Global Trade, Contracts and Poverty Alleviation in Indigenous Communities: Cochineal in Mexico
Preliminary and incomplete

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July 5, 2012

Abstract

We explore the role played by contractual incentives generated by non-replicable factors, high risk and costly verifiability in securing long term, sustained gains from world trade for indigenous communities. We examine the long term effects on indigenous populations on cultivating one of the world’s most valuable traded commodities: the “Spanish Red” dye extracted from the cochineal insect. We exploit the discontinuous fragility of cochineal with respect to micro-climatic differences during the growing season to identify the effect of a legacy of cochineal production. We find that a legacy of cochineal production lowered the headcount poverty ratio in Mexican municipalities by 0.1, comparable to the entire effect of the Progressa conditional cash transfer program over a ten year period. Furthermore, cochineal production raised female literacy by 0.6 percentage points. Municipalities that contained pueblos that once produced cochineal are significantly more unequal, however, have significantly fewer indigenous households and are less likely to formalize indigenous local government institutions. We interpret these results as reflecting the long-term effects of cochineal and the Repartimento contract that emerged to support the cochineal trade, provided opportunities to women and provided an alternative to indigenous institutions as a means to manage risk.

*Address: albertod@ucsd.edu; saumitra@gsb.stanford.edu. We would like to thank Sergio Juarez of the Nocheztlicalli: Museo Vivo de la Grana Cochinilla in Oaxaca for sharing his expertise on cochineal cultivation and Rodolfo Acuna and David Stahle for sharing their tree-ring reconstructions of historical climate. We are also grateful to Angeles Frizzi, Dorothy Kronick, Jessica Leino, Beatriz Magaloni and seminar participants at Stanford and in the US-Mexico conference on the Great Death for valuable comments. Katrina Kosec provided excellent research assistance.
1 Introduction

Poor, disenfranchised or indigenous populations that live in regions with resources that can be extracted for sale on world markets have long been seen as the accursed of globalisation. Indeed, given the often dramatic differences in military and technological capabilities between those seeking to acquire geographically-delimited resources and non-elite indigenous populations that inhabit those areas, it is perhaps not surprising that this is the case. Where such groups are able to employ the “weapons of the weak”, these usually persist in marginal occupations that have relatively small gains (Scott 1985). Whether through violent coercion, the generation of inequality that results in oligarchic political arrangements or due to the direct introduction by external actors of extractive institutions, a large body of work suggests that openness to trade can lead indigenous groups to face a long-term future of low growth and stunted development (Engerman and Sokoloff 2000, Acemoglu, Johnson, and Robinson 2002, Nunn 2008, Dell forthcoming).

A related, but relatively unexplored aspect of the effects of openness on many indigenous communities lies in the replicability of their human capital, intellectual property and natural resources. The ability to replicate and outsource the skilled production of artisanal goods to lower-cost regions of the world has often meant that communities do not benefit from world demand for goods researched and developed by their cultures over centuries. Similarly, the ability of communities to gain from the exploitation of their indigenous biological resources or processes of exploitation, such as spices, silkworms, dyes or rubber, have often proved less durable sources of wealth as these processes and goods are replicated elsewhere.\footnote{For a description of the desolation of the Spice Islands following the transplantation of the nutmeg, see Keay 1991. On the importance of non-replicable sources of complementarity in supporting a legacy of inter-ethnic tolerance in South Asia, see Jha 2008b, and more generally, Jha 2008a. An irony of being the originating region of biological resources is that the indigenous flora or fauna are often more difficult to cultivate there than in new areas—being indigenous, they also tend to have natural predators that are absence elsewhere Donkin 1977.}

Further, little empirical evidence is available on the conditions under which indige-
nous societies are able to secure and sustain gains from indigenous human capital or commodity trades valued by global demand over time, even in the absence of benign third party intervention that could protect such gains. In this paper, we explore the role played by contractual incentives generated by non-replicable factors, high risk and costly verifiability in securing long term, sustained gains from world trade for indigenous communities. We examine in particular the long term effects on indigenous populations on cultivating one of the world’s most valuable traded commodities up until the late 19th century: the “Spanish Red” dye extracted from the fragile cochineal insect. We perform this study in Mexico, a country where indigenous, colonial and modern identities and institutions of governance have co-existed for centuries, and thus provides a useful laboratory for understanding the long-term effects of trade on indigenous communities.

From the conquest of Mexico until the development of synthetic dyes in the late 1880s, cochineal was the best source of red dye known to the West, and was highly prized in the production of textiles, of which dyeing could constitute close to 40% of the overall cost (Marichal, 2001). Crimsons and reds in particular were highly prized as colours denoting status, both among the church and among royalty. Cochineal-dyed textiles, further, were ten to twelve times more brilliant and remained fast compared to those of the known alternatives derived from madder and the also-rare Mediterranean kermes (Lee, 1948, Marichal, 2001). As a result, from the 16th century to the independence of Mexico in 1820, cochineal was also the most valuable processed good exported to Spain from the Indies, second in value only to silver and gold. The average exports of cochineal between 1580-1600 were worth 550,000 pesos, close to 9% of the value of the silver exports from New Spain (Lee, 1948). At its peak in 1771, cochineal had risen to be worth more than 4,200,750 pesos (Baskes, 2000).\(^2\)

\(^2\)This price is based on the market price of cochineal in Oaxaca, near the main production areas of cochineal. Naturally European prices would be considerably higher.

Fine cochineal – *la grana cochinilla fina*– was thus a highly prized commodity in world trade. However, the domesticated cochineal insect also had one key distinguishing
feature from other types of agricultural or mineral commodity: it was extremely fragile. Unlike wild cochineal (*cochinilla silvestre*), fine cochineal only survived in regions with particular combinations of precipitation, heat and cold. A sudden rain, frost or elevation in temperature could kill the entire harvest (Donkin, 1977).

The fragility of cochineal had two effects: first, despite numerous attempts by Spain’s rivals—England and France—it proved very difficult to transplant and replicate in experimental farms outside of New Spain. Thus, unlike other prized agricultural commodities, such as Brazilian rubber, Chinese silkworms or Indian indigo, cochineal was secure from world competition and continued to prove a lucrative (New) Spanish monopoly for two hundred and fifty years. Its fragility made cochineal much less transplantable and much more localized in its production, in this sense, more like mineral resources than many agricultural goods.

Second, because of its fragility, cochineal differed from mineral resources in that it was both highly risky and required great care and attention to cultivate. Domesticated cochineal had to be ‘seeded’ onto the paddles of the opuntia cactus. Immobile and virtually defenseless itself, cochineal had also to be shielded from many potential threats. The 16th century chronicler of New Spain, Gonzalo Gomez de Cervantes devoted several sections to cochineal, listing the “enemies” that ranged from wild cochineal and other insects to the *gusano tolero* worm, and chickens and other birds that required constant vigilance (Figure 1.)

We argue that the fragility of cochineal led both to the need for high-powered incentives to care for the crop, as well as a basic problem of moral hazard or hidden action: it was difficult for a principal to verify whether a cochineal crop had been destroyed due to lack of effort, had been secretly sold on the market due to high prices or had been lost due to the multiple natural threats that cochineal faced.

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3 French spies attempted to smuggle live cochineal to Haiti, while the English made similar attempts at establishing cochineal plantations in India, but the cochineal insects were not to survive sea-borne transplantation until the independence of Mexico and successful attempts by Spaniards to raise cochineal in the Canary Islands (Greenfield, 2005).
mm and a dry season of three to four months were close to the minimum requirements.

The question whether D. coccus derives from a superior wild form which has now disappeared, or is a product of the improvement of one of the known wild species cannot be satisfactorily resolved. The notable differences between the present wild and cultivated forms at first suggest the former. Early commentators, however, generally assumed that the two were directly related, the differences being ascribed solely to cultivation.43 Certainly, the domestic Dactylopius is a delicate and vulnerable insect, closely dependent on man. Improvement has come about through the selection and care of breeding populations, management of the host nopals, and partial protection from a large number of enemies, besides inclement weather. Gomez de Cervantes described in some detail the creatures that devoured or attacked cochineal larvae and the immobile insects (fig. 3). They included turkeys and chickens (gallinas de la tierra, gallinas de Castilla), birds generally, and various pests that called for constant surveillance—lizards (lagartijas), a kind of leech (sanguijuela), an insect "resembling a spider,"44 and several grubs or worms (gusanos).45 Rats and mice armadillos, and some snakes were similarly harmful.46 In well-tended gardens, wild cochineal was removed,47 primarily to conserve the nopals and also to guard against interbreeding. The wild population must always have been kept severely in check by natural enemies, and it is difficult to visualize an improved and less robust species surviving at all. D. coccus tends quickly to disappear when cultivation and protection cease.48 The differences between fina and silvestre forms appear to be largely the result of processes of domestication operating over a considerable period of time.

43Memorial (1620), 1931: p. 50 ("la silvestre fue el mismo genero que el de la fina y en la cultivacion esta la diferencia"). Discussed by Humboldt (1811: 3: pp. 65-66) and Dahlgren de Jordan (1963: p. 12).

44 According to Diguet (1928: p. 520), spiders themselves were welcomed, chiefly because they fed on harmful insects, but not cochineal.


46 Clavijero (ca. 1780), 1964: p. 233; Alzate (1777-1794), 1852: p. 84; Humboldt, 1811: 3: p. 74. See also Leon Pinelo (1650), 1943: p. 248; Landivar (1781), 1948: p. 195; Dunlop, 1847: p. 130; Squier, 1858: p. 523; M. Herrera, 1919: p. 120.


48 Alzate (1777), 1794: p. 228) refers to the testimony of the alcade mayor of Nexapa (southern Oaxaca), according to which grana requisima was to be found, seven leagues or so from Nexapa, without cultivation, either of nopals or insects. This has no clear explanation, and falls short of proof of the existence, then or earlier, of a superior wild species.

Figure 1: Enemies of cochineal—Gonzalo Gomez de Cervantes (1599), La vida económicay social de Nueva España el finalizar el siglo XVI, reproduced in Donkin (1977)
There were a number of institutional responses to this contracting environment. First, we argue, to provide high-powered incentives, residual claims (and ownership of the means of production) were left in the hands of the cultivators (as in Hart and Moore (1990)). Thus rather than becoming vertically integrated in large hacienda-style plantations, cochineal-growing areas were left in the hands of small individual peasant producers.\footnote{Some haciendas did emerge in the Vale of Oaxaca to cultivate cochineal, but the vast majority of production remained on small plots (Donkin 1977). \textit{Op cit Taylor.}} This appears confirmed by the historical record. According to Donkin (1977):  

\begin{quote}
\textit{Hacendados} were discouraged by the uncertainties of production and the sharp variations in prices, by the number of field laborers required, particularly at certain times of the year; and by the rather complex preparation of \textit{grana fina} for the market. At the same time, larger holdings brought little saving in time and effort. The industry was peculiarly dependent on the skill and patience of individual workers, qualities generally encouraged by the prospect of personal gain . . .
\end{quote}

A second feature of cochineal production was that it was left almost overwhelmingly in the hands of indigenous producers in areas that were otherwise marginal to agriculture (Marichal 2001, Greenfield 2005, Donkin 1977, Baskes 2000). Though indigenous producers did have some initial human capital advantages in raising cochineal, the fact that production moved relatively easily between regions and across ethnolinguistic boundaries among the native populations over time suggests that these initial human capital advantages were not impossible to replicate, particularly for the relatively-technically advanced Europeans.\footnote{For example, production did move within ethnically very different areas of New Spain, such as between Tlaxcala and Oaxaca, and was later introduced successfully in Guatemala and ultimately the Canary Islands.} Instead, there appears to have been ethnically-based specialization, with Spanish traders providing credit and access to the world market to Indian producers.

Third, the main contractual form that supported the cochineal industry, the \textit{Repartimento}, appears to have been a relatively efficient method of balancing risks \footnote{Baskes}. 

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\end{quote}
The standard contract was for the local Spanish official, the *alcalde mayor*, having bid for the position and accumulated funding from Spanish merchants, to advance 12 pesos to indigenous producers for each pound of cochineal six months before harvest. This was considered a “fair” price”, and did not fluctuate much over time (Baskes, 2000)[62-92]. To the extent that cochineal producers were financed by the repartimento, then the downside risk, and the exposure to world markets was borne by the alcalde mayor (naturally, when self-financed, the risk was borne by the individual producers). In practice however, when prices for cochineal were high, Indians would sell in markets and claim that their harvests were destroyed. In his study of the cochineal contract, Jeremy Baskes documents that this practice appears to be widespread. For example, the alcalde mayor of Nexapa (1752) lamented:

that when market prices dropped he had no difficulty collecting the cochineal owed to him, but that when prices were high debtors sold their stuff to traveling merchants or in Antequera and later claimed to him that they lost their harvests. The same was claimed by the alcalde mayor of Villa Alta, who in 1770 was unable to collect his cochineal debts from the Indians of his district because, as he testified to the Viceroy, the prevailing high prices had led debtors to renege on their contracted obligations and sell their output elsewhere. In 1784, the alcalde mayor of Zimitlan-Chichicapa also noted the propensity of Indians to abandon their obligations and sell elsewhere when prices rose. Arij Ouweneel noted that the Indians of Puebla also “developed a flair for the market” and bypassed their repartimento debts to the official when market prices rose. . .” (Baskes, 2000)[77].

In essence, therefore, the lack of ability to verify negative shocks to production resulted in a contract where the indigenous population were insured against world market fluctuations on the downside but possessed a call option through their ability to renege on contracts, claim that the cochineal was destroyed and instead sell on the open market.
This maintained the high-powered incentives necessary for cultivating a risky crop, even among the risk-averse poor.

A fourth feature of cochineal production was that it could be produced in small plots near the home, and though it was labour-intensive, it did not require large degrees of animal or human motive power. This provided particular possibilities for women and children to engage in this lucrative activity, and indeed women and children were often heavily involved in the cultivation of cochineal \cite{Baskes2000}. This may have altered bargaining power within the household.

The strong relationship between indigenous identity and poverty, particularly in Mexico and Latin America, has led to a long tradition which sees colonial institutions as largely extractive and having deleterious effects on those communities. Similarly, the Repartimento has long been seen as an exploitative contract, with Spanish traders as the main beneficiaries. Though cochineal production in Mexico disappeared in the 19th century, first with competition from Guatemala and the Canary Islands and then ultimately with the synthesis of artificial dyes in the 1880s, historians have pointed to the relative poverty and continued strength of the indigenous populations in cochineal-producing areas such as Oaxaca as indicative of the exploitative nature of the Repartimento and the role of cochineal in maintaining indigenous identity, institutions and customs \cite{Baskes2000, Greenfield2005}. However there has been hitherto no attempt, to our knowledge, to document the long term effects of these contractual arrangements on the indigenous communities themselves.

In this paper, we exploit the fragility of cochineal with respect to micro-climatic differences, using the discontinuous propensity to produce cochineal in areas that possess the optimal raising conditions to areas just on the other side of these thresholds that

\footnote{A recent reassessment by \cite{Baskes2000} on the profitability of the Repartimento suggests that the indigenous communities were important beneficiaries of the Repartimento, while continuing to contend that cochineal production led to the maintenance of indigenous identities and institutions. This is likely because Baskes’ focus is on the colonial period, when indigenous communities were the ones who benefited from cochineal production.}
lacked the right combination of precipitation and rainy season temperatures, to identify the effect of cochineal production on poverty, female literacy, inequality, indigenous assimilation and the maintenance of *usos y costumbres*—traditional indigenous usages and customs to manage local government. We find that a legacy of cochineal production lowered the headcount poverty ratio in a municipality by around 0.1, a large value comparable to the entire effect of the Progressa/Opportunidades conditional cash transfer program over a ten year period. Furthermore, cochineal production appears to have raised female literacy by a remarkable 0.6 percentage points. Municipalities that contained pueblos that once produced cochineal are significantly more unequal, however, and, in a dramatic reversal from the 18th century, actually have significantly fewer indigenous households, and fewer who are monolingual in an indigenous language. They are less likely to adopt indigenous local government institutions (*usos y costumbres*). Public goods provision is generally as good however, apart from the provision of roads and transport, which is considerably improved in cochineal producing areas.

We interpret these results as reflective of the long-term legacy of the repartimento contract that underlied cochineal production in the colonial period. By providing access to world markets and downside insurance, Spanish traders provided members of poor indigenous communities, particularly women, a means to benefit from world trade and to engage in market activity, leaving a beneficial legacy both on poverty reduction and on women’s opportunities. However, because of the ability to exercise the “call option”, renege on the repartimento contract and sell in markets when prices were high, the risky nature of cochineal on the upside engendered inequality. Concurrently, Spanish officials had an incentive to build roads to cochineal producing areas to improve the ability to access and monitor valuable goods for which they themselves were providing credit. Despite cochineal production having initially safeguarded indigenous communities from hacienda-isation and homogenization, increased inequality and access to market opportunities appears to have later undermined traditional (largely redistributive) political
institutions by leading first the richer and most mobile members to opt out and “hisp-
panicize”. Thus, part of the reason that indigenous communities appear poor in Latin
America and other areas may have less to do with colonial predation but instead precisely
because their most successful members chose to opt out and assimilate.

2 Empirical Strategy

In our empirical analysis, we will compare regions that possessed the optimal growing
conditions for cochineal to those that otherwise very similar to examine the effects of
cochineal in both geographical and climate space. We seek to identify the effect of past
cochineal production on contemporary measures of poverty, inequality, ethnic assimila-
tion, and the maintenance of traditional institutions. To do this, we will make two types
of comparison. First we will match cochineal producing areas to non-producing areas in
terms of their geography, in terms of climate, and both. The identifying assumption is
that the choice to produce cochineal in pueblos that are very close by to one another
in either (or both) geographic or climatic spaces was not shaped by unobserved initial
differences that also affect subsequent economic and political development.

In our benchmark specification, we will run cross-sectional regressions comparing
those municipalities that contained Indian pueblos in 1790.

\[ y_i = \beta_{Cochineal} i + \sum_{j}^{4} \gamma_{j} Geog_{j}^{i} + \sum_{j}^{2} \xi_{j} Clim_{j}^{i} + X_{i}B + \epsilon_{i} \]  

(1)

Where \( y_i \) is a set of 18th and 21st century measures of poverty, female literacy, ethnic
identity and public goods provision as well as whether the municipality has chosen to
explicitly adopt traditional governance institutions (usos y costumbres). Since only the
historically cochineal-growing state of Oaxaca has so far implemented laws recognizing
usos, we implement these specifications both for all Mexico and in Oaxaca only.

\( Cochineal \) is a measure of whether any pueblo within the municipality once produced
cochineal. We exploit a number of primary and secondary sources to identify the locations of cochineal production, including a comprehensive search of all documents in the Archivo General de Nueva España in Seville (please see data section).

Geog\(_i\) is a vector of geographical initial conditions (higher order polynomials in latitude, longitude and altitude). Clim\(_i\) is a set of climatic conditions—polynomials in temperature and precipitation. We also include X\(_i\)-cultural initial conditions which include distance to pre-Columbian native population or administrative centres and to Conquest-period missions, arguably a good measure of the native population at the time of the Conquest. We use robust standard errors\(^7\)

Though we attempt to identify all cochineal growing areas, there is a possibility that Spanish colonial sources might have underestimated the extent to which cochineal was grown in remote areas. To address this source of bias, we exploit the particular climactic requirements of cochineal to compare areas that happen to be in the optimal growing area for cochineal to generate a fuzzy discontinuity in geographical and climactic spaces.

As mentioned above, cochineal cultivation was highly dependent on favorable climactic conditions. During the main growing season of March-August, the cochineal had to be protected from precipitation (below 700mm was best) and large temperature variations (i.e. frosts and temperatures above 30 C).\(^8\) The first stage regression is of the following form:

\[
Cochineal_i = \zeta OptimalClim_i + \sum_{j}^{4} \gamma_j Geog_j^{i} + \sum_{j}^{2} \xi_j Clim_j^{i} + X_iB + \nu_i \tag{2}
\]

By including the polynomials in geographical and climactic space, we are essentially exploiting the discontinuity in the propensity to produce cochineal in some microclimates

\(^{7}\)Clustering the standard errors at the modern province level does not affect the results substantively, but adds anachronism. A later version will report Conley standard errors to address potential spatial auto-correlation.

\(^{8}\)Secondary sources do differ on the precise cutoffs—we follow Lee (1948). The ideal conditions for cochineal are 25C with very low precipitation (we thank Sergio Juarez, one of the two remaining modern producers of cochineal in Oaxaca, for this observation.)
compared to others that are right next to each other. While we should be using historical climate, average temperatures have largely been preserved over the last four centuries at least in two cochineal producing regions- Puebla and Tlaxcala- for which reliable tree-ring reconstructions are possible (Figure 2).  

![Temperature fluctuations in Tlaxcala and Puebla over 5 centuries from tree-ring data.](image)

**Figure 2:** Temperature fluctuations in Tlaxcala and Puebla over 5 centuries from tree-ring data.

3 Data

We geographically identify 124 cochineal growing locations using a variety of colonial sources. We relied primarily on the appendix compiled by [Donkin (1977)](https://example.com), which lists

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9This is still a tentative conclusion. Though the preservation of the mean appears a robust conclusion, the calibration of the dendochronologies may not be precise, and it is possible that we should be using the second moment, and this is currently under research.
cochineal producing towns on the basis of the Matricula de Tributos for the precolonial period; the Suma de Visitas for the early 16th century; the Relaciones Geograficas de Indias for the late 16th Century; the Memoriales del Obispo de Tlaxcala by Alonso de la Mota y Escobar for the 17th century; and B. Dahlgren de Jordan for the 18th century, as well as some additional secondary sources.

We cross-examined this list by searching all ‘grana’ and ‘cochinilla’ mentions in Mexico’s National Archives (the Archivo General de la Nacion, AGN), where we found 154 documents containing references to cochineal and specific town locations. There was substantial overlap in the two listings.\(^\text{10}\)

The sources we have used were explicitly designed by colonial administrators for the purpose of identifying cochineal production and trade.\(^\text{11}\) Our data sources thus enable us not only to identify cochineal growing regions, but also the specific century when production was taking place.\(^\text{12}\)

We geo-referenced all cochineal locations to their modern locality, using the Archivo Historico de Localidades (AHL) produced by the Mexican National Statistical Institute, INEGI.\(^\text{13}\) We failed to identify only 3 towns, which are not included in our dataset.

\(^\text{10}\) We did not pursue around two dozen potential locations that are mentioned in AGN documents but are not in the more comprehensive colonial documents. We decided not to invest research resources on archival work for those towns because the AGN documents are most likely mentions in passing of towns that may not be growing cochineal or if they were, they are most likely small villages surrounding the main cochineal growing regions.

\(^\text{11}\) For example, the Matricula de Tributos is an Aztec document that Cortez seized from Moctezuma, which identifies tributary provinces and towns, specifying cochineal taxed in kind by the Cololhua-Mexica Empire. The Suma de Visitas of 1548 was a census collected for tributary purposes, at a time when Indian tribute was paid in kind, which allows for the identification of cochineal tribute paying places. The Relaciones Geograficas was a census ordered by Phillip II, explicitly asking in question 28 to report “the mines of gold, silver and other metals, and dyes that may exist in the town or its surroundings”. Dahlberg de Jordan’s source is the customs report of the port of Veracruz, identifying the producing towns of cochineal exported during the late 18th century.

\(^\text{12}\) Some of the Relaciones Geograficas of the late 16th century have been lost and that there might be some missing data for relevant growing regions in a given century, but we are quite confident that we have included all the relevant towns where this activity existed in the colonial period, and if there are any missing towns, they are most likely in the immediate vicinity of the ones we have located.

\(^\text{13}\) The AHL is a comprehensive geographic gazetteer that includes not only the modern place names, but variations in their spellings as well as brief references to the etymology and history of the towns. Due to changes in spelling and place names, as well as multiple modern possibilities with the same place name, we searched for confirmatory evidence to make sure we have identified the correct locality. For example, there are 10 modern localities in the state of Puebla with the name Acatlan, but we narrowed
In order to limit the range of our comparisons only to the territorial extent of the settled areas of the New Spain we geographically identify the Indian *pueblos* and Spanish cities ( *ciudades* and *villas*) at the end of the colonial period. We take advantage of the georeferenced Atlas produced by Dorothy Tanck de Estrada, who geocoded the full range of towns in New Spain at around 1790, the end of the colonial period. We matched each of the more than 4500 pueblos in Tanck de Estrada (2005) to its modern locality. For further details of the data, please see the Data Appendix.

4 Results

(Figure 3) overlays the conditions for cochineal growing with actual cochineal growing among Indian pueblos, providing the 2-dimensional geographical equivalent of a univariate regression discontinuity plot (Dell, forthcoming). Notice that pueblos that satisfy none of the conditions were very unlikely to produce cochineal, while adding each condition sequentially raises the likelihood of doing so, such that there is an additional, discontinuous benefit from falling the optimal growing area. We can exploit each discontinuity separately as well as combine them into a single “optimal growing region” variable. The results are consistent using either specification, though in what follows we focus on the simple univariate specification.

As Table 1 reveals, the discontinuities in the graphical relationship in geographical space are reflected in multivariate regressions of the propensity to produce cochineal in the colonial period. Notice first that cochineal producing municipalities do not seem to be systematically related to the level of pre-Columbian development as measured by either proximity to pre-Columbian cities or to monasteries established at the time of

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14 Given that there is some uncertainty regarding externalities in the production of cochineal between localities, and that in urban areas pueblos have become part of larger metropolitan areas, we end up using modern municipalities as the geographic units of analysis. Thus, instead of having around 2500 municipalities, we restrict attention to 1700 municipalities that are relevant from the point of view of the colonial period.
Figure 3: **Optimal growing conditions and cochineal production.** Red dots denote cochineal (*dactylopius coccus*) producing locations in the colonial period. Green dots denote the locations of Indian towns (*pueblos de indios*) that existed in 1790. Darker areas denote higher precipitation. Overlaid purple regions denote areas that satisfied all three climactic conditions for growing cochineal.
the Conquest (arguably a measure of Conquest-era population densities (Díaz-Cayeros, 2010)). However, there is strongly significant and robust positive increase of around 3 to 5 percentage points of the presence of optimal growing conditions for cochineal on whether a pueblo within the municipality was recorded as having grown cochineal in the colonial period (1520-1820) (thus close to the mean propensity to produce cochineal of around 5 percentage points). This is true controlling flexibly (using quadratic and quartic specifications) for latitude, altitude and longitude (Cols 1-9) and comparing municipalities within the same state (Cols 3-5,7-8). Cols 4-9 add polynomial controls for average precipitation and temperature, but do not significantly alter the increase due to optimal growing conditions.\(^{15}\)

Subsetting the data to those municipalities within 100 km (62 miles) of the optimal growing frontier halves the sample but yields very consistent results (Cols 6-8). Finally comparing only those 451 municipalities within the cochineal-rich state of Oaxaca that once had Indian pueblos raises the effect of the confluence of optimal growing conditions on growing cochineal to around 10 percentage points.

Figure 4 shows an important outcome of interest—those municipalities designated “poor” in 2001 and how they related spatially to the incidence of historical cochineal production and climatic conditions, zooming into the poorer regions of Southern Mexico. Notice that there are visible and striking differences among neighbouring municipalities, with similar climatic conditions, that were considered poor and non-poor. Cochineal producing municipalities often appear as islands of non-poverty in a relatively poor part of the country.

These visible differences are also reflected in the effect of cochineal in reducing head-count poverty ratio by around 10 percentage points and raising female literacy rates 5 percentage points seen in the OLS specifications in Table 2. Observe that these effects are remarkably robust and stable across specifications, including matching in both geo-

\(^{15}\)The F-test of the univariate instrument exceeds the Stock-Yogo criteria for weak instruments for a number of specifications but can be improved upon.
Figure 4: Cochineal production and poor Southern Mexican municipalities (2001 CIMMYT data).
graphical and climatic space and comparing within municipalities within the same state within 100km and 75km of the optimal growing frontier as well as within the state of Oaxaca (Cols 1-9). The “fuzzy” regression discontinuity results (Cols 9-13) reveal broadly consistent results in sign (and in the most tight comparisons (Cols 12-13), magnitude) for poverty, though the effects are not precisely estimated. At the the same time, the equivalent results on female literacy rates are unequivocally significant and robust: female literacy rates in regions that produced cochineal because they happened to fall in the growing region are around 50 percentage points higher than those municipalities just outside the region in both geographical and climate space (Cols 9-13).

The reduction in overall poverty and the rise in female literacy are consistent with two features of the Repartimiento contract that underlied cochineal production—the downside insurance provided by Repartimiento credit to poor farmers by providing a price floor for cochineal, along with the role of cochineal in providing women in particular access to a valued market activity. The relatively greater size of the fuzzy regression discontinuity results are consistent with the possibility that we may be underestimating the location of cochineal growing areas by using the actual mentions in colonial sources.

Historians have hypothesised that the small-scale cultivation of the cochineal and the fact that land under cochineal production was mainly in the hands of indigenous producers in the colonial period has had lasting effect on the maintenance of indigenous identity and institutions [Greenfield, 2005; Baskes, 2000]. Indeed, Oaxaca, Puebla and Tlaxcala, three major cochineal producing states are also among the most ethnically diverse. However, Table 3 shows the effect of a legacy of cochineal production on the proportion of people in a municipality speaking an indigenous language, and decomposing this figure into those that are monolingual and bilingual. A consistent picture emerges—a legacy of cochineal production reduces the proportion speaking an indigenous language.

\footnote{Cross-state evidence shows that these states also show relatively higher incidence of O- blood types, a blood type that is much more common among indigenous Mexicans than among those of Spanish origins.}
by 6 percentage points across OLS specifications. Furthermore, the effect is mainly to reduce the number that are monolingual in an indigenous language in a municipality. Even within poor, ethnically diverse Oaxaca, residents of municipalities who produced cochineal as they were on the frontier of the optimal growing region were 0.56 percentage points less likely to be monolingual (Panel C, Col. 13). Paradoxically, the residents of cochineal-growing lands, despite having been left in the hands of indigenous producers in the colonial period, have fewer residents that maintain a distinct indigenous linguistic identity.

Table 4 suggests two reasons why this might be the case: cochineal producing municipalities are now more unequal (Panel A), and also have greater access to the modern road network (Panel B). Both of these effects are consistent with the Repartimento contract and the incentives of global trade. The riskiness of cochineal production and the “call option” that allowed cochineal producers to renge on the Repartimento contract by selling cochineal at the market rate when prices were high is likely to lead to ex post inequality. At the same time, access to cochineal-producing areas was valuable to Spanish local administrators, as this facilitated monitoring of contracts as well as reducing the transportation costs of cochineal production. Since the local administrators were themselves the main financiers of cochineal production, it is likely that the colonial road network adapted itself towards cochineal producing areas. As noted above, cochineal producing pueblos were not any closer on average to pre-Columbian sites. Furthermore, lacking the need to design around Spanish-introduced mules, horses and in fact any pack animal, pre-Columbian roads in Mexico tended to be superceded by a relatively independently-created colonial road network that was built to link the newly-created Spanish cuidades. However, Figure 5 shows road networks in 1790 (Gerhard, 1993) and the network of paved roads today. While many Indian pueblos were bypassed, cochineal producing pueblos appear to have been systematic beneficiaries of the expansion of the road network, providing visual confirmation of Table 4 (Panel B).
The presence of increased inequality and ease of access to outside opportunities provides an explanation for the decline of indigenous identity and the relative assimilation of cochineal-producing areas, when combined with a third factor— that those that committed to maintaining an indigenous identity also were more likely to have pay into often highly redistributive indigenous governance institutions. These governance institutions, while potentially playing an important risk-sharing role in many communities, are likely to less important in an environment where Repartimento contracts for cochineal provided risk insurance (and reduced poverty) instead. On the other hand, increased inequality and ease of mobility is likely to have encouraged the most productive members “opt” out by hispanicizing.\footnote{This logic has clear parallels to the decision of productive members to opt out of the highly-redistributive Israeli Kibbutz (see Abramitzky (2008)).} Indeed, as Panel C, suggests, cochineal producing municipalities, both exploiting cross-state variation and looking within Oaxaca, were much less likely to opt for formalizing the use of highly redistributive indigenous governance institutions (\textit{usos y costumbres}).

Despite having failed to maintain indigenous governance, as Table 5 reveals, municipalities with a legacy of producing cochineal are at least as good as nearby areas at providing public goods such as water, electricity and drains to their populations. Thus it appears that increased inequalities and the failure to maintain traditional institutions have not had a deleterious effect on these indicators of development.

\section{Conclusion}

World trade has not treated most indigenous communities well. The members of such communities often number among the poorest and most vulnerable. Despite the benefits that world trade should confer in principle, the conditions under which indigenous communities with replicable human capital or expropriable resources can benefit over the long term from openness to trade have not been adequately explored. In this paper, we pro-
vide an example where indigenous communities succeeded in wresting a share of the gains from trade over more than two centuries, leaving a lasting legacy of reduced poverty and improved female literacy. At the same time, access to the contracts that supported the trade appear to have changed the communities themselves, providing individuals alternative means to mitigate risk that appear to have undermined local indigenous governance institutions and encouraged broader assimilation. In this way, successful and sustained gains from trade may have led indigenous communities to cease being indigenous. The relationship between indigenous identity and poverty visible throughout Latin America then may be due in part to the “opting out” of those successful at securing the gains from globalization.

Our example of an instance where indigenous communities gained from openness to globalization does however raise the issue of the special nature of the conditions under which poor indigenous societies can protect their intellectual property and expropriable resources in the absence of benign third party enforcement. The unusual fragility of cochineal, that made it difficult to transplant, in combination with the need for high-powered incentives to encourage cultivation, was not characteristic of many other forms of intellectual property, human capital or resources. Indeed, the entrepreneurial spirit of colonial administrators in transplanting indigenous crops and techniques researched and developed over centuries throughout their empires, while fostering world trade in the 18th and 19th centuries, may have also played a major role in providing indigenous societies with nothing to sell and thus little to bargain with when confronted by globalization.
Figure 5: Cochineal production and the evolution of road networks in Southern Mexico. The light blue lines denote the road networks of New Spain (1790), as documented by Gerhard (1993). The red lines represent modern roads.
6 Data Appendix

For the vector of geographic conditions we use latitude, longitude and altitude. Longitude and latitude are measured in degrees, calculated at the geographic centroid of each municipality using ArcGIS. Altitude is calculated as the average of each municipality, measured in meters, using the Digital Elevation Model with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) produced by the US Geological Survey EROS Data Center.

For the climatic data we have used two distinct data sources. For each municipality we calculated the average rainfall and temperature according to the official climatology maps of the Mexican National Statistical Office, INEGI. The data was collected from meteorological stations from 1921 to 1975 and processed in 2000. For the monthly data on precipitation we used a 30 arc second resolution database from Worldclim, version 1.4, interpolated by Hijmans, Cameron, Parra, Jones, and Jarvis (2005). The monthly data is calculated for the 1950-2000 period. This monthly data is used to restrict the optimal cochineal growing regions as those that during the main growing season (March to August) are always below 700 mm and did not experience frosts and temperatures above 30 degrees Celsius.

To control for the initial conditions before the colonial period, we have calculated hiker distances to the main archeological sites that were developed before the conquest and the hiker distance to the network of missions established by the Dominican, Augustine and Franciscan religious orders during the 16th century. These topographic distances are averaged over the municipality. Hiker distances are used because the available means of transportation without horses or mules meant that the network of urban settlements and transportation corridors was connected through trails that followed the valleys and areas of relatively easy access. We use the most important archeological sites, which are the 170 sites open to the public.

Given the high mortality that characterized the 16th century we cannot use population
headcounts during the first century of contact as a measure of population density or settlement patterns. Those population figures most likely reflect differential mortality rates across pueblos. Instead, we use the network of missions, which gives us a proxy for the population density and the network that connected Indian society before the time of contact. The three religious orders competed during the 16th century seeking to place their missions in the places where they could maximize Christianization and access to Indian communities. The geocoding of missions is made on the basis of the maps provided by Kubler (1948). Details on the calculation of hiker distances, which use the slope of the terrain, can be found in Diaz-Cayeros (2010).

The data used for the contemporary measures of development, ethnic composition, inequality and local public goods provision we calculate the following indicators from official INEGI 2000 census data:

Female literacy rates (Alfamujeres): women over 12 years old who cannot read or write. Indigenous: percent of municipal inhabitants over 5 years old who speak an indigenous language. Bilingual: percent of municipal inhabitants over 5 years old who speak Spanish and an indigenous language. Monolingual: percent of municipal inhabitants over 5 years old who speak an indigenous language but do not speak Spanish. Inequality: Gini coefficients calculated by Jensen and Rosas (2007) on the basis of the household income reported in the census, measured as multiples of the minimum wage.

Distance to roads is calculated as the Euclidean distance to the main roads as of 2000 from INEGI, calculated with ArcGIS.

Usos y Costumbres is a dummy variables denoting the municipalities that elect mayors through traditional methods instead of partisan elections. The source for this data is the Electoral Institute of Oaxaca.

Poverty headcount ratio (paliha) is a poverty headcount at the municipal level calculated by the Mexican Commission for Social Evaluation (CONEVAL) on the basis of a small area estimation using the 2002 income distribution survey (ENIGH) and the 2000
References


GOMEZ DE CERVANTES, G. (1599): La vida económica y social de Nueva España el finalizar el siglo XVI. 1944 edn.


Table 1: Regression: Cochineal in the colonial period

<table>
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<tr>
<th>Municipalities containing 1790 pueblos only</th>
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<td>0.031***</td>
<td>0.031*</td>
<td>0.031*</td>
<td>0.030*</td>
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<td>0.014</td>
<td>0.014</td>
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<td>0.026***</td>
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<td>0.08</td>
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Sample restricted to municipalities containing 1790 pueblos de los indios. Robust standard errors in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%; Note: `<100km` represents those municipalities within 100km of the optimal growing region frontier. This is approx. 62 miles.
Table 2: Regression: Poverty and FemaleLiteracy

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<th>Panel A: Poverty Headcount Ratio (Paliha)</th>
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<td>10</td>
<td>11</td>
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<tr>
<td>State FE, &lt;100km</td>
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<tr>
<td>State FE, &lt;100km</td>
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<td>-0.561***</td>
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<td>-0.576***</td>
<td>-0.174</td>
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Sample restricted to municipalities containing 1790 pueblos de indios. Robust standard errors in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%; Note: ‘‘<100km’’ (75km) represents those municipalities within 100km (75km) of the optimal growing region frontier. This is approx. 62 miles (47 miles).
Table 3: Regression: Indigenous Language Use

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<td>Oaxaca only</td>
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Panel A: % speaking an indigenous language

- **Cochineal producer**
  - Coefficient: -0.067**
  - Standard Error: [0.028] [0.029] [0.028] [0.032] [0.034] [0.034] [0.042] [1.386] [1.165] [0.718] [0.655] [0.757]
  - p-value: <0.05

- **Hiker's distance to pre-Columbian sites, 1000km**
  - Coefficient: 0.443**
  - Standard Error: [0.178] [0.179] [0.179] [0.299] [0.309] [0.310] [0.329] [0.536] [0.535] [0.566] [0.520] [0.523]
  - p-value: <0.01

- **Hiker's distance to monasteries (16C), 1000km**
  - Coefficient: 1.343***
  - Standard Error: [0.165] [0.176] [0.173] [0.309] [0.316] [0.304] [0.308] [0.367] [0.493] [0.534] [0.542] [0.606] [0.566] [0.669]
  - p-value: <0.001

Observations: 1763
R-squared: 0.42

Panel B: % bilingual in Spanish and an indigenous language

- **Cochineal producer**
  - Coefficient: -0.038
  - Standard Error: [0.024] [0.025] [0.024] [0.027] [0.029] [0.028] [0.030] [0.034] [0.090] [0.091] [0.058] [0.059] [0.051]
  - p-value: <0.01

- **Hiker's distance to pre-Columbian sites, 1000km**
  - Coefficient: 0.352**
  - Standard Error: [0.131] [0.134] [0.130] [0.236] [0.245] [0.247] [0.245] [0.360] [0.388] [0.433] [0.401] [0.354]
  - p-value: <0.01

- **Hiker's distance to monasteries (16C), 1000km**
  - Coefficient: 0.877***
  - Standard Error: [0.116] [0.125] [0.121] [0.243] [0.250] [0.240] [0.244] [0.264] [0.331] [0.362] [0.464] [0.435] [0.447]
  - p-value: <0.001

Observations: 1763
R-squared: 0.44

Panel C: % monolingual in an indigenous language

- **Cochineal producer**
  - Coefficient: -0.028***
  - Standard Error: [0.008] [0.008] [0.008] [0.007] [0.007] [0.007] [0.007] [0.013] [0.046] [0.052] [0.177] [0.163] [0.277]
  - p-value: <0.001

- **Hiker's distance to pre-Columbian sites, 1000km**
  - Coefficient: 0.085
  - Standard Error: [0.066] [0.063] [0.066] [0.087] [0.087] [0.089] [0.128] [0.179] [0.144] [0.134] [0.199]
  - p-value: <0.001

- **Hiker's distance to monasteries (16C), 1000km**
  - Coefficient: 0.445***
  - Standard Error: [0.069] [0.069] [0.073] [0.090] [0.089] [0.090] [0.087] [0.160] [0.183] [0.150] [0.142] [0.264]
  - p-value: <0.001

Observations: 1763
R-squared: 0.44

Quadratic in Lat, Long, Altitude
- Coefficient: 0.25
  - Standard Error: 0.23
  - p-value: 0.21

Quadratic in Precipitation and Temperature
- Coefficient: 0.25
  - Standard Error: 0.23
  - p-value: 0.21

Quartic in Lat, Long, Altitude
- Coefficient: 0.25
  - Standard Error: 0.23
  - p-value: 0.21

Sample restricted to municipalities containing 1790 pueblos de indios. Robust standard errors in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%. Note: ‘<100km’ (75km) represents those municipalities within 1.00km (75km) of the optimal growing region frontier. This is approx. 62 miles (47 miles).
### Table 4: Regression: Inequality and Indigenous Governance

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#### Panel A: Gini coefficient

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<tr>
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<th>Cochineal producer</th>
<th>Hiker's distance to pre-Columbian sites, 1000 km</th>
<th>Hiker's distance to monasteries (16C), 1000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.022***</td>
<td>-0.104*** -0.116*** -0.113*** -0.046 -0.02 -0.06 -0.401 -0.208*** -0.116** -0.116*** -0.091 -0.069 -0.239***</td>
<td></td>
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<tr>
<td></td>
<td>[0.006]</td>
<td>[0.006] [0.006] [0.007] [0.007] [0.007] [0.007] [0.007] [0.008] [0.013] [0.159] [0.091] [0.085] [0.094]</td>
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<tr>
<td></td>
<td>0.021***</td>
<td>0.191*** 0.221*** 0.203*** 0.273*** 0.257*** 0.287*** 0.276*** 0.084 0.218*** 0.243*** 0.329*** 0.314*** 0.042</td>
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<tr>
<td></td>
<td>[0.006]</td>
<td>[0.037] [0.039] [0.062] [0.064] [0.066] [0.066] [0.065] [0.054] [0.053] [0.071] [0.070] [0.080]</td>
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#### Panel B: Distance to major 21st century roads (km)

<table>
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<tr>
<th></th>
<th>Cochineal producer</th>
<th>Hiker's distance to pre-Columbian sites, 1000 km</th>
<th>Hiker's distance to monasteries (16C), 1000 km</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>[0.810] [0.800] [0.803] [0.786] [0.800] [0.791] [0.805] [1.090] [30.406] [38.116] [12.050] [11.953] [25.225]</td>
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<td></td>
<td>2.037*** 31.118*** 27.326*** 26.362*** 78.527*** 35.922*** 34.979*** 27.700*** 23.729*** 73.168***</td>
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<td>[5.936] [5.770] [5.875] [7.781] [8.207] [7.198] [7.479] [7.422] [12.045] [12.819] [8.148] [7.654] [17.847]</td>
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#### Panel C: Municipality adopted Indigenous local governance institutions (Usos y Costumbres)

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<th>Cochineal producer</th>
<th>Hiker's distance to pre-Columbian sites, 1000 km</th>
<th>Hiker's distance to monasteries (16C), 1000 km</th>
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<tbody>
<tr>
<td></td>
<td>-0.515*** -0.477*** -0.500*** -0.525*** -0.533*** -0.529*** -0.532*** -0.819*** 2.108 1.155 -0.069 0.334 2.682</td>
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<tr>
<td></td>
<td>[0.149] [0.154] [0.149] [0.183] [0.193] [0.184] [0.194] [0.222] [1.677] [1.720] [4.017] [1.322] [2.282]</td>
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<td>[0.606] [0.641] [0.614] [1.024] [1.054] [1.036] [1.066] [1.280] [0.713] [0.661] [1.138] [1.102] [1.692]</td>
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</table>

Observations: 1763 1778 1763 1011 933 1011 933 485 1707 1707 975 902 451

R-squared: 0.19 0.18 0.19 0.24 0.25 0.25 0.26 0.16

Sample restricted to municipalities containing 1790 pueblos de indios. Robust standard errors in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%. Note: ‘‘<100km” (75km) represents those municipalities within 100km (75km) of the optimal growing region frontier. This is approx. 62 miles (47 miles).
## Table 5: Regression: Local Public Goods

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<td>-0.179</td>
<td>-1.293***</td>
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<td>[0.202]</td>
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<td>0.585***</td>
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<td>0.547**</td>
<td>0.521**</td>
<td>0.511**</td>
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<td>0.691***</td>
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### Panel A: % Households without piped water

### Panel B: % Households without electricity

### Panel C: % Households without drains

Sample restricted to municipalities containing 1790 pueblos de indios. Robust standard errors in brackets; * significant at 10%; ** significant at 5%; *** significant at 1%; Note: ‘<100km’ (75km) represents those municipalities within 100km (75km) of the optimal growing region frontier. This is approx. 62 miles (47 miles)