end{aligned} \tag{20}$$

which is positive if $\frac{dv}{dS} > 0$.

To study the conditions for $\frac{d\omega}{dS} > 0$ when $\frac{dv}{dS} < 0$, we first re-write (20) replacing $\frac{dv}{dS}$ using expression (18):

$$\frac{d\omega}{dS} = C - \frac{dL_e}{dw}\frac{dw}{dS} - \theta,$$

where

$$\begin{aligned}C \equiv -\{2(1-\alpha)\alpha\tau(\frac{w}{p_a})^{\alpha}\frac{\sigma-1}{\mu}(\frac{w}{G})^{-\mu}v + c_a\}\frac{df}{dS}+ \\ (1-\alpha-\mu)(\frac{w}{p_a})^{1-\alpha-\mu}w^{-1}\frac{\sigma-1}{\mu}(\frac{w}{G})^{-\mu}v\frac{dw}{dS}.\end{aligned}$$

Hence the condition for $\frac{d\omega}{dS} > 0$ when $\frac{dv}{dS} < 0$ is:

$$C - \frac{dL_e}{dw}\frac{dw}{dS} > \theta.$$

Note, from Proposition 7, that $\frac{dv}{dS} < 0$ implies $-\frac{dL_e}{dw}\frac{dw}{dS} > \varepsilon\theta$. That means that a sufficient condition for $\frac{d\omega}{dS} > 0$ when $\frac{dv}{dS} < 0$ is:

$$C > \theta(1-\varepsilon).$$

This condition is more likely to be satisfied for high values of ε or low values of μ and θ. ■

A.4 Proof of Propositions 1 and 2

Using the definition of real income from (15) and re-arranging, we can re-write the food market equilibrium condition (10) as:

$$\frac{p_a}{P} = \left[2\left(1-\alpha\right)\int_0^f e^{-\tau r}dr\right]^{-1} \alpha L y,$$

where y is the real income in the city. Note that $\frac{dy}{dS} > 0$ implies $\frac{dp_a/P}{dS} > 0$, because $\frac{df}{dS} < 0$ and $\frac{dL}{dS} > 0$. However if $\frac{dy}{dS} > 0$ the sign of $\frac{dp_a/P}{dS}$ is ambiguous.

Recall that real income in the rural hinterland is:

$$y(r) = \frac{1}{k}\frac{p_a}{P}e^{-2(1-\alpha)\tau|r|}.$$

It is immediate to see that $\frac{dy(r)}{dS} > 0$ and $\frac{d^2y(r)}{dSdr} < 0$.

A.5 Proof of Proposition 3

Using (2) and (4), we can write the relative prices of food and the import good as:

$$\begin{aligned} \frac{p_a(r)}{P(r)} &= \frac{p_a}{P}e^{-2(1-\alpha)\tau|r|} \\ \frac{p_m(r)}{P(r)} &= \frac{p_m}{P}e^{2\alpha\tau|r|}. \end{aligned}$$

By proposition 1, we know that if $\frac{dy}{dS} > 0$, then $\frac{dp_a/P}{dS} > 0$ which also implies that $\frac{dp_a(r)/P(r)}{dS} > 0$ Since $\frac{dP}{dS} \lesseqgtr 0$ and $\frac{dp_m}{dS} = 0$, it follows that $\frac{dp_m(r)/P(r)}{dS} \lesseqgtr 0$.

B Additional Empirical Results

B.1 Effect on Relative Prices: Price of Non-local Food

In addition to study the effect on the prices of locally produced crops, we evaluate the effect of the mine on the price of non-local food stuff. This falsification test allow us to evaluate whether the increase of local crop prices is driven by a general increase of food prices.

We use the unit value of commodities consumed by a large number of households and less likely to be locally produced such as rice, sugar, cooking oil and canned fish.[64] In the model, these goods correspond to the import good.

Similar to the previous regressions, we use the baseline specification 16 and include the log of real income per capita as an additional control variable. Table 13 displays the results. In contrast to the case of local crops, the effect of the mine on relative prices is negative or insignificant.

Table 13: Effect of mine expansion on price of non-local goods

	Ln relative price of:			
	Rice	Sugar	Cooking oil	Canned fish
	(1)	(2)	(3)	(4)
Mine's wage bill and local purchases × distance < 100 km	0.021	0.037	0.020	-0.111*
	(0.033)	(0.029)	(0.028)	(0.064)
Prices reported by:	consumer	consumer	consumer	consumer
Real income per capita	yes	yes	yes	yes
Observations	5174	5520	2349	925
R-squared	0.416	0.349	0.591	0.486

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 ln(real income per capita) as control variable.

B.2 Fiscal Revenue Windfall: Effect on Municipal Revenue and Spending

The expansion of the mine created a fiscal revenue windfall to local governments. In this section, we 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:

$$y_{it} = \alpha_i + \eta_t + \beta transfer_{it} + \epsilon_{it}, \tag{21}$$

where y_{it} is a measure of the revenue or expenditure of municipality i in year t, and $transfer_{it}$ is the logarithm of the amount of mining transfer received. This specification includes year and

[64]For example, 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. Of particular interest is canned fished (sardine), because the region is landlocked and thus the production is certainly not local.

municipality fixed effects, and exploits within municipality variation. The standard errors are clustered at municipality level to address possible serial autocorrelation.

Table 14 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 β 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 that other expenditures, as the increase of its share in total expenditure indicates. This result is expected since, by law, the revenues from the mining transfer should be used only for capital expenditures.

Table 14: Effect of mining transfers on municipal revenue and expenditure

	Total revenue	Total expenditure	Capital expenditure	Share of capital expenditure
	(1)	(2)	(3)	(4)
Mining transfer	0.034***	0.030***	0.047***	0.007***
	(0.004)	(0.003)	(0.005)	(0.001)
Observations	1414	1414	1414	1414
Nr. Municipalities	179	179	179	179
R-squared	0.738	0.733	0.476	0.156

Notes: Robust standard errors in parentheses. * 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, are expressed as logarithms.

B.3 Alternative Explanations: Fiscal Revenue Windfall

In the paper, we explore whether the increase on local public spending could explain the observed effects of the mine expansion. We addressed this issue by including as an additional regressor the value of municipality spending or revenue in the baseline regression. The results are similar and suggest that the main driver is the expansion of the mine local procurement not the expansion of public spending.

We explore the robustness of this result in two additional steps. First, we evaluate the role of public spending on explaining the increase of the relative value of house rents. The rationale for this is that even if public spending was unable to affect real income, it may have increased household welfare -and willingness to live in a location- due to a better provision of public goods.

To do so, we estimate the same hedonic regression including measures of municipality revenue or expenditure as additional control variables. Table 15 reports the results. Similar to the estimates using real income, the increase of house rents is driven mainly by the expansion of the mine. The expansion of public spending has an insignificant effect and the point estimates are negative.

Table 15: Effect of the mine on house rents, controlling for municipal revenue or expenditure

	Ln (relative value of house rent)			
	(1)	(2)	(3)	(4)
Mine's wage bill and local purchases × distance < 100 km	0.239**	0.360***	0.353***	0.353***
	(0.096)	(0.102)	(0.101)	(0.101)
Municipal revenue or expenditure	-0.016	-0.230**	-0.194*	-0.194*
	(0.242)	(0.097)	(0.106)	(0.106)
Observations	7696	6365	6365	6365
R-squared	0.650	0.667	0.666	0.666
Municipal revenue or expenditure	Mining transfers	Total revenue	Total expenditure	Capital expenditure

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 6). The measures of municipal expenditure or revenue and mine wage bill and local purchases are expressed as logarithms of the total amount.

Second, we estimate the baseline regressions including the measure of municipal revenue or expenditure *interacted* with our measure of proximity to the city (an indicator of the household living less than 100 km to the city or not). This procedure addresses possible heterogenous impact of public spending by location.

Table 16 displays the results using both real income and relative value of house rents as dependant variables. In both cases, the results are similar to the baseline regressions and support the claim that public spending is not the main driver of the observed effects.

Table 16: Effect of the mine on real income, controlling for municipal revenue or expenditure

	Ln(real income per capita)			
	(1)	(2)	(3)	(4)
Panel A: Dependent variable is Ln(real income per capita				
Mine's wage bill and local purchases × distance < 100 km	0.250*	0.295*	0.361**	0.169
	(0.129)	(0.172)	(0.152)	(0.123)
Municipal revenue or expenditure × distance < 100 km	-0.081	-0.178	-0.346*	-0.015
	(0.056)	(0.184)	(0.185)	(0.144)
Observations	7138	6305	6305	6305
R-squared	0.524	0.536	0.536	0.536
Panel B: dependent variable is Ln(relative value of house rent)				
Mine's wage bill and local purchases × distance < 100 km	0.286**	0.472**	0.447**	0.381**
	(0.131)	(0.206)	(0.176)	(0.159)
Municipal revenue or expenditure × distance < 100 km	-0.055	-0.182	-0.171	-0.059
	(0.056)	(0.218)	(0.191)	(0.164)
Observations	7696	6365	6365	6365
R-squared	0.650	0.667	0.667	0.667
Municipal revenue or expenditure	Mining transfers	Total revenue	Total expenditure	Capital expenditure

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 Tables 3 and 6). The measures of municipal expenditure or revenue and mine wage bill and local purchases are expressed as logarithms of the total amount.

B.4 Alternative Explanations: Direct Beneficiaries

In the paper we explore the robustness of the results to the exclusion of groups of potential direct beneficiaries of the mine. We find that the effect on real income remains similar. In Table 17 we show the results using the relative value of house rents as dependant variable. Similarly, in this case, the exclusion of direct beneficiaries does not alter the baseline results.

Table 17: Effect on households not directly employed by public sector, mining industry or living adjacent to the mine

	Ln (relative value of house rent)			
	(1)	(2)	(3)	(4)
Mine's wage bill and local purchases × distance < 100 km	0.238***	0.240**	0.255***	0.256***
	(0.092)	(0.096)	(0.096)	(0.097)
Observations	7696	6829	6718	6613
R-squared	0.65	0.595	0.583	0.583
Public sector workers	yes	no	no	no
Mining workers	yes	yes	no	no
Live in district adjacent to mine pits	yes	yes	yes	no

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 6).

B.5 Robustness Checks: Including Proximity to Other Cities.

We include as additional control to the baseline regression the measure of mine activity interacted with distance to other cities, to rule out that proximity to other city centers is driving the results.

Table 18 presents the estimates of the baseline regression with real income as the dependant 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 18: Effect of the mine on real income, controlling by proximity to other cities

	Ln(real income per capita)		
	(1)	(2)	(3)
Mine's wage bill and local purchases ×			
distance to Cajamarca	0.160*	0.160*	0.144*
< 100 km	(0.083)	(0.083)	(0.082)
distance to Chachapoyas	-0.088	-0.088	-0.103
< 100 km	(0.154)	(0.155)	(0.153)
distance to Chiclayo		0.014	0.001
< 100 km		(0.179)	(0.179)
distance to Trujillo			-0.042
< 100 km			(0.170)
Observations	7738	7738	7738
R-squared	0.520	0.520	0.520

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.

B.6 Robustness Checks: 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 19 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 Euclidian 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.

Table 19: Alternative measures of distance

	Ln(real income per capita)		
	(1)	(2)	(3)
Mine's wage bill and local purchases × distance < median	0.137*	0.150**	0.134*
	(0.077)	(0.075)	(0.074)
Measure of distance	Shortest path by road	Topographic	Straight line
Median distance (km)	90	75	65
Observations	7738	7738	7738
R-squared	0.521	0.521	0.521

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.

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 20 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.

Table 20: Exploring the decrease of the effect by distance

	Ln(real income per capita)		
	(1)	(2)	(3)
Mine's wage bill and local purchases x			
distance	-0.128**		
	(0.062)		
Ln(distance)		-0.034**	
		(0.016)	
$distance^{-1}$			0.002*
			(0.001)
Observations	7738	7738	7738
R-squared	0.521	0.521	0.521

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.