Export Commodity Booms, Labor Coercion, and the Historical Containment of Education*

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Current version: February 2010

First version: May 2007

Abstract: A significant share of labor arrangements during the colonial period in the Americas involved the use of coercion. To what extent did labor coercion affect individuals' accumulation of human capital? What was the role of primary commodity exports in influencing this relationship? We study these questions in the context of nineteenth century Puerto Rico, where unskilled laborers were forced to work for legally-titled landowners from 1849 until 1874. We develop a model of labor market coercion under an elite-controlled regime, and show that coercion depresses the effective wages of unskilled labor, inducing workers to acquire more schooling than in a case without coercion. Guided by this model, we use unique micro data from individuals and municipalities in Puerto Rico and exploit variation in the suitability of coffee cultivation across municipalities and changes in world coffee prices across time to estimate the response of schooling to coffee price changes. During the coercive period, governments in coffee growing regions allocated more public resources towards coercive labor measures and fewer resources towards primary schooling – with the latter declining 40 percent. Following the abolition of coercive measures in 1874, literacy rates declined 25 percent, consistent with a significant drop in the skilled labor wage differential. These results strongly suggest that labor market liberalization reduced the extraction of rents from unskilled laborers' wages by local landowners.

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* A previous version of the paper was titled "Endowments, Coercion, and the Historical Containment of Education". We appreciate the discussions with Dwayne Benjamin, Loren Brandt, and James A. Robinson, as well as helpful comments and suggestions by Ken Chay, Ernesto Dal Bó, Stanley Engerman, Berta Esteve-Volart, Fred Finan, Price Fishback, Claudia Goldin, Deepak Lamba-Nieves, Naomi Lamoreaux, Ted Miguel, Francisco Moscoso, Petra Moser, Nathan Nunn, Torsten Persson, João Manoel Pinho de Mello, Carlos Serrano, Dan Trefler, and numerous seminar and conference participants. We are especially grateful to Miguel Vega, Angel Ríos, María Isabel Rodríguez, Pedro Roig, José Charón, and the personnel at the Puerto Rico Collection of the University of Puerto Rico-Río Piedras Library and the P.R. General Archives for their assistance and support throughout. Emilú Berríos De León, Enrique Bobonis, Aileen Cardona, Nicole Díaz, Jonatham Quiñones Roque, Evangelina Pérez, and Waldemar Pérez provided superb research assistance. Antonio González's ArcGIS expertise proved of invaluable assistance. Research support from the All-UC Group in Economic History, the University of Toronto Connaught Fund, SSHRC, and the Canadian Institute for Advanced Research is gratefully acknowledged. We are responsible for any errors that may remain.

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I. Introduction

A significant portion of labor arrangements throughout modern history have involved the use of coercion. Slavery was the most common form of labor in the plantation economies of the Caribbean, in parts of South America such as Brazil, Colombia, and Venezuela, and in the Southern United States (Mintz 1969; Fogel and Engerman 1974; Wright 1978; Lockhart and Schwartz 1983). Other forms of coerced labor – such as anti-vagrancy laws and debt servitude – also played an important role in these economies. These types of arrangements permeated the hacienda and plantation systems throughout the region, notably during the expansion of the Atlantic trade (e.g., Coatsworth 1974; Katz 1974; Lockhart and Schwartz 1983; McCreery 1994).

A large literature across the social sciences has argued that among the former American colonies, a society's dependence on coercive forms of labor had substantial negative consequences for its economic development. Following Moore (1966), this literature argues that these forms of economic organization concentrated power in the hands of small groups of elites and thus adversely affected the development of domestic political and economic institutions needed for sustained growth (e.g., Engerman and Sokoloff 1997; Coatsworth 1999).[1] Consistent with these arguments, empirical studies have found a negative relationship between current economic development and the historical prevalence of slave use across U.S. states and counties (Mitchener and McLean 2003; Lagerlöf 2005) and across British colonies in the Caribbean (Nunn 2008). However, establishing the causality of these and other forms of labor coercion on these countries' economic trajectories is difficult due to potentially confounding effects, such as differential degrees of economic inequality and ethno-linguistic polarization.[2]

In this paper, we examine the consequences of labor market coercion for individuals' decisions to accumulate human capital, arguably one of the most prominent determinants of long-run development throughout the nineteenth and twentieth centuries.[3] We study legislation by the Spanish government in Puerto Rico that forced free unskilled workers—*jornaleros*—to seek employment on legally titled farms during the 1849-1874 period, followed by labor market liberalization brought about by abolition of this legislation. Combining these labor regime changes with exogenous variation in coffee prices allows us to study the following two questions. First, how did labor market coercion affect the incentive of individuals

[1] Engerman and Sokoloff (1997), Acemoglu, Johnson and Robinson (2001), and Acemoglu and Robinson (2005) among others study the roles played by the limited extension of voting rights and the lack of constraints on government rent-seeking activities on countries' long-run economic performance. Engerman, Mariscal, and Sokoloff (2002) and Galor, Moav, and Vollrath (2008) examine the consequences of colonial inequality for the provision of growth-generating public goods such as schooling across the Americas and within the U.S., respectively.

[2] Other competing explanations concentrate on differences in legal systems (La Porta et al. 1999), contemporaneous effects of the tropical disease burden on health and development (Bloom and Sachs 1998), selective migration of colonizers (with varying levels of human and social capital) into different countries (Glaeser et al. 2004), and differences in the ethnic and religious composition of populations across regions (Easterly and Levine 1997).

[3] See Galor (2005) for a survey of the literature on human capital accumulation and long-run development.

to accumulate human capital? Second, what was the role of primary commodity exports in influencing this relationship?

To guide our empirical analysis, we first develop a general equilibrium model of public provision of education, coercion of unskilled workers, and workers' endogenous human capital accumulation decisions in a small open economy. We show that in the absence of coercion, if a commodity boom affects both the skilled labor wage premium and government tax revenue, the equilibrium amount of educational attainment will be determined by government revenue-driven supply and skill premium-driven demand factors. We then introduce a coercive regime in which an elite-controlled government reallocates resources away from educational public goods and into the enforcement of coercive labor regulations, allowing landowners to pay below-market wages to unskilled workers. We show that labor market coercion dampens the effect of the commodity boom on unskilled laborers' wages, effectively increasing the relative returns to education and inducing workers to accumulate human capital in the face of rising coffee prices. [4]

We then use unique micro data on cohorts of individuals and municipalities in Puerto Rico to examine these issues empirically. We exploit variation in the suitability of coffee cultivation across municipalities and coffee prices over time using a difference-in-difference specification to examine the predictions of the theoretical model. We find that during the coercive period, coffee-region local governments allocated more public resources towards the enforcement of coercive labor measures and allocated fewer resources towards the provision of primary schooling – a 40 percent relative decline in the provision of public primary schools. We also find that increased coffee prices led to no change in individuals' literacy rates in coffee growing regions during the coercive period. After the abolition of coercion in 1874, similar changes in coffee prices reduced literacy rates by 25 percent as the relative return to remaining unskilled increased. These results suggest that the abolition of coercion had important welfare consequences as it eliminated landowners' ability to extract unskilled workers' income but also reduced laborers' incentives to accumulate human capital.

The richness of the data allows us to distinguish our explanation for educational outcomes from competing theories of long-run development in the Americas. Using unique land registry data during the end of the coffee booms we show that the coffee region did not experience a disproportionately greater concentration of land relative to a comparison group of municipalities. We also present evidence that rules out other explanations for our results, such as differences in natives' sorting patterns across regions, in transportation cost changes and other technological improvements, and alternate consequences of the

[4] Our theoretical framework is related to Acemoglu (2006)'s argument that inefficient economic institutions such as coercive labor regulations that promoted factor price manipulation (i.e., wage depression) may have been instituted by governing elites to redistribute rents away from poor and middle classes. It also relates to Domar (1970), who argued that in low population density environments, a competitive labor market economy would result in high wages thus increasing the incentives to enslave workers.

establishment of a coercive political system. In summary, our findings emphasize the incentive of elites to create and maintain a coercive labor regime under a non-democratic political system as the main mechanism for the apparent divergence in local governments' policy choices, and for the interaction of this incentive with workers' incentive to accumulate human capital in explaining patterns of literacy.

Our work relates to an extensive literature on the impact of globalization on the transformation of labor institutions. Economic historians have extensively studied the role of export commodity booms on labor coercion in the contexts of U.S. slavery and European serfdom (e.g., Fogel and Engerman 1974; Wright 1978; 1986; North and Thomas 1973; Brenner 1976). Postan (1944) pointed out that serfdom declined most in the period after the Black Death when trade *collapsed*, and that the re-introduction of serfdom in Eastern Europe correlated closely with the trade expansion in the Baltic in the late Medieval period.[5] A well developed literature also examines how the globalization boom in the late nineteenth century led to the deterioration of labor (and other) institutions in parts of Latin America, including Mexico and Guatemala (e.g., Coatsworth 1974; McCreery 1994). These arguments are consistent with our findings, as more profitable trade opportunities may have increased wages of unskilled workers leading to increased coercion. To our knowledge, our paper is the first to document and quantify the general equilibrium consequences of labor coercion for individuals' human capital accumulation decisions using exogenous within-country variation.

The paper is structured as follows: Section II describes the historical background and context. Section III presents our theoretical framework. Section IV describes of the data used in the analysis and discusses the empirical strategy. Section V presents the central empirical results of the paper, evidence supporting the identifying assumptions, and robustness tests. Section VI discusses alternative explanations. Section VII concludes.

II. Historical Background

In this section we discuss essential features of nineteenth century colonial Puerto Rican economy, the coffee industry in particular, and institutional details affecting the enforcement of coercive labor regulations and the provision of public primary schooling in this period.

II.A. The Coffee Industry in Puerto Rico throughout the 19th Century

Starting in the late eighteenth century and for extended periods throughout the nineteenth century, an international coffee boom increased coffee cultivation and processing in Puerto Rico (P.R.) (Topic

[5] Acemoglu, Johnson, and Robinson (2005a) examine the effect of globalization in early modern Europe under heterogeneous political institutions. They find that trade stimulated growth in locations where initial political institutions placed significant checks on the monarchy and the opposite took place in places with initially poor political institutions.

1998).[6] From 1828-1855, the coffee industry remained small with the volume of coffee exports averaging 9.8-12.2 million pounds (Figure 1, Panel A). Throughout the 1820s and early 1830s, economic activity concentrated in the sugar industry (Scarano 1984). Starting in the mid-1850s, coffee exports increased drastically, stimulated by rising international coffee prices.[7] During 1871-1881, Puerto Rican coffee exports increased 227 percent to 47.2 million pounds, reaching a peak of 58.0 million pounds in 1896, up fivefold from the mid-1850s. By the turn of the century, the coffee sector had become a major driver of P.R.'s economy (Dietz 1986).

Although coffee became central to the local economy, P.R. remained a relatively minor player in the international coffee market throughout the period. During the mid-1860s, 60 percent of world coffee exports was produced in Brazil. As the dominant producer in the world during the period, Brazil's exports largely influenced the international price of coffee (Bates 1997). Variation in international coffee prices throughout this period can be attributed largely to the Brazilian coffee industry (Figure 1, Panel B). In contrast, exports from P.R. constituted less than 4 percent of world exports. Importantly, this allows us to consider international coffee prices as exogenous to P.R.'s production.

Throughout the second half of the nineteenth century, coffee cultivation was concentrated in the west-central region of the island which possessed the most favorable geographic characteristics for cultivation:.[8] We focus on high annual rainfall and cool temperatures as factors that led to the geographic concentration of coffee production in this region. Figure 2 shows a precipitation map of Puerto Rico using estimates from data for the years 1971-2000 (National Weather Service 2007). Average annual precipitation is highest in the West-Central region of the island, followed by the East-Central region. A similar pattern holds using data for the 1899-1930 period. Annual rainfall levels are higher in the West-Central than in the East-Central region (90.2 inches and 74.1 inches, respectively; Table 1, Panel A). Annual precipitation levels above 80 inches are required for high coffee yields. Below this threshold coffee trees are prone to attacks by the coffee leaf miner (Roberts 1941). Based on cumulative monthly precipitation averages, the West-Central region surpasses this threshold during the month of October, whereas precipitation in the East-Central region never reaches this threshold.

As coffee trees produce higher yields in cooler climates, the West-Central region also benefited from cooler temperatures relative to the East-Central region (with average minimum temperatures of 63.2

[6] Abbad y Lasierra (1788) had noted coffee's role in the contraband trade with foreigners in the 1770s. The stimulus provided by the rise in international coffee prices after the Haitian revolution led to the general expansion of coffee cultivation, particularly in coastal municipalities (Bergad 1983; Ledrú 1863). However, by the first decade of the nineteenth century, the boom conditions of the 1790s subsided as new world market supplies satisfied the demand created by the decline of Haitian exports.

[7] Coffee trees require five to seven years after planting to achieve high coffee bean yields. It comes as no surprise that the surge in coffee exports thus follows the increase in coffee prices by approximately seven years.

[8] The West-Central region encompasses the municipalities of Adjuntas, Ciales, Jayuya (part of Utuado at the time), Lares, Las Marías, Maricao, San Sebastián, Utuado, and Yauco

ºF and 66.7 ºF, respectively),.[9] Apart from differences in precipitation and temperature, other geographic, socio-economic, and demographic characteristics across the two groups of municipalities were very similar based on a census of all municipalities carried out by provincial authorities in 1828 (Table 1, Panels B and C).[10]

These precipitation and temperature differences led to the establishment of the coffee industry in the West-Central region, and the production of food crops, cattle ranching, and later some tobacco, in the East-Central. As of 1896, 12.3 percent of all land in the West-Central region was under coffee cultivation, relative to only 4.1 in the East-Central region. Moreover, the relationship between annual precipitation levels and the extent of coffee cultivation is quite strong.[11] Figure 3 plots the bivariate relationship between a municipality's mean annual rainfall levels between 1899 and 1930 and the share of all land under coffee cultivation for the 24 municipalities in central Puerto Rico, as well as a linear OLS fit. The relationship between annual precipitation and coffee cultivation is strongly positive.[12] This quantitative evidence is corroborated by historical accounts of differences in coffee cultivation due to rainfall and temperature differences across municipalities (Bergad 1983; Cabrera Collazo 1988; Picó 1987; 2007; Seda Prado 1996).

Table 2 documents that this relationship is robust to conditioning on other geographic factors. The unconditional relationship between precipitation and coffee cultivation in the year 1896 indicates that municipalities with annual rainfall levels 10 inches higher had, on average, a 4.4 percentage points (67 percent) higher share of agricultural land under coffee cultivation (column 1). Conditioning on other geographic controls (the municipality average annual maximum and minimum temperatures, mean altitude, mean degree of ruggedness as proxied by the land gradient, and distance to the nearest port) the relationship is significant at 3.8 percentage points (58 percent; column 2). Since the suitability for coffee cultivation varies significantly over the municipalities of the central region, we are able to exploit these differences to examine the impact of the expansion of the coffee industry on the local enforcement of labor institutions and the sub-national educational outcomes of the population.

II.B. Coercive Labor Institutions and their Local Enforcement [13]

[9] This difference is significant at 95 percent confidence, Panel A.

[10] Measures of geological determinants of crop-specific agricultural productivity at the municipality-level (i.e. soil pH and permeability) also indicate that the West-Central region is more suitable for coffee cultivation (Acevedo and Gierbolini 1982; Gierbolini 1982a,b; Boccheciamp, 1982a,b).

[11] This relationship holds unconditionally as well as conditional on other geographic determinants of coffee suitability

[12] The relationship is robust to the exclusion of Las Marías and Maricao, municipalities located in the West-Central region which were founded in the 1870s. Due to the lack of longitudinal data on the area under coffee cultivation for each municipality, it is not possible to show evidence on the specialization of municipalities in coffee cultivation over time.

[13] This section provides a brief sketch of local government activities. Useful more specialized overviews are Bergad (1983) and Trías Monge (1980).

In 1849, the provincial government established a General Laborers' Law ("*Ley General de Jornaleros"*). This legislation established the legal capacity for landowners to coerce free laborers. Specifically, it entailed a series of measures to control the mobility and work activities of landless peasants and small landowners by establishing a legal category of "*jornaleros*".[14] This category was composed of all male individuals who could not prove land ownership or did not own more than two "*cuerdas*" of land and had no professional skill. Those classified as *jornaleros* were forced to seek employment on legally titled farms where employers were empowered to record work schedules, behavior, and insular movement in small notebooks ("*libretas*") to be carried at all times by the *jornalero* population (Bergad 1983; p. 92). Any *jornalero* found with no labor contract or in breach of one could be denounced as vagrant by the district commissioner. Three denunciations led to prison time. A second measure required authorization from local authorities for peasants to migrate across municipalities, substantially restricting inter-municipality migration (Picó 1979; Figueroa 2005).

Vigilance and enforcement of these measures, which lasted until 1874, was assigned to municipal governments. Local authorities prepared censuses of jornaleros for the enforcement of these regulations and undertook policing and law enforcement duties, as evidenced by the records of anti-vagrancy councils ("*Juntas de Vagos y Amancebados*"). The historical literature documents that the enforcement of these measures varied substantially across municipalities. Bergad (1983) provides qualitative evidence that in the coffee growing municipality of Lares, enforcement was influenced substantially by commodity prices and local labor market conditions. In the municipality of Utuado there is also significant documentation of individuals spending prison time in San Juan as a result of the vagrancy law (Picó 1979). In contrast, Picó (2007) documents that in the East-Central municipality of Cayey, although "…during some years certain rigor in controlling the conduct of landless peasants was observed […], it was quite rare that "jornaleros" from Cayey would be sent to "La Puntilla" [the San Juan prison]."

We provide systematic quantitative evidence of the enforcement of these coercive measures across municipalities by constructing quantitative measures of enforcement of these regulations for a sub-sample of five central municipalities.[15] Based on the monthly acts of the anti-vagrancy councils for the years 1851-1867, we construct two measures of sanctioning of *jornaleros*: the annual share of jornaleros ordered to spend prison time as a result of three denunciations, and the annual share of laborers accused or denounced in the anti-vagrancy councils.

Panel A of Figure 4 illustrates the two-year cumulative share of laborers spending time in prison in three high rainfall municipalities (Comerío, Lares, and Yauco; represented by the solid brown line) and in two low rainfall municipalities (Caguas and Juncos; represented by the dashed green line). Although

[14] The establishment of the General Laborers' Law of 1849 was closely linked to addressing problems of limited labor supply in the sugar industry, concentrated in coastal municipalities.
[15] See the Data Appendix for details of the construction of the libreta sanctioning measures.

only suggestive due to the small sample size, the cumulative proportion of penalized laborers is greater in the high rainfall municipalities at all points in time. More importantly, this measure increases substantially following a significant coffee price increase in the mid-1850s (marked by a solid red line). In contrast, low rainfall municipalities display no evidence of laborers being penalized with prison time by the anti-vagrancy councils. A similar pattern holds in the cumulative share of laborers accused of or denounced for vagrancy: this proportion increases steadily in the high rainfall municipalities – to 23 percent of the jornalero population by the mid-1860s – and the difference across high and low rainfall municipalities increases during the mid-1850s coffee price boom (Panel B).

Additional evidence of the importance of the coercive labor system in the coffee-region municipalities comes from a survey of municipal governments carried out by the provincial government in 1866 regarding the potential abolition of the regime. The Provincial Governor requested that all municipal authorities provide their preferences over the elimination of the coercive regime as well as reasons for this preference.[16] Using binary responses for 16 central region municipalities, a simple correlation with annual rainfall levels shows that coffee region municipalities were (significantly) more likely to be opposed to the elimination of the system. A ten inch increase in annual rainfall levels reduces the probability of reporting a preference for the elimination of the *libreta* by 16 percentage points.[17] This corroborates historical accounts that the preference for and enforcement of these coercive labor laws was heavily influenced by commodity prices and the associated increase in unskilled labor demand at the local level.

The coercive labor regime was eliminated in 1874 in response to concerns about political unrest throughout the remaining Spanish colonies in the Caribbean (Cuba and P.R.). There is evidence of substantial wage increases among the *jornalero* population following this labor market liberalization. Modal wages for the *jornalero* population increased from 5 pesos per month for 1850-1873, to 9 pesos per month in 1874, 12.50 pesos in 1886, and 24 pesos in 1889.[18] This limited evidence on the stability of *jornalero* wages during the coercive period and increases following labor market liberalization is suggestive of how powerful a tool coercion was for landowners.

II.B. Municipal Governments Institutions and the Provision of Public Primary Schooling [19]

[16] The main 'survey' question requested by the Marchesi administration to be answered by each local government was the following: "Should the *libreta* be eliminated or sustained, as is or with any amendment?" (authors' translation).
[17] This is a 51 percent 'effect', given an average positive preference of 31 percent; significant at 90 percent confidence; not shown in the tables. The estimated relationship is robust to the inclusion of the same geographic controls, although the point estimates are less precisely estimated. The results are available from the authors upon request.
[18] These nominal modal monthly wage rate figures are based on evidence from various hacienda records in Buitrago (1976) and Bergad (1983).
[19] This section provides a brief sketch of local government institutions and activities. Useful more specialized overviews are Coll y Toste (1909), Flores Collazo (1991) and Trías Monge (1980).

Municipal governments carried out a wide range of activities in nineteenth century Puerto Rico, including the collection of property and excise taxes, the allocation of municipal resources for the provision of local public goods, and the enforcement of some provincial legislation.

The local government executive throughout the period was composed of mayors ('alcaldes ordinarios') and council members ('regidores'). Municipal governments in Puerto Rico were the only government jurisdiction in which natives gained any political representation until the turn of the century. Municipal council members were elected by eligible voters, defined as males, 21 years of age or older, who were literate, with a minimum residence period in the municipality of two years, and paying a minimum amount of income and/or property taxes annually (25 pesetas), or who were municipal government employees or professionals. Council members provided a short list of candidates to the Governor for the positions of mayor and lieutenant mayor. The Governor had the power to appoint individuals to these positions.[20]

The mayor and members of the municipal boards enjoyed in practice a significant degree of control over municipal activities (e.g., construction and administration of primary schools, supervision of public works projects and maintenance). Because of very limited accountability to the majority of the local population, these officials possessed significant leeway in terms of the administration of the local territories. Municipal authorities thus possessed both de jure and de facto power over several dimensions of crucial importance, such as the enforcement of coercive measures against laborers and the provision of primary schooling.

Provincial governments throughout the 19th century provided very limited regulation and promotion of public primary education in the Island until the last three decades of the nineteenth century (Coll y Toste 1909; Osuna 1949; Cuesta Mendoza 1974). Although there were various attempts at establishing an island-wide public school system from the 1820s onwards, these plans did not fully materialize until 1865.

Because of discontent with the Spanish regime at that time, the central government instituted a number of reforms to promote the establishment of a public primary school system.[21] Importantly, although guidelines from the central government were provided as to the need for primary schools in each municipality, the founding, financing, and management of schools remained under the responsibility of municipal governments. Opposition by municipal governments to such legislation led to heterogeneity in the founding and management of public primary schools across municipalities during the last third of the

[20] The Governor also had the capacity to name individuals outside the short list for these executive positions, as well as the power to remove officials from office.

[21] This education law, the Organic Decree of June 10, 1865, instituted a number of reforms to rationalize the curriculum, standardize the system of public primary education, to promote the training and qualification of teachers. However, according to education historians, the legislation was implemented with very limited success.

nineteenth century.[22] The operation of the educational system would continue in this manner, with minor reforms, until the end of the century.

III. Theoretical Framework

To guide our empirical analysis, we develop a general equilibrium model of labor market coercion of unskilled workers, public provision of education, and workers' human capital accumulation decisions in a small open economy. We examine the equilibrium educational responses to an increase in an export commodity price (i.e., coffee).

We start by solving for equilibrium educational attainment where potential students weigh the returns from schooling against the opportunity cost of the forgone unskilled wage and not working during matriculation. The quantity of educational capital supplied by the government directly affects the quality of education. If a commodity boom affects both relative wages and government tax revenue, the equilibrium amount of educational attainment will be determined by the interaction of these factors. Under reasonable parameter restrictions, we find that the coffee boom in Puerto Rico led to *lower* educational attainment during the period considered.

We then introduce a regime in which the government can expend resources to enforce coercive labor regulations that allow landowners to offer below-market wages to unskilled laborers. Coercive efforts are only undertaken against unskilled workers leading to an additional incentive to obtain an education as a protectant against such coercion.[23] We then analyze the response of education to a commodity boom where unskilled labor is subject to labor market coercion and compare this to the result without coercion. Under reasonable parameter values, we find that the negative educational attainment response to an increase in the price of coffee is mitigated and possibly undone in this case relative to the case without coercion.

III.A. Model of Public Education Provision and Skills Accumulation without Coercion

Consider a small open economy that produces three goods subject to exogenous world prices: coffee (c), food (f), and tobacco (b). The three factors of production are unskilled labor (U), skilled labor (S), and land (L). Factors are mobile across sectors with factor prices w_u, w_s, and r, respectively. Production in all sectors is subject to constant returns to scale. Assume that the economy is diversified with an equal number of goods and factors so that factor prices are determined by international goods prices. Factor markets clear such that $U_c + U_b + U_f = U$, $S_c + S_b + S_f = S$, and $L_c + L_b + L_f = L$. The total

[22] See Osuna (1949), De la Rosa Martinez (1980), Colón Ramírez (1994) for detailed accounts.
[23] Given the political structure/environment, even though we could allow for government-backed coercion of skilled workers, this will not occur in equilibrium. We abstract from this additional coercive instrument.

population size is exogenous and fixed, but its composition between unskilled and skilled labor is determined endogenously. The stock of land is exogenous and fixed.

We follow Findlay and Kierzkowski (1983) in examining the endogeneity of the stocks of skilled and unskilled labor in an overlapping generations model. $N_{0,t}$ individuals are born each period t and live for two full periods. We define a household as two generations co-existing at a given time t: one youth and one adult. In the following period, the adult dies, the child becomes an adult, and a new child is born. $N_{0,t}$ is the total number of youth and $N_{1,t} \equiv N_{0,t-1}$ is the total number of adults such that the total population at any period is $N_t = N_{0,t} + N_{1,t}$.

Each period the altruistic adult in the household chooses the youth's education level to maximize the child's lifetime income. The choice is discrete – the youth either attends school or works as an unskilled laborer. If the youth remains unskilled he earns the going wage for unskilled labor for two periods. To become a skilled worker, the youth attends school in the first period and works in the second period earning the going wage for skilled labor. An education can only be obtained during youth. Therefore the aggregate number of unskilled workers is $U_t = U_{0,t} + U_{1,t}$, the number of skilled workers is $S_t = E_{1,t}$, and $E_{0,t}$ is the number of students such that the total population is $N_t = S_t + U_t + E_{0,t}$.

Provision of Public Education

An education sector combines students with educational capital K_t (e.g., schools) to produce skilled workers. The total flow of skills Q_t is produced according to the following constant returns to scale production function:

$$Q_t = F(K_t, E_{0,t}) \tag{1}$$

which is increasing in each of its arguments with diminishing marginal products. The effectiveness of a worker educated that period, as measured by skill per worker, is denoted by $q_t = Q_t/E_{0,t} = f(k_t)$ where $k_t = K_t/E_{0,t}$. Thus, the effective stock of skilled labor can differ from the physical stock due to productivity enhancing education. Assume that educational capital depreciates fully each period.

We model K_t as a public good whose equilibrium value is determined endogenously. We assume that the government maximizes the sum of landowners utility and skilled workers' altruistic utility (both assumed to be linear in income) given an exogenous linear tax rate on land.[24] We view this as being a reasonable representation of the government's objective function given that only landowners and skilled workers were given the right to vote and they comprised the entirety of the legislative body. This leads to maximizing the following function with respect to educational capital expenditures at time t where β is the exogenous discount factor:

[24] The budget data collected by the authors indicates that property taxes were the main source of local government revenue.

$$(1-\tau)r_t L + w_{s,t} f(k_{t-1})E_{1,t} + \beta E_t\left[w_{s,t+1} f(k_t)E_{0,t}\right].$$[25]

Trivially, this leads to a corner solution in which all tax revenue is spent on educational capital for youth:

$$K_t = \tau r_t L. \tag{2}$$

Household Educational Decisions

Adults in each household decide whether to send their youth to school considering the payoff to an education relative to the youth working as an unskilled laborer. The key tradeoff is that youth can earn a higher wage by obtaining an education but the payoff is deferred. The wage that each physical skilled worker earns as an adult at time t is comprised of two components: the wage per effective skilled worker ($w_{s,t}$) and the number of effective skilled workers each physical skilled worker comprises ($f(k_{t-1})$) which is determined in youth. Consequently, the present discounted value of a stream of payments to a skilled worker (at the time of their birth) is as follows where $E_t[\bullet]$ is the expectations operator:

$$\beta E_t\left[w_{s,t+1} f(k_t)\right]. \tag{3}$$

Because of our assumption that education is provided as a public good, the only cost associated with education is the forgone unskilled wage stream:

$$w_{u,t} + \beta E_t\left[w_{u,t+1}\right]. \tag{4}$$

The condition that imposes indifference for educational attainment is one in which the (deferred) payments to a skilled worker must equal the stream of forgone wages if a worker is to remain unskilled over the entire time span. Assume that goods prices (and therefore factor prices) follow a random walk such that the current wage is each individual's best guess of the wage that will prevail when they are adults.[26] This leads to the indifference condition

$$\beta w_{s,t} f(k_t) = (1+\beta) w_{u,t}. \tag{5}$$

Rearranging this expression, equilibrium skill per worker is a function of wages and the discount factor:

$$f(k_t) = \frac{w_{u,t}}{w_{s,t}}\left[\frac{1+\beta}{\beta}\right]. \tag{6}$$

[25] For simplicity, we assume that all students have educated parents. This will not affect the results of the non-coercion case but will restrict the dynamics of the coercion case which we will discuss next.

[26] This allows $E_t[w_{s,t+1}] = w_{s,t}$ and $E_t[w_{u,t+1}] = w_{u,t}$. All agents are risk neutral such that uncertainty plays no role.

We refer to this as the *educational indifference condition*.[27] This expression shows that educational capital per student will fall as the relative wage of skilled workers increases. This result comes from the fact that this is an indifference condition; as the relative wage of skilled workers increases, indifference for a potential student requires that education must be relatively less skill augmenting, due to a smaller amount of educational capital per student.

Due to the structure of the model, the equilibrium can be solved for recursively. Exogenous goods prices determine a unique vector of factor prices. These factor prices can be combined with the tax revenue and equilibrium skill per worker conditions (equations (2) and (6)) to deliver equilibrium values of K_t and k_t which can then be used to solve for $E_{0,t}$, and, subsequently $E_{1,t+1}$.

Determination of Factor Prices

As previously noted, with an equal number of factors and goods and no factor intensity reversals, the following three zero profit conditions pin down equilibrium factor prices as a function of international goods prices where we take tobacco as the numeraire good and suppress time subscripts for convenience:

$$\begin{aligned} p_c &= a_{sc}w_s + a_{uc}w_u + a_{lc}r, \\ p_f &= a_{sf}w_s + a_{uf}w_u + a_{lf}r, \\ 1 &= a_{sb}w_s + a_{ub}w_u + a_{lb}r, \end{aligned}$$

where a_{ij} is the unit input requirement of factor $i \in \{s,u,l\}$ in production of good $j \in \{c,f,b\}$. Taking proportional changes of the system of zero profit conditions and expressing it in matrix notation yields

$$\begin{pmatrix} \hat{p}_c \\ \hat{p}_f \\ 0 \end{pmatrix} = \begin{pmatrix} \theta_{sc} & \theta_{uc} & \theta_{lc} \\ \theta_{sf} & \theta_{uf} & \theta_{lf} \\ \theta_{sb} & \theta_{ub} & \theta_{lb} \end{pmatrix} \begin{pmatrix} \hat{w}_s \\ \hat{w}_u \\ \hat{r} \end{pmatrix},$$

where θ_{ij} represents the relevant cost share for factor i in production of good j. As is well known (e.g., Ethier 1983) the Stolper-Samuelson theorem loses a great deal of intuitive content and its ability to predict changes in factor prices in response to the change in the price of a given good when there are more than two goods and two factors. Consequently, we restrict the cost share parameter space considered above and state the following proposition:

[27] Note that we can introduce a weight that adults place on their children's welfare. For example, the adult might value children's skilled and unskilled wages as $\alpha\beta w_s f(k)$ and $\alpha(1+\beta)w_s$ where $\alpha < 1$. However, these terms will cancel such that equation (6) will be unaffected.

Proposition 1. *If* $(\theta_{sb} / \theta_{lb}) > (\theta_{sf} / \theta_{lf})$ *and* $(\theta_{sf} / \theta_{uf}) > (\theta_{sb} / \theta_{ub})$*, and* θ_{sc} *is sufficiently small, then an increase in the price of coffee will lead to an increase in the wage of unskilled labor and an increase in the rental rate of land. In addition, the wage of skilled labor will fall.*

Proof. See Appendix B.

We have substantially restricted the unit input requirements in deriving this proposition. We do so not to generate a specific theoretical result but rather to "match the moments" in which a rise in coffee prices led to increases in the wages of unskilled labor and land rents during the coffee boom in Puerto Rico during this time, based on historical accounts (Buitrago 1976; Bergad 1983).[28]

The Response of Education to a Change in the Price of Coffee without Coercion

This framework delivers the result that an increase in the price of coffee is likely to lower educational attainment across stationary equilibria where $E_{0,t}=E_{1,t}$. For all comparative statics, understand "changes" to refer to differences between stationary equilibria. Because we analyze differences in stationary equilibria, we suppress the time subscript t. Based on equation (2) and Proposition 1, the provision of educational capital rises as tax revenue rises in response to increasing land income ($K \uparrow$). The equilibrium amount of educational capital per student rises ($k \uparrow$) as the unskilled-skilled wage gap narrows. The movement in E is ambiguous as both K and k increase. A larger quantity of educational capital normally increases the attractiveness of education for a given set of relative wages. However, as the relative value of remaining unskilled increases, households demand relatively less education. We can see this by taking proportional changes of equations (2) and (6), and combining them to deliver:

$$\hat{E} = \hat{r} - \frac{1}{\varepsilon_{f(k),k}}\left[\hat{w}_u - \hat{w}_s\right]. \tag{7}$$

where $\varepsilon_{f(k),k} = (\partial f(k) / \partial k)(k / f(k))$.

This expression is useful in that it decomposes the change in educational attainment into "supply side" and "demand side" effects. The "supply side" effect comes from the fact that increased land rents lead to increased tax revenue and greater expenditure on educational capital which is complementary with the number of students in the skills production function (equation 1). The "demand side" effect shows that the incentive to obtain an education declines because the relative wage of unskilled to skilled labor increases due to Stolper-Samuelson effects. If the "supply side" effect dominates, then E will rise. If the change in relative wages is strong enough, the "demand side" effect dominates and E falls. The latter case provides a simple model of how increased coffee prices can lead to falling educational attainment. Noting that $f(k)$ is subject to diminishing returns in k and using equation (7), if unskilled wages increased

[28] We also explain the economic representation of these assumptions in Appendix B.

proportionally more than land rents as a result of a coffee price increase, this is sufficient for educational attainment to have fallen. Consequently, with no coercion, we predict that the demand side dominates and that *E* falls as the price of coffee rises. We maintain this assumption for the entirety of the paper.

III.B. Public Education Provision and Skills Accumulation with Endogenous Coercion

We now introduce the possibility that tax revenue does not go exclusively to educational capital but can also be allocated towards the enforcement of coercive labor market regulations through which unskilled workers are paid below-market wages. The government spends its tax revenue on some combination of educational (*K*) and coercive (*V*) capital. As with educational capital, we assume that coercive capital fully depreciates at the end of each time period.

As mentioned in Section II.B, the local enforcement of the *libreta* regime was carried out by policing laborers; *jornaleros* who were found with no labor contract or in breach of one would be sent to prison. We model this by allowing workers to choose to work for a landowner under a coercive contract, or attempt to breach this contract and work in some farm household production at the market clearing wage. With probability $\pi(V)$ the laborer is caught in breach of the regulation, is imprisoned for a period and receives a payoff that we normalize to zero. With probability $1 - \pi(V)$ such attempt at avoiding the ex ante coercive contract is successful, in which case the worker earns the non-coercive wage w_u. Greater coercive capital expenditures increase the probability that laborers are caught in breach of the law ($\pi'(V) > 0$), but this is subject to decreasing marginal effectiveness (($\pi''(V) < 0$).

We assume that firms pay unskilled workers a coercive wage equal to their expected return from attempted escape $w_c \equiv (1 - \pi(V))w_u$.[29] Consequently, the educational indifference condition becomes:

$$f(k) = \left[\frac{1+\beta}{\beta}\right]\frac{[1-\pi(V)]w_u}{w_s}. \tag{8}$$

As before, the government maximizes the utility of landowners and the altruistic utility of skilled workers.[30] In this case, the government's objective function is:

$$(1-\tau)r_t L + \pi(V_t)w_{u,t}U_{1,t} + w_s f(k_{t-1})E_{1,t} + \beta E_t\left[w_s f(k_t)E_{0,t}\right] \tag{9}$$

[29] Assume that workers can be "re-captured" such that the coercive wage *in each period* equals the one-period expected return from trying to escape.

[30] We depart from other models such as the median voter theorem because they have very stark and counterfactual implications. For example, if the median voter is a landowner (skilled worker), all tax revenue will go towards coercive activity (education). Allowing for the government objective function consist of a weighted average of social welfare and income to municipal council members (à la Grossman and Helpman (1994) special interest group politics models) shows that nearly identical results hold as below with minimal restrictions. The model also abstracts from another mechanism for under-investments in education – in order to restrict the electoral franchise (Bourguignon and Verdier 2000; Galor, Moav, and Vollrath 2008). Although this mechanism may be at play, the short-run price variations should not induce large incentives for (long-run) slow franchise adjustments.

The first two terms reflect landowners' utility: their after-tax income from land and the value of coerced adult unskilled income that is reallocated to them, respectively. The last two terms are components of the utility of the (altruistic) adult skilled workers: the wage income of adult skilled workers and the (discounted) anticipated income of youth who attend school in the current period.[31] This objective function is maximized with respect to *current* coercive (V_t) and educational (K_t) expenditures subject to the budget constraint $\tau r_t L = V_t + K_t$.[32]

Maximizing the constrained objective function and examining the stationary equilibrium yields the following first order condition relating expenditures on educational and coercive capital where we suppress the subscripts t and $t+1$:

$$\pi'(V) w_u U = \beta w_s f'(k). \tag{10}$$

The left hand side represents the marginal net return to coercion which, in a stationary equilibrium, equals the (discounted) marginal return to educational capital. As before, the stationary equilibrium can be solved recursively given that exogenous world prices determine a unique vector of equilibrium factor prices.[33] Appendix B discusses the existence, uniqueness, and stability of the stationary equilibrium.

The Response of Education to a Change in the Price of Coffee with Coercion

To predict the response of educational attainment to a change in coffee prices with coercion, we express the new education indifference condition (equation (8)) and the budget constraint in proportional changes and substitute to yield

$$\widehat{E} = \underbrace{\left(\frac{\tau r L}{K}\right)\widehat{r} - \frac{1}{\varepsilon_{f(k),k}}\left(\widehat{w}_u - \widehat{w}_s\right)}_{A} + \underbrace{\frac{V}{K}\left[\underbrace{\left(\frac{K}{V}\right)\left(\frac{-\varepsilon_{(1-\pi(V)),V}}{\varepsilon_{f(k),k}}\right)}_{c.a.} - \underbrace{1}_{e.q.}\right]}_{B}\widehat{V}, \tag{11}$$

where $\varepsilon_{(1-\pi(V)),V}$ represents the elasticity of the coercive wage with respect to coercion holding the shadow wage constant. This derivation relies on the fact that equation (8) holds in equilibrium.

Although V is still an endogenous variable, equation (11) yields substantial insights on the effect of increased coercion on educational attainment in a stationary equilibrium. The first term ("A") is nearly

[31] Even if allowed, there will be no coercion of skilled workers. This is because coercion reallocates income to landowners from skilled laborers. However, as income is reallocated from one group of voters to another there will be no gain in the objective function but there will be a positive opportunity cost in that they are not providing educational capital nor coercing unskilled workers.

[32] We assume that skilled laborers live in the same households as students for simplicity given that we examine a stationary equilibrium. Assuming that skilled parents get (higher) utility value from having skilled children would satisfy this. Because our model does not predict who will obtain an education, we do this to avoid cases where some unskilled youth live with skilled parents such that some skilled parents have no incentive to provide educational capital.

[33] The endogenous variables K, V, E, U, k, equations (8),(10), $\tau rL = V + K$, $k = K/E$, and $U + E = N$, and the assumption of stationarity determine the equilibrium. See Appendix B for more details.

identical to the no-coercion case. Educational attainment is increasing in the land rental rate as tax revenue allows for more educational capital spending but is declining in the relative wage of unskilled labor as the opportunity cost of investing in education rises.

The second term ("B") represents two conflicting forces that determine how educational attainment responds to increased coercion. The first part ("c.a.") is a *coercion avoidance effect* through which, as coercion increases, the payoff to being an unskilled laborer diminishes relative to being a skilled worker. This increases the incentive to obtain an education, *ceteris paribus*. However, the *educational quality effect* ("e.q.") states that every extra peso spent on coercion necessarily diminishes expenditures on educational capital and diminishes the effectiveness of an education. This diminishes the incentive to obtain an education, *ceteris paribus*. The overall effect of increased coercion on educational attainment is based on the sum of these two effects. Although the net effect is ambiguous in theory, we calibrate this expression using available data for the period and reasonable parameter values to develop a prior about the net effect of increased coercion on educational attainment. Appendix B discusses this calibration in detail and shows that, for reasonable parameter values, the coercion avoidance effect dominates such that increased coercion leads to greater educational attainment. We assume that this holds for the entirety of the section.

We now show how the stationary equilibrium changes in response to a change in factor prices (determined uniquely by exogenous goods prices). To do this we start by expressing the government's indifference condition (equation (10)) in proportional changes and rearranging to obtain $\hat{V}$ as a function of the other variables in this expression:

$$\widehat{V} = \left[\frac{-\varepsilon_{f'(k),k}(\pi rL/K)}{D}\right]\widehat{r} + \left[\frac{\varepsilon_{f'(k),k} - (E/U)}{D}\right]\widehat{E} + \frac{1}{D}\left[\widehat{w}_u - \widehat{w}_s\right] \tag{12}$$

where $D = -[\varepsilon_{\pi'(V),V} + \varepsilon_{f'(k),k}(V/K)] > 0$. Based on this expression, an increase in land rental income will *increase* coercion as the government's budget expands. An increase in educational attainment will *diminish* coercion as the pool of workers against whom coercion can be undertaken falls. This generates a feedback loop in general equilibrium in which increases in coercion are softened because increased coercion leads to a smaller pool of coercible labor, diminishing the incentives for such coercion. Finally, an increase in the wage of unskilled labor relative to skilled labor increases coercion as landowners' relative gains to coercion increase.

Combining equations (11) and (12) yields an expression for changes in educational attainment as a function of changes in (shadow) factor prices:

$$\hat{E} = \underbrace{\frac{1}{\kappa}\left[\left(\frac{\pi rL}{K}\right)\hat{r} - \frac{1}{\varepsilon_{f(k),k}}\left(\hat{w}_u - \hat{w}_s\right)\right]}_{A} + \underbrace{\alpha_0\hat{r}}_{B} + \underbrace{\alpha_1\left(\hat{w}_u - \hat{w}_s\right)}_{C} \tag{13}$$

where κ, α_1, and α_2 are all positive constants with $\kappa > 1$. Appendix B discusses the structural composition of these coefficients in detail.

The first term ("*A*") is less negative than in the baseline case in which there is no coercion, as the feedback loop for educational attainment represented by the parameter κ makes the coefficient smaller in absolute value.[34] In addition, the possibility of coercion leads to the presence of two additional terms ("*B*" and "*C*") which were not present in the case without coercion. The first additional term ("*B*") illustrates how the increase in land tax revenue leads to greater coercion and increased efforts to avoid this coercion. The second additional term ("C") shows how an increase in the relative wage of unskilled labor provides greater incentive for coercion, leading to increased coercion avoidance through education. Both "B" and "C" lead to educational attainment falling by less, or rising in response to an increase in coffee prices relative to the no-coercion case.

The Response of Public Education Provision to a Change in the Price of Coffee with Coercion

Having developed a prediction on how *E* responds to a change in the exogenous price of coffee, we now examine how educational capital (*K*) responds to higher coffee prices and changes in educational attainment. Noting that $\pi rL = V + K$, taking proportional changes and substituting into equation (12) we obtain the following expression:

$$\hat{K} = \left[\frac{-\varepsilon_{\pi'(V),V}(\pi rL/K)}{D}\right]\hat{r} + \left(\frac{V}{K}\right)\left[\frac{(E/U) - \varepsilon_{f'(k),k}}{D}\right]\hat{E} + \left(\frac{V}{K}\right)\left(\frac{1}{D}\right)\left[\hat{w}_u - \hat{w}_s\right] \tag{14}$$

where $D = -[\varepsilon_{\pi'(V),V} + \varepsilon_{f'(k),k}(V/K)] > 0$. Whether *K* rises or falls is generally ambiguous (recall that $\varepsilon_{\pi'(V),V}$, $\varepsilon_{f'(k),k} < 0$). Therefore, *ceteris paribus*, *K* will correlate positively with *r* and *E* but negatively with $(\hat{w}_u - \hat{w}_s)$. This is because increases in *r* will have a positive income effect via the government's budget constraint. In addition, for given values of *V* and *U*, the government targets spending per student (*k*) according to the first order condition (10) leading *K* and *E* to move in the same direction. *K* correlates negatively with $(\hat{w}_u - \hat{w}_s)$ through a price effect in which increased unskilled wages increase the incentive for coercion and dampens the government's desire to supply *K*. The overall movement in *K* in response to these forces will be determined by the sum of these effects and is ambiguous.[35] This is in

[34] The coefficient on the proportional change in *r* is also greater than one also making the expression more positive.
[35] See Appendix B for a discussion of these opposing effects on the level of school provision.

contrast with the no-coercion case in which K moves (proportionally) one-for-one with land rents and thus must increase with an increase in coffee prices.

Main Predictions of the Models

We explore a model in which a change in the exogenous world price of coffee changes the domestic wages of skilled labor, unskilled labor, and land rents. Changes in these factor prices affect both the government's ability to provide education and workers' incentive to pursue this education. Consistent with the historical record, we consider the case in which a higher price of coffee increases unskilled wages and land rents with the wage of unskilled labor increasing more than land rents ($\hat{w}_u > \hat{r} > 0$) (Buitrago 1976; Bergad 1983). This allows us to make the following predictions, which we examine in the empirical analysis that follows:

Prediction 1. In a non-coercive regime, a higher price of coffee increases the provision of education ($K\uparrow$). Equilibrium educational attainment falls ($E\downarrow$), as demand for education falls more than supply rises.

Prediction 2. In a coercive regime, a higher price of coffee will increase coercion ($V\uparrow$). The provision of education may increase or decrease ($K\uparrow\downarrow$) and will be strictly less than in the case without coercion. The change in equilibrium educational attainment may be negative, zero, or positive but will be strictly greater than the fall in the case without coercion.

IV. Data and Research Design

IV.A. Description of the Data

We employ a unique data set to examine in detail the reduced-form relationships under scrutiny. In addition to the geographic and agricultural production data discussed in the Historical Background section, we use the sample of individuals from the Public Use Micro-Sample (PUMS) of the 1910 Puerto Rico Population Census. This provides us with data on literacy, age, municipality of residence, and other socio-demographic information for a representative sample of individuals for the early twentieth centuries. We link individuals' personal information to data on the municipality where they would have been eligible to attend school for school-eligible cohorts throughout the 1861-1891 period, assuming that the municipality where the individual resided was the same as where he or she made the schooling decision.. Table 3, Panel A, row 1 reports an average literacy rate of 17.8 percent in this population for these individuals (ages 25-59 years at the time of the 1910 Census). This is low in comparison to other Caribbean and American countries during the period (Engerman, Mariscal, and Sokoloff 2002). The PUMS data also reports information on the individual's gender, ethnicity, and native born status.

We also collected data from multiple primary administrative sources to measure the provision of public elementary schooling as measured by the number of primary schools in each municipality for 1828, 1866, 1876-77, and 1897.[36] Since the number of school-aged children in each municipality for each time period is unavailable, we normalize school availability by the corresponding municipality-level population (Table 3, Panel B).[37] We estimate that only 8 percent of children in the municipalities had access to public primary schools on average during this period.[38]

We have also collected additional data to evaluate alternate explanations for our results. First, we have constructed additional geographic variables to demonstrate whether our results are driven by differences in other geographic determinants of agricultural productivity. Specifically, we calculate the annual minimum and maximum temperatures, mean area weighted land gradient, mean area weighted elevation, distance to the ports of each municipality. We employ these as explanatory variables to demonstrate that our results are not driven by differences in other potential geographic determinants of agricultural productivity.

Second, we also use the 1828 Population Census municipality-level data, which includes detailed demographic information such as the racial and gender composition of the population, the extent of the slave population, and basic demographic data that allow us to construct crude birth and death rates (Córdova 1831-33). These data are used to assess the pre-coffee era demographic composition of municipalities. We also collect data on land and wealth distribution to assess this potential channel. Data on the distribution of land ownership at the municipality level comes from (a 25 percent sample of) the actual property tax registers for one year in the 1891-1894 period. These tax records contain information on the location, owners, and size of every plot in each municipality during these time periods. For each municipality at each date, we construct the land plot-size ownership Gini coefficient among landed individuals. Since we possess data on the number of landless households in the 1899 census, we can also construct overall land Gini coefficients for this period.

IV.B. Research Design

We compare the literacy decisions of primary school-age cohorts in municipalities with greater precipitation to those in municipalities with lower precipitation levels, in periods following varying coffee price levels to measure the effects of the coffee boom on human capital accumulation. In this sense, we use a (quasi) difference-in-difference strategy. Specifically, comparing individuals who belonged to

[36] See the Data Appendix for more details.

[37] We normalize the provision of public primary schools in 1897 by the number of 10-19 year old children in the municipality in 1899 as we have the latter data.

[38] Under the conservative assumption that a public primary school could hold 100 students (since the anecdotal evidence is that these held up to 50 students), 0.80 schools per thousand children would imply 8 seats per 100 school-aged children. Making these assumptions more stringent would reduce the estimated mean capacity of the school system in the central municipalities.

cohorts entering school (assumed at age 6) five years following an increase in coffee prices, we estimate the following model:

$$y_{icm} = \theta P^{C}_{c-6} * R_m + \beta_1 R_m + \beta_2 X_{icm} + \gamma P^{C}_{c-6} + \alpha_{(m)} + \varepsilon_{icm}, \quad (15)$$

where y_{imc} is a literacy indicator for individual i in school-entry cohort c in municipality m; P^{C}_{c-6} denotes the international price of coffee six years preceding the individual's school-entry decision; R_m is the municipality-specific continuous measure of average annual precipitation; X_{icm}, are individual-level gender, non-white, and age group indicator variables; and ε_{icm} is the disturbance term, allowed to be correlated at the municipality level. [39] Alternate specifications include additional geographic controls and their interactions with the relevant coffee price level and/or municipality fixed effects (α_m) that control for all time-invariant unobserved determinants of literacy in each municipality. Our procedure produces reduced-form effect estimates of being in a coffee-suitable municipality following a coffee price increase, captured by the θ parameter.[40] Estimating equation (15) separately for school-age cohorts in the coercive and non-coercive regimes allows us to test theoretical predictions 1 and 2.

In order to capture the average effects of the labor regimes on literacy rates, we compare average literacy rates of individuals who were of school age during the coercive 1861-1874 period to those who were of school age during the non-coercive 1876-1890 period. This comparison is made across municipalities with varying annual rainfall levels. Consequently, we estimate the following (quasi) differences-in-differences model:

$$y_{icm} = \theta Post\text{-}coercion_c * R_m + \beta_1 R_m + \beta_2 X_{icm} + \gamma Post\text{-}coercion_c + \alpha_{(m)} + \varepsilon_{icm}, \quad (16)$$

where $Post\text{-}coercion_c$ is an indicator variable for being in the latter post-coercion school-age cohort-group. Other variables and specifications are as defined above.

Finally, we estimate the following (quasi) differences-in-differences model to measure the impact of the coffee boom on municipality-level provision of public primary schooling:

$$y_{mt} = \theta_P Post\_coercion_t * R_m + \theta_C Coercion_t * R_m + \beta_1 R_m + \beta_2 X_m + \gamma_t + \alpha_{(m)} + \varepsilon_{mt}, \quad (17)$$

where y_{mt} is the number of schools per thousand individuals in each municipality m in time period t; $Coercion_t$ and $Post\_coercion_t$ are indicator variable for the respective time periods (i.e., 1867, 1876; and 1897); X_m are the remaining municipality-level geographic controls; γ_t are period fixed effects; and ε_{mt} is

[39] The empirical methodology closely follows Duflo (2001), who implements a similar strategy to identify the effects of a primary school construction program on adult men's school attainment and wages in Indonesia.

[40] An alternative empirical strategy would be to implement an IV approach, in which the possibly endogenous explanatory variable of interest would be a measure of coffee cultivation in each municipality during each time period. This variable would be instrumented with the $P^{C}_{c-6} * G_m$ variable. Unfortunately, we do not have period-specific measures of the extent of coffee cultivation, and thus cannot perform this alternative empirical approach.

the disturbance term which is allowed to be correlated within municipalities over time. Municipality fixed effects (α_m) control for all time invariant unobserved determinants of public school provision in each municipality. Because we include fixed effects for each municipality and period, the effect of the coffee boom is identified by the change in the municipalities with precipitation levels more suitable for coffee cultivation, relative to other municipalities, in 1867 or later relative to 1828.

Our research design relies on the assumption that municipalities with different precipitation patterns would have experienced similar trajectories in the absence of a boom to coffee prices. Although this identifying assumption is not directly testable, the available evidence supports it. Baseline mortality rates and baseline differences in public school provision were quite similar during the first half of the century. Population trends across these municipalities also do not differ until the 1850s (results not shown), suggesting that these municipalities experienced equivalent development trajectories until the 1850s (see Table 1, Panel C). We assess potential threats to the validity of our assumptions in the alternative explanations section (Section VI).

V. Empirical Results

V.A. Adult Literacy

We start by examining the relationship between international coffee prices and individuals' levels of literacy across higher and lower rainfall municipalities in each of the labor regimes. This can be done by generalizing empirical model (16) presented above, where we allow each cohort to have a (smoothed) potential effect, as follows:

$$y_{icm} = \alpha_m + \gamma_c + \sum_c (R_m \times d_c)\theta_c + \varepsilon_{icm}, \tag{18}$$

where d_c is a variable that indicates whether the individual is in the two-year birth cohort group 1855-56, 1856-57, …, 1884-85; and the other variables are defined as above. Each θ_c coefficient can be interpreted as the effect of residing in a higher-rainfall municipality on a given cohort. By plotting θ_c against coffee prices, we can examine if differential educational attainment in coffee growing regions is correlated with coffee prices and if this movement varies between coercive and non-coercive periods.

Figure 5 illustrates the cohort-specific rainfall correlation estimates (θ_c) from equation (18) (with 95 percent confidence intervals in dashed lines). The year of abolition of the coercive legislation is demarked with a red line. The coefficient estimates in this model fluctuate, and are statistically indistinguishable from zero for cohorts born between 1855 and 1869. This is consistent with a muted

disincentive for human capital accumulation in response to coffee price increases under coercion.[41] In contrast, following the labor market liberalization of 1874, we observe a clear negative relationship between coffee price increases and cohort literacy rates across higher and lower rainfall municipalities. The point estimates indicate, among individuals born between 1873 and 1885, a reduction in literacy rates of 0.25-0.50 percentage points per inch of additional mean annual rainfall. These estimates are significantly different from zero at conventional confidence levels. In summary, these findings are evidence in favor of our theoretical predictions.

Table 4 provides regression-based evidence of the relationships depicted in Figure 5 using estimation based on equations (15) and (16). The first specifications use the annual rainfall post-coercion cohort interaction as the 'treatment' measure, which imposes a homogeneous effect of the program across post-boom cohorts. Column (1) includes demographic but not geographic controls and finds that literacy rates were 2.27 percentage points (13 percent) lower among post-coercion cohorts in municipalities with 10 in. higher annual rainfall levels. Column (2) includes geographic controls and finds similar effects: 2.27 percentage points lower,. Column (3) includes municipality fixed effects and finds similar effects as well: 2.20 percentage points lower. These estimates are all significant at the 99 percent confidence level.

Columns 4 and 5 estimate gender-specific effects. Column 4 shows that the coffee boom led to a substantial 2.86 percentage points (12 percent) decrease in literacy rates for males in municipalities with 10 in. higher annual rainfall levels, whereas column (5) finds substantially smaller effects for females: 1.47 percentage points lower (11 percent). These two results are both significant at the 95 percent confidence level. Although the gender-specific effects are precisely estimated, we cannot reject at conventional confidence levels that these are significantly different (p-value = 0.86).[42]

Columns 6-9 estimate equation (15) for school-age cohorts in the coercive and non-coercive regimes pooling all cohorts for a given regime and estimating an expression for each group. Columns 6 and 7 show estimates of θ for school-age cohorts during the coercive regime. These effects are positive, small, and statistically indistinguishable from zero. The point estimate of the specification excluding municipality fixed effects (column 6) implies that a one standard deviation increase in coffee prices induced a 1.7 percentage points (11 percent) higher literacy rate in municipalities with 10 in. higher annual rainfall levels. The preferred municipality fixed effects estimate (column 7) implies a smaller positive response of 0.9 percentage points (6 percent).

[41] An exception is the 1863 birth cohort, which became of school age in the year 1869 following the main peasant revolt in 1868, and a brief period of a conservative backlash that involved the firing of liberal-oriented school teachers (Moscoso 2003).

[42] Differences across municipalities do not vary significantly by racial background. Estimates indicate that literacy rates were 3.03-3.07 percentage points (28.5-28.9 percent) lower among native-born blacks and mulattos in municipalities with 10-inches higher rainfall (significant at 90 percent confidence) whereas the estimated impacts for native-born whites lie in the 1.95-2.06 (9.5-10.1 percent) range (significant at 99 percent confidence).

Columns 8 and 9 show the literacy responses among the school-age cohorts during the non-coercive regime. In contrast to cohorts during the coercive regime, estimates of θ are negative and significantly different from zero at conventional confidence levels. The point estimate of both specifications (with and without municipality fixed effects) imply that a one standard deviation increase in coffee prices induced a 1.2 percentage points (6 percent) reduction in literacy rate in municipalities with 10 in. higher annual rainfall levels. Given the differences in rainfall of approximately 20 inches across coffee and non-coffee central municipalities, these point estimates imply significant reductions in literacy rates following the liberalization of labor markets in 1874.

V.B. Provision of Public Primary Schooling

We now investigate whether the coffee boom influenced municipal governments' provision of public primary schooling. Because public primary schooling provision data is not available by cohort or year, we cannot replicate the exercises in the previous section but, rather, examine patterns of provision in high and low rainfall regions and how these differences changed over time in response to coffee prices. Figure 6 illustrates the average time path of public school provision in above average and below average annual rainfall municipalities. For each type of municipality, the figure plots the unadjusted mean number of schools per thousand individuals, in each time period, as well as the mean difference across regions and the confidence interval of this difference.

The average number of public schools per thousand individuals was similar preceding the coffee boom in 1828: it was approximately 0.023 in the above average rainfall municipalities and 0.053 in the below average rainfall municipalities, (the difference is not significant at conventional levels). In contrast, in the coercive coffee boom years 1867 and 1876, there is a substantially lower number of public primary schools per thousand individuals in the high rainfall region relative to the low rainfall region. The respective mean differences were 0.20 and 0.24 schools per thousand individuals (32 and 39 percent) in 1867 and 1876, respectively. These differences are significant at 95 percent confidence. In contrast, in the non-coercive regime period (in 1897), the difference had fallen to 0.06 (11 percent) and not significantly different from zero.

Table 5 presents estimates of the relationships depicted in Figure 6 using the model of equation (17). The dependent variable is the number of public primary schools per thousand individuals in the municipality in each time period. The specifications reported in the first two columns use annual rainfall-period interactions as the 'treatment' measure, assuming a homogeneous effect of the program across coercive and non-coercive regimes. Column 1 excludes geographic characteristics and indicates that municipalities with 10 in. higher annual rainfall levels experienced a reduction in the provision of schools of 0.075 per thousand individuals (19 percent). Column 2 includes geographic controls which reduce the

point estimate to 0.071 schools (18 percent) per thousand individuals. Both estimates are significant at 99 percent confidence.

Columns 3 and 4 are analogous to columns 1 and 2 except that they allow for period-specific treatment effects. Including and excluding geographic controls respectively, we find greater and statistically significant effects for coercive regime years 1867 (0.082-0.084 fewer schools per thousand, or 20-21 percent) and 1876 (0.118-0.130 fewer schools per thousand, or 29-32 percent), whereas the estimated impacts are smaller and insignificantly different from zero for the 1897 non-coercive regime period. F-tests indicate that the coercive period-specific terms are jointly significant at 99 percent confidence for both columns 3 and 4.[43] Column 5 estimates the pooled treatment effect model controlling additionally for the black/mulatto population share in year 1899. We do this to control for differences in ethnic composition across regions although we explore this further in Section VI. We find similar results, with an estimated reduction of 0.066 schools per thousand individuals (significant at 99 percent confidence). Columns 6 and 7 include municipality fixed effects. These specifications show similar reductions in the provision of public primary schools: municipalities with 10 in. higher annual rainfall reduced the provision of primary schools by 0.067 schools per thousand (17 percent) and the time pattern of the effects is unchanged. Our findings indicate that local governments in the coffee-region allocated relatively fewer resources towards the provision of primary schooling during the coercive regime but not after the derogation of these measures.

VI. Assessment of Alternative Explanations

The scholarly debate has identified multiple geographic or institutional factors that may have played a role in explaining the observed pattern of falling literacy with rising coffee prices during the non-coercive period. We address five alternate hypotheses, test our underlying assumptions, and present evidence that rules out each of the alternate explanations. In order, the alternate explanations we evaluate are centered on: (1) the geographic sorting of the native born population, (2) geographic sorting of immigrants, (3) land inequality, (4) technological and economic changes that may depend on geographic factors correlated with rainfall, and (5) the political consequences of the establishment of a coercive system.

Geographical Sorting of the Native-Born Population and Differential Returns to Schooling

The geographic sorting of the population during the non-coercive period provides important alternate hypothesis. Individuals sorting into jurisdictions based on their unobserved characteristics could explain differences in literacy outcomes and the demand for schooling. For instance, a disproportionate

[43] In contrast, the coercive period-specific effects are statistically distinguishable from the non-coercive period relationship; p-values of joint significance tests are 0.014 and 0.015.

share of less skilled individuals might have sorted into high rainfall regions in response to higher coffee prices. If these individuals demanded lower levels of public schooling due to unobserved differences in the return to education, the demand for education could have been lower.

Although migration across regions did occur, the central government imposed strong restrictions on inter-municipality migration for the landless population across all regions in the island during a significant part of the second half of the century. These measures, enforced by local governments, mitigate some concern of sorting of this population (Picó 1979).

In addition, we can assess whether there is evidence of sorting based on several pre-determined individual observable characteristics possibly correlated with unobservable determinants of migration and literacy.[44] We start by examining the relationship between international coffee prices and predetermined characteristics of school-age cohorts such as gender and race across high and low rainfall municipalities. We do this by estimating variants of the empirical model (18), where we allow each cohort to have a (smoothed) potential effect on the predetermined variable:

$$x_{icm} = \alpha_m^{PRE} + \gamma_c^{PRE} + \sum_c (R_m \times d_c)\theta_C^{PRE} + \nu_{icm}, \tag{19}$$

where x_{icm} is the predetermined indicator variable (i.e. female gender, non-white individual) and the other variables are defined as above. The θ_c^{PRE} coefficient can be interpreted as the marginal probability that individuals from a given cohort possessed characteristic x in a municipality with higher rainfall. By plotting θ_c^{PRE} against coffee prices, we can observe whether individuals with certain demographic characteristics were more likely to reside in higher rainfall municipalities in response to higher coffee prices at the age of school entry.

Figure 7 plots cohort-specific rainfall correlation estimates (θ_c^{PRE}) from equation (19); Panels A and B report the correlation for female and non-white individuals, respectively. There is no clear relationship between the proportion of female individuals and coffee price increases or decreases during the coercive or non-coercive regimes. In addition, although the proportion of non-white school-age cohorts is consistently lower in higher rainfall municipalities, there is no clear relationship of sorting based on individuals of distinct racial categories in response to changing coffee prices.

Table 6 provides regression-based evidence of the relationships depicted in Figure 7. Columns 1-2 and 3-4 estimate equation (15) using the female and the non-white individual indicators respectively as the dependent variables for school-age cohorts in the non-coercive regimes to capture differential changes in cohort composition in response to changes in coffee prices across municipalities with varying rainfall

[44] This is essentially an indirect test of the unconfoundedness assumption required for consistent estimation of the reduced-form relationships See Imbens and Wooldridge (2008, pp. 45-46) for a discussion of empirical assessments of this assumption.

levels. The point estimates are small and statistically indistinguishable from zero. This suggests that there was no significant change in the population's gender or race composition in response to coffee prices.[45]

Substantial migration would also entail increased cohort size. We find no evidence of this during the non-coercive period. Models that estimate (log) cohort size correlations with coffee prices give small and statistically insignificant point estimates (see columns 5 and 6). In summary, we find no evidence that educational group-specific geographic mobility patterns drive our results of falling literacy in response to higher coffee prices.[46]

Immigrants' Location Patterns

Selective immigration of *foreigners* of varying socio-economic status across the regions of the island could have induced differences in the patterns of development if immigrants with higher levels of physical and human capital migrated to the lower rainfall municipalities (Glaeser et al 2004).[47] Such selective immigration of foreigners across different regions implies that their literacy rates should differ across higher and lower rainfall municipalities. Using 1899 Census data on the municipality-level shares of the foreign adult population and foreigners' literacy rates we find that foreigners composed only 0.6 percent of the population in these municipalities. We also find that foreigners' literacy rates were not significantly different across municipalities with varying rainfall levels (Table 7, columns 1-2). Consequently, we do not find evidence of any differential presence of high-skilled foreigners across low- and high-rainfall municipalities.

One might be concerned that the cross-sectional comparison of municipality-level averages in the year 1899 drives our lack of evidence of sorting among foreigners. However, cross-sectional comparisons of literacy rates for native-born adult males provide a weighted average of the estimates for the coercive and non-coercive period cohorts' literacy rates correlation with annual rainfall levels (Table 7, columns 3-4). The cross-sectional estimates for this group are qualitatively similar to the weighted-average of those estimated based on the individual-level data (see Section V.A). Because we are able to reconstruct our results for natives, it is less likely that data quality issues are driving our findings of differences for literacy rates of foreigners.

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[45] Also, note that literacy rates of 40-59 year old adults, who might have sorted out of the coffee region it this were driven by selective migration in the post-coercion period, are not significantly different from zero across higher and lower-rainfall municipalities, which suggests no evidence of sorting among coercive-period school age cohorts during the post-coercive period (see the discussion in Section V.A).

[46] Finally, to the extent that differential trends in the pre-boom variation in the provision of public schooling capture differential demand for schooling across municipalities based on pre-existing preferences, this does not seem to be driving the literacy results. The analogous (pre-coffee boom schools per capita-conditioned) estimates of the effects of the coffee boom on public school provision and literacy rates are greater in absolute value and precisely estimated (see Appendix Tables A1, columns 4-5, and A2, columns 5-6).

[47] For instance, Bergad (1983) documents that Catalan and Mallorquín families, highly involved in the coffee cultivation and distribution industries, moved into Lares, whereas Corsican families assented in Yauco (also a coffee region municipality). Similar immigration patterns occurred however in East-Central municipalities, as exemplified by the case of Cayey (Picó 2007).

Land Inequality

Other lines of inquiry emphasize differences in land ownership concentration as being a strong determinant of poor provision of educational public goods and schooling outcomes. The stark divergence in agricultural production only led to small differences in the distribution of land ownership across municipalities. Figure 8 presents kernel density and Lorenz curve estimates of the distribution of individual land ownership among landowners for each region (Panels A and B, respectively). The density estimates suggest that land ownership was only slightly more concentrated in the coffee-growing region relative to the food crops region. This is because there is a greater share of landowners with very small plots in the latter region relative to the former (Panel A). However, most differences may be explained by the fact that plot sizes were larger on average in coffee-region municipalities (43.9 and 35.4 acres, respectively). Lorenz curves presented in Panel B suggest that land ownership inequality among landowners was only slightly greater in the food crops region than in the coffee region. These distributional differences suggest that the land tenure structure did not diverge dramatically across regions during the coffee boom.

These patterns are confirmed by comparing local-level land inequality more systematically across all municipalities during the period 1891-94 (Table 7). There is no correlation between the overall land Gini coefficient and annual precipitation levels (columns 5-6).[48] In addition, any land stratification differences across higher and lower rainfall municipalities are driven mainly by variation in the degree of land concentration among landed individuals, rather than by differences in the share of the landless population across municipalities. The rainfall–landowners Gini correlation is 2.8 percentage points (3.7 percent) excluding geographic controls and 0.9 percentage points (1.2 percent) including these but neither relationship is precisely estimated (columns 7-8). The correlation between the proportion of landless households in 1899 and annual rainfall is small, negative, and statistically indistinguishable from zero (columns 9-10).[49] These comparisons suggest that the coffee booms of the 1800s did not lead to broad differences in the distribution of land ownership of the sort hypothesized by the factor endowments–economic inequality hypothesis.

Even if inequality in the distribution of land ownership negatively impinged on the literacy rate of the population, our estimates would be biased upwards. This is because the partial correlation of inequality in land ownership and literacy is *positive* (not reported in the tables) corroborating existing work on the historical relationships between land inequality and development outcomes across local

[48] The point estimate from the raw correlation suggests that the overall level of land inequality was 0.9 percentage points (1 percent) higher in municipalities with 10 in. higher rainfall levels, where as the point estimate from the partial correlation suggests a smaller and negative relationship (Table 7, columns 5 and 6).

[49] Since the sample of municipalities with land distribution data among landowners is a subset of the overall sample of 23 municipalities, the differences in results may be driven by differences in the sample composition. However, note that the differences in the landless households share are similar for this subset of municipalities (Table 7, column 11).

jurisdictions (Acemoglu et al. 2008; Nunn 2008). Moreover, using models analogous to equations (15) and (16) for the sub-sample of municipalities with 1890s land ownership data, we find even larger (in absolute value) estimates of the coffee-price literacy relationship (see Appendix Tables A1, columns 1-3).[50] These models additionally control for the 1890s (overall or landowners') land ownership Gini coefficient and its interaction with the post-boom birth cohort or coffee prices. These pieces of evidence are inconsistent with economic inequality as the mechanism explaining these effects.

Technological and Economic Changes Associated with Geographic Factors Correlated with Rainfall

Other technological changes in Puerto Rico such as an expansion of the transportation system (i.e., railroads) could have differentially influenced product and/or factor markets during the post-coercion period (Cabrera Salcedo 2007). If the impact of these broader technological and economic changes depended on geographic factors correlated with rainfall, such as elevation and gradient, our estimated literacy effects may be biased.

To address these alternative explanations, we estimate models analogous to (15) where we sequentially allow for an additional interaction term between the coffee price and alternative geographic variables: altitude, land gradient, and distance to ports (Table 8, rows 1-3). The point estimates on the coffee price – rainfall interaction for the sample of post-coercive period cohorts are in the (-0.071, -0.067) percentage points range (each significant at 95 percent confidence), whereas those for the sample of coercive period cohorts in the (0.001, 0.008) range. All are quantitatively similar to those reported above for both the coercive period and post-coercive period cohorts.[51] These robustness checks help to mitigate possible concerns that the evidence is consistent with broader technological change effects that may be correlated with other geographic characteristics.

Political Consequences of the Establishment of a Coercive System

A competing explanation for the fall in literacy under the non-coercive regime is that there was extra-legal coercion. In this case, establishment of an extra-legal coercive apparatus at the local level may have led to intimidation or repression and shifted local public goods provision decisions away from the preferences of poor households – independently of the direct effects on local labor markets. These political dynamics may have been prevalent during periods of export commodity booms, as the rents available to the state increased during these times and could have been channeled towards politically coercive activities (Besley and Persson 2008). In short, the fall in literacy may have been coming from the "supply side" even during the non-coercive regime.

[50] Although the analogous (land ownership Gini-conditioned) estimates of the effects of the coffee boom on the provision of public primary schooling are somewhat smaller in absolute value, these are still large and precisely estimated (see Appendix Tables A2, columns 2-4).

[51] The results are also robust to including a sugar cane price – rainfall interaction term (available from the authors upon request).

Consistent with this alternate mechanism there existed a threat of unrest following the *Grito de Lares of 1868*, a major liberal pro-independence revolutionary attempt that originated in the coffee region.[52] This threat induced members of the landowning classes to expend military resources to protect the regime and maintain public order (Bergad 1983; Moscoso 2003). Consequently, a volunteer-based paramilitary group composed of large landowning family members and promoted by the provincial authorities organized itself in 1869 at the municipality level as the Volunteer Corps (VC) (Rosado Brincau 1891).[53] Concurrently, the Provincial Government created the Provincial Civil Guard, which replaced a militia based on draft by lottery (Flores Collazo 1994).

To measure the extent of repression following this episode, we coded information on the distribution of VC units across municipalities in 1886 and of the Civil Guard in 1876. The VC data are the share of individuals in a company assigned to a specific municipality and an indicator variable for whether a local VC headquarters was located in that municipality. The Provincial Civil Guard data represent the number of men assigned to a municipality.[54]

Using this data we estimate models analogous to (15) sequentially allowing for additional interaction terms between the coffee price and these coercive apparatus variables (Table 8, rows 4-6). The point estimates on the coffee price – rainfall interaction for the sample of post-coercive period cohorts are in the (-0.071, -0.067) percentage points range (statistically significant at 95 percent confidence), whereas those for the sample of coercive period cohorts in the (0.005, 0.008) range. All are quantitatively similar to those reported above for both the coercive period and post-coercive period cohorts. Consequently, these data show no evidence that political repression was responsible for diminished literacy during the non-coercion period in the municipalities considered.

VII. Conclusion

This paper studies coffee booms throughout the second half of the nineteenth century in Puerto Rico to examine whether changes in the incentive for elites to enforce coercive labor institutions affected human capital accumulation decisions in the population. First, we find that local governments in coffee growing regions allocated more resources to the enforcement coercive labor measures arguably with the goal of depressing the realized wage of unskilled labor. This induced workers to acquire significantly

[52] The political cleavages leading to the insurrection were primarily class-based. As noted by Bergad (1980): "… the leaders of the insurrection were all coffee farmers. The working men who seized Lares were all coffee pickers. And those arrested by the revolutionaries were the major coffee merchants and creditors of the town." See Moscoso (2003) for a contrarian view.

[53] Volunteer Corps members had to satisfy certain eligibility requirements: Spanish citizenship or naturalization; no criminal record; generate earnings and/or have an 'honorable' occupation; and own sufficient resources to support their activities in the Corps. The economic resources requirement was most significant, since the State did not incur expenditures on personnel or military equipment for volunteers. (It would do so following the Volunteer Corps reorganization of 1886, at which point volunteers would be compensated for their time in the Corps at times forces had to be mobilized). In addition, the eligibility requirement arguably had the intention of promoting the selection of individuals that supported the conservative regime.

[54] See the Data Appendix for a detailed description of the construction of these variables.

more schooling in equilibrium. Moreover, following the abolition of these coercive measures in 1874, we observe a decline in literacy rates, consistent with a declining skilled labor wage differential. These results are consistent with models of factor price manipulation under elite-controlled regimes, in which the return to unskilled labor is depressed as a result of the extraction of rents by landowning elites and then rises when the coercive regime is abolished (e.g., Acemoglu 2006). Because we do not examine formally why the abolition of this coercive legislation took place, we do not study whether different national-level political or governance institutions would have led to different trajectories in local government policies. This and its implications for levels of human development across jurisdictions remains an important topic for future research.

The paper makes two contributions to the empirical development literature from a methodological standpoint. First, we use micro-data combined with regional and temporal variation in the establishment of specific *de facto* institutions to explore empirically how these affect human capital formation, a crucial determinant of long-run economic performance. It exploits the fact that the incentives under a given institutional setting vary with individuals' economic and political status to study their consequences for local populations (Pande and Udry 2005). Second, by studying how equilibrium levels of human capital accumulation are determined by both government policy-driven supply and skill premium-driven demand factors, our work also provides an example of the roles played by general equilibrium effects and political economy considerations in explaining processes of development at the micro level (Acemoglu 2009).

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Appendix A: Data Sources and Description

Geographic Characteristics:

Average monthly and annual rainfall, 1899-1928 (in.): available at the weather station from Roberts (1941). If there are a non-zero number of weather stations in the municipality, the simple average of precipitation measures is assigned to the municipality. For municipalities with no available weather stations, the simple average of adjacent municipalities' weather measures is assigned to the municipality.

Average altitude (meters), average land gradient (degrees), distance to nearest port (km): GIS data are available from the Government of Puerto Rico Planning Board. Municipality-level averages are constructed using ArcGIS software.

Average maximum and minimum temperature, 1950-2000 (ºC): National Climatic Data Center (NCDC) and non-NCDC data available at The UNC-Chapel Hill Southeast Regional Climate Center. Imputation for municipality-averages following the same algorithm as the one for average monthly and annual rainfall. Link: http://radar.meas.ncsu.edu/climateinfo/historical/historical_pr.html

Coffee Prices, Cultivation and Production; Aggregate Economic Activity:

International coffee prices data: International wholesale coffee export prices are quoted in the UK (London) market, rather than in the domestic one. These data are taken from Sauerbeck, Augustus. "Prices of Commodities and Precious Metals," *Journal of the Statistical Society of London*, vol. 49/3 September 1886 Appendix C, for the years 1860-85. Sauerbeck, A. "Prices of Commodities During the Last Seven Years," *Journal of the Royal Statistical Society*, vol.56/2 June 1893 p.241 ff., for the years 1885-1892. Sauerbeck, A. "Prices of Commodities in 1908," *Journal of the Royal Statistical Society*, 72/1 Mar 1909 for the years 1893-1898.

Number of coffee mills, feet ("pies") of coffee cultivation, coffee production ("quintales"), aggregate private income and wealth: available from Pedro Tomás de Córdova's statistical and qualitative description of geographic and economic conditions across municipalities in the island (Córdova, 1831-33). These data were prepared by municipal governments, as required by the Spanish Crown (and collected by Córdova, an emissary of the Crown) to improve the central government's information regarding economic conditions in the island during a period of Bourbon reforms.

Agricultural land under coffee, sugar cane, 1896: is available from Henry K. Carroll's report to the U.S. Government on economic conditions in the island following the end of the 1898 Spanish-Cuban-American War (Carroll, 1899). These data on rural lands, as declared by their owners for assessment, is considered to be of reasonable quality, since it was collected by property and income tax collection officials during the end of the Spanish regime.

Literacy Data, Socio-Economic, and Demographic Information:

Total population in 1824, 1828; number of sharecroppers, slaves, free blacks, mulattos, whites, year 1828; number of births, deaths, and marriages, year 1828: available from Córdova (1831-33). Population shares are constructed based on total population in 1828; crude rates are constructed using total population in 1828 as denominator.

Total population in 1846, 1860, 1862, 1865, 1867: available from Gaceta de Puerto Rico (1868a).

Adult literacy, gender, age (in years), nationality, father's nationality, mother's nationality, municipality of residence: available from Public Use Micro-Sample (PUMS) of the 1910 Puerto Rico Population Census (Palloni, Winsborough, and Scarano, 2006)

Native and foreign-born adult males' literacy rates, by racial category, year 1899 available from Academia Puertorriqueña de la Historia ("APH") (2003).

Public Primary School Provision:

Number of primary schools in the municipality, years 1828, 1866-67, 1876-77, 1897: available respectively in Córdova (1831-33), Gaceta de Puerto Rico (1868b), Ubeda y Delgado (1878), and APH (2003).

Jornalero Regulation Enforcement, Military and Paramilitary Forces Data:

Number and share of 'jornaleros' in population, year 1867: available from 1867 Census of Puerto Rico, published in Gaceta de Puerto Rico (1868c).

Annual share of jornaleros ordered to spend prison time; *annual share of laborers accused or denounced in the anti-vagrancy councils, 1851-1867*: the counts of jornaleros ordered to spend prison time or denounced in the anti-vagrancy councils were collected from the monthly acts of the anti-vagrancy councils for five municipalities: (Caguas, Comerío, Juncos, Lares, and Yauco). To construct the share of jornaleros prosecuted by the local anti-vagrancy councils, we estimate the number of jornaleros in each municipality throughout the period in the following way. 1) We estimate the proportion of jornaleros in each municipality in years for which we have census counts data (1846, 1860, 1862, 1865, 1867) by assuming that the proportion for each municipality remains constant over time throughout the 1846-1867 period (the jornalero share data is only available in year 1867). 2) We interpolate the share of jornaleros in the municipality within census years by assuming a constant growth rate of the jornalero and total population.

Total population in 1846, 1860, 1862, 1865, 1867: available from Gaceta de Puerto Rico (1868a).

Volunteer Corps (VC) distribution data: Rosado Brinacu (1891) documents the distribution of Volunteer Corps units (companies) across municipalities of the island for the year 1886. Unfortunately, the source does not provide data on the number of men in the VC company in each municipality; it only provides the geographic distribution of VC companies to all municipalities across the island. Therefore, we impute the share of men in a company assigned to each municipality using equal shares for each company. The following information on the 10th VC battalion exemplifies the data available and our imputation method.

> Volunteer Corps - 10th Battalion
>
> Company 1 – Municipality of Coamo (Battalion Headquarters) (1 company)
>
> Company 2 – Municipality of Juana Díaz (1 company)
>
> Company 3 – Municipality of Aibonito (1 company)
>
> Company 4 – Municipalities of Barros (0.5 company), Barranquitas (0.5 company)

Provincial Civil Guard distribution data: Molinero y Gómez Cornejo (1879) documents an analogous distribution of Civil Guard units (companies) across municipalities of the island for the year 1876. Again, the source does not provide data on the number of men in each municipality. Therefore, we impute the share of men in a company assigned to each municipality using equal shares for each company. In some cases, particular units are assigned to '*barrios*' (municipal districts – smallest administrative unit), and we aggregate the coding at the municipality level.

Land Distribution:

Plot size and owner of each plot for each taxed plot in municipality, for one year in 1891-1894 period: available from cadastral land censuses for all municipalities in center of the island. Source: Archivo General de Puerto Rico, Fondo: Administración Provincial (Gobernadores Españoles). Land Gini coefficient for each municipality constructed from the distribution of plot sizes for each individual owner. Source: Archivo General de Puerto Rico, Fondo: Administración Provincial (Gobernadores Españoles). Land gini coefficient for each municipality constructed from the distribution of plot sizes for each individual owner.

Appendix B: Theoretical Appendix

B.1. Proof of Proposition 1

Taking proportional changes of the system of zero profit conditions and expressing it in matrix notation yields

$$\begin{pmatrix} \hat{p}_c \\ \hat{p}_f \\ 0 \end{pmatrix} = \begin{pmatrix} \theta_{sc} & \theta_{uc} & \theta_{lc} \\ \theta_{sf} & \theta_{uf} & \theta_{lf} \\ \theta_{sb} & \theta_{ub} & \theta_{lb} \end{pmatrix} \begin{pmatrix} \hat{w}_s \\ \hat{w}_u \\ \hat{r} \end{pmatrix},$$

where θ_{ij} represents the relevant cost share for factor i in production of good j. Inverting this system to obtain a matrix of Stolper-Samuelson derivatives yields

$$\begin{pmatrix} \hat{r} \\ \hat{w}_u \\ \hat{w}_s \end{pmatrix} = \frac{1}{|M|} \begin{pmatrix} \theta_{uf}\theta_{sb} - \theta_{ub}\theta_{sf} & \theta_{sc}\theta_{ub} - \theta_{uc}\theta_{sb} & \theta_{uc}\theta_{sf} - \theta_{uf}\theta_{sc} \\ \theta_{lb}\theta_{sf} - \theta_{lf}\theta_{sb} & \theta_{lc}\theta_{sb} - \theta_{lb}\theta_{sc} & \theta_{lf}\theta_{sc} - \theta_{lc}\theta_{sf} \\ \theta_{lf}\theta_{ub} - \theta_{lb}\theta_{uf} & \theta_{lb}\theta_{uc} - \theta_{lc}\theta_{ub} & \theta_{lc}\theta_{uf} - \theta_{lf}\theta_{uc} \end{pmatrix} \begin{pmatrix} \hat{p}_c \\ \hat{p}_f \\ 0 \end{pmatrix},$$

where

$$|M| = \theta_{lc}(\theta_{uf}\theta_{sb} - \theta_{ub}\theta_{sf}) + \theta_{uc}(\theta_{lb}\theta_{sf} - \theta_{lf}\theta_{sb}) + \theta_{sc}(\theta_{lf}\theta_{ub} - \theta_{lb}\theta_{uf}). \quad \text{(B1)}$$

We now invoke the following factor intensity restrictions: $(\theta_{sf} / \theta_{uf}) > (\theta_{sb} / \theta_{ub})$, $(\theta_{sb} / \theta_{lb}) > (\theta_{sf} / \theta_{lf})$.

The first assumption states that food is skilled labor-unskilled labor intensive relative to tobacco. The second states that tobacco is skilled labor-land intensive relative to food. Note also that these assumptions ensure that the first two terms in the determinant are negative while the final term is positive. We now introduce a third assumption. We assume that the cost share for skilled labor in coffee is sufficiently small that the sign of the determinant is strictly negative. Algebraically, this results in the restriction that

$$\frac{\theta_{lc}(\theta_{uf}\theta_{sb} - \theta_{ub}\theta_{sf}) + \theta_{uc}(\theta_{lb}\theta_{sf} - \theta_{lf}\theta_{sb})}{\theta_{lf}\theta_{ub} - \theta_{lb}\theta_{uf}} > \theta_{sc}. \quad \text{(B2)}$$

Consequently, the shadow wage of unskilled labor and the return to land rise, while the skilled wage falls.

B.2. Uniqueness and Stability of a Stationary Coercive Equilibrium

Equilibrium will be determined by the four following expressions in conjunction with the definition of a stationary steady state:

$$\pi'(V_t) w_u U_{l,t} = f'(k_t)(E_{l,t}/E_{0,t})$$

$$f(k_t) = [(1 + \beta)/\beta]^* \{[(1 - \pi(V_t)]^*(w_u/w_s)]$$

$$K_t + V_t = \tau r L$$

$$E_{l,t} + U_{l,t} = N_{l,t}$$

$$E_{l,t} = E_{0,t}$$

We assume that there is an interior solution with positive amounts of educational and coercive capital. While we do not pursue an existence proof, It can be shown easily using the functional forms $f(k) = (k)^{\gamma}$, where $0 < \gamma < 1$, and $\pi(V_t) = [V_t/(1 + V_t)]$.

The system has four equations and five unknowns. We pursue a strategy where we show that an expression with the two unknowns $E_{1,t}$ and $E_{0,t}$ cuts through the "45 degree line" that defines $E_{1,t} = E_{0,t}$ "from above" unambiguously. This allows us to state that a stationary equilibrium is unique and stable. To do this, we show that taking a total derivative of this expression yields a slope strictly less than 1 in the neighborhood where $E_{1,t} = E_{0,t}$. To do so take total derivatives of the first four equations above in their endogenous variables (assuming that factor prices have been pinned down by international goods prices):

$$E_{0,t}\pi'(V_t)w_u dU_{1,t} + E_{0,t}\pi''(V_t)\mathrm{w_u}U_{1,t}dV_t + \pi'(V_t)w_u U_{1,t}dE_{0,t} = f''(k_t)*(E_{1,t})k_t - f''(k_t)*(E_{1t}/(E_{0,t})^2)dE_{0,t} + f'(k_t)dE_{1,t}$$

$$f'(k_t)(1/E_{0,t})dK_t - f'(k_t)(K_t/(E_{0,t})^2)dE_{0,t} = [(1+\beta)/\beta][(1-\pi(V_t)]\mathrm{d}(w_u/w_s)] - [(1+\beta)/\beta](w_u/w_s)\pi(V_t)]dV_t$$

$$dK_t = -dV_t$$

$$dE_{1,t} = -dU_{1,t}$$

Substituting out expressions for $dU_{t,1}$ and dK and simplifying gives

$$\left[\frac{\pi''(V_t)}{\pi'(V_t)}E_{0,t} + \frac{f''(k_t)}{f'(k_t)}\right]dV_t = -\frac{f''(k_t)}{f'(k_t)}\frac{1}{E_{0,t}}dE_{0,t} - dE_{0,t} + \frac{E_{0,t}}{E_{1,t}}dE_{1,t} + \frac{E_{0,t}}{U_{1,t}}dE_{1,t}$$

$$\frac{V_t}{K_t}\left[\frac{f(k_t)\pi'(V_t)E_{0,t}}{f'(k_t)[1-\pi(V_t)]} - 1\right]dV_t = \frac{V_t}{E_{0,t}}dE_{0,t}.$$

Combining these two expressions and evaluating them in the neighborhood where $E_{1,t} = E_{0,t}$ allows the following expression:

$$\frac{dE_{1,t}}{dE_{0,t}} = \left[\frac{U_{1,t}}{U_{1,t}+E_{0,t}}\right]\left[1 + \frac{f''(k_t)}{f'(k_t)}\frac{1}{E_{0,t}} + \frac{\left[\frac{\pi''(V_t)}{\pi'(V_t)}E_{0,t} + \frac{f''(k_t)}{f'(k_t)}\right]k_t}{\left[\frac{f(k_t)\pi'(V_t)E_{0,t}}{f'(k_t)[1-\pi(V_t)]} - 1\right]}\right].$$

Note that the first expression is strictly less than one. The second expression is also strictly less than one – it is the sum of one and two negative numbers. This is correct given our parameter restrictions such that the coercion avoidance effect dominates. See Appendix B.3. for details. Consequently, an expression in $E_{1,t} = E_{0,t}$ cuts the line $E_{1,t} = E_{0,t}$ from above which proves uniqueness and stability of the stationary equilibrium.

B.3. Calibration of the Response of Education to a Change in the Price of Coffee with Coercion

To predict the response of educational attainment to a change in coffee prices with coercion, express the education indifference condition (equation (8)) and the budget constraint in proportional changes and substitute to yield

$$\widehat{E} = \left(\frac{\pi rL}{K}\right)\widehat{r} - \frac{1}{\varepsilon_{f(k),k}}(\widehat{w}_u - \widehat{w}_s) + \frac{V}{K}\left[\left(\frac{K}{V}\right)\left(\frac{-\varepsilon_{(1-\pi(V)),V}}{\varepsilon_{f(k),k}}\right) - 1\right]\widehat{V}, \tag{11}$$

where $\varepsilon_{(1-\pi(V)),V}$ represents the elasticity of post-coercion wages with respect to coercion and $\varepsilon_{f(k),k}$ the elasticity of skills per worker with respect to educational capital per worker.

We calibrate the elasticity of human capital accumulation with respect to coercive capital based on parameter values and Puerto Rican data during the period, to develop a prior about the net effect of increased coercion on educational attainment. Using data on the ratio of public school expenditures to rural/urban police expenditures, we obtain a value of V/K of 0.091. Note that for the coercion avoidance effect to dominate we need for the expression in brackets to be greater than zero.

Given that K/V is approximately 11, and we assume that $\varepsilon_{f(k),k} = 0.5$, the coercion avoidance effect will dominate if $|\varepsilon_{(1-\pi(V)),V}| > 0.045$. Even if we allowed for constant returns to scale in the education production function ($\varepsilon_{f(k),k} = 1$), we would only need that the elasticity of post-coercion wages with respect to coercion to be greater than 0.09 in absolute terms. We consider this to be an extremely small number and not a binding constraint for purposes of our analysis. Consider the case where workers keep 50 percent of their income. This would imply that a 10 percent increase in military expenditure decreases post-coercion wages from 50 to 49.1 percent. Given the effectiveness of anti-vagrancy restrictions, the elasticity of coercion with respect to coercive expenditures would be greater than this minimal magnitude.

B.4. Education Response to a Change in the Price of Coffee with Coercion: Structural Parameters

Combining equations (11) and (12) yields an expression for changes in educational attainment as a function of (shadow) factor prices:

$$\hat{E} = \frac{1}{\kappa}\left[\left(\frac{\pi rL}{K}\right)\hat{r} - \frac{1}{\varepsilon_{f(k),k}}\left(\hat{w}_u - \hat{w}_s\right)\right] + \alpha_0\hat{r} + \alpha_1\left(\hat{w}_u - \hat{w}_s\right) \tag{13}$$

where κ, α_1, and α_2 are all positive constants with $\kappa > 1$. The detailed structural composition of these coefficients is

$$\kappa = 1 + \left(\frac{V}{K}\right)\left[\frac{-\varepsilon_{(1-\pi'(V)),V}}{\varepsilon_{f'(k),k}(V/K)} - 1\right]\left[\frac{\varepsilon_{f'(k),k} - (E/U)}{\varepsilon_{\pi'(V),V} + \varepsilon_{f'(k),k}(V/K)}\right] > 1,$$

$$\alpha_0 = \left(\frac{V}{\kappa K}\right)\left[\frac{-\varepsilon_{(1-\pi'(V)),V}}{\varepsilon_{f'(k),k}(V/K)} - 1\right]\left[\frac{\varepsilon_{f'(k),k}(\pi rL/K)}{\varepsilon_{\pi'(V),V} + \varepsilon_{f'(k),k}(V/K)}\right] > 0,$$

and

$$\alpha_1 = \left(\frac{V}{\kappa K}\right)\left[\frac{\varepsilon_{(1-\pi'(V)),V}}{\varepsilon_{f'(k),k}(V/K)} - 1\right]\left[\frac{1}{\varepsilon_{\pi'(V),V} + \varepsilon_{f'(k),k}(V/K)}\right] > 0.$$

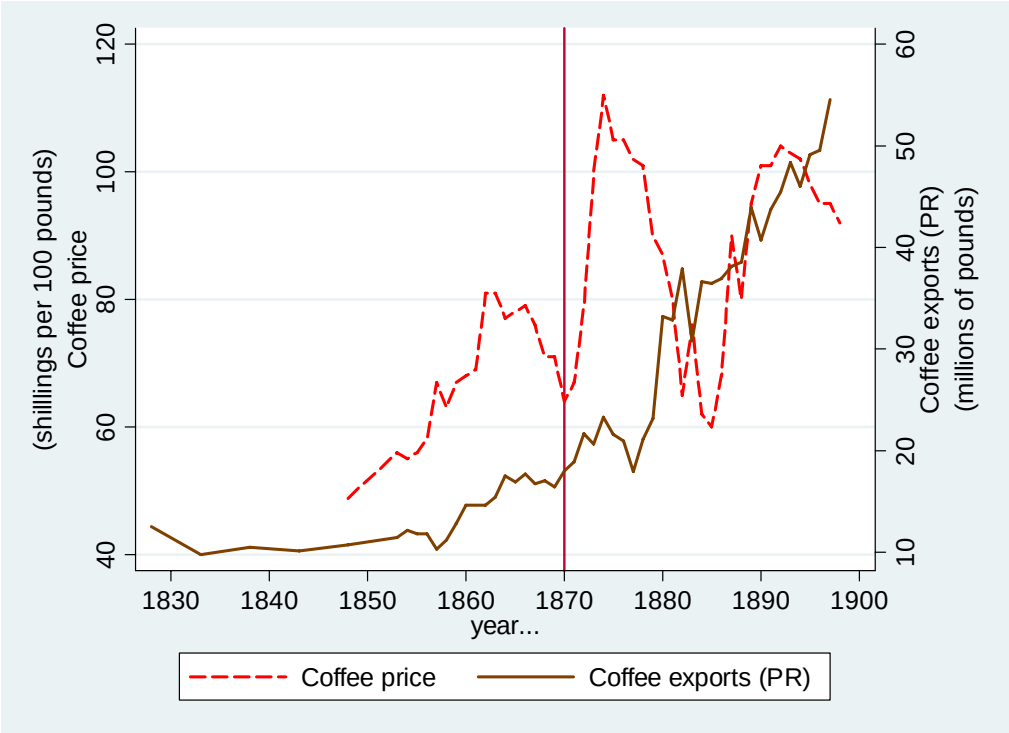
B.5. Calibration of the Response of School Provision to a Change in the Coffee Price with Coercion

An obvious question is if we need pathological parameter values to obtain a fall in educational expenditures in response to an increase in coffee prices.

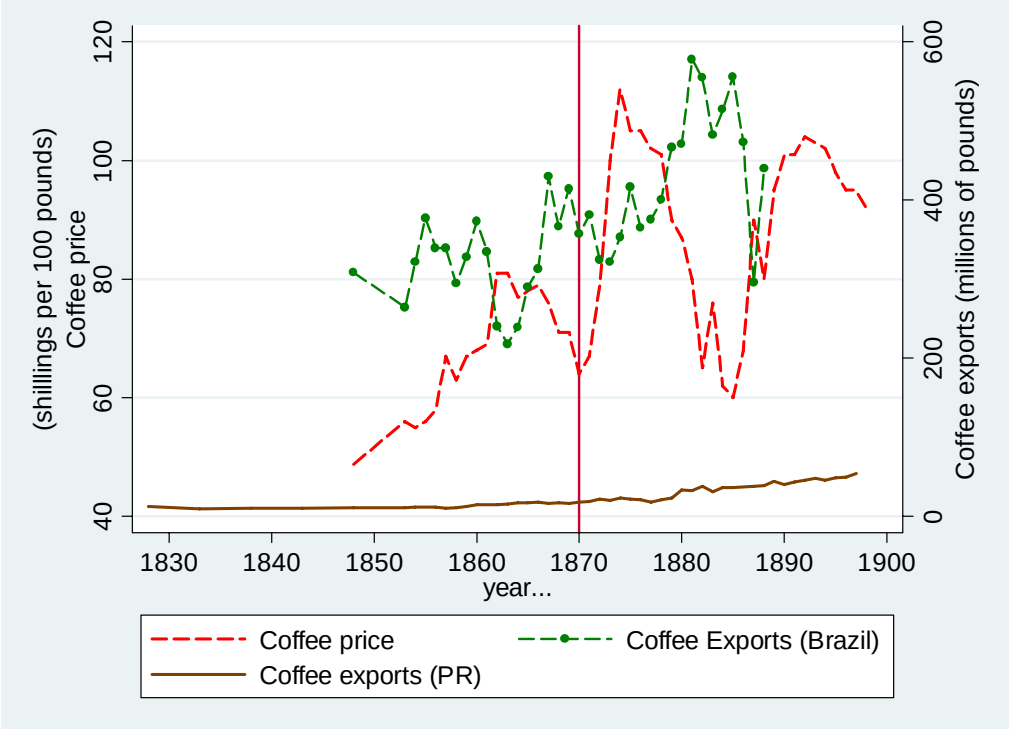
To assess this, we simulate values of $\hat{E}$ using equation (13) and all possible combinations of factor-good cost shares that satisfy the assumptions in Proposition 1. We then generate the associated values of $\hat{K}$ using equation (14) and the same changes in factor prices. We can then estimate a relationship between $\hat{E}$ and $\hat{K}$ to observe $\hat{K}$ in the neighborhood of $\hat{E} = 0$ for differing values of $\varepsilon_{\pi'(V),V}$ and given the parameter values discussed in Appendix B.3. We find that if the coercion function is sufficiently close to constant returns, K will fall in response to the coffee price shock when E is constant. Specifically, if $\varepsilon_{\pi'(V),V} = 0$, we observe constant returns, and K will fall when E is constant if $\varepsilon_{\pi'(V),V} \geq -0.20$. While we do not have a strong prior on what the actual value of this parameter is, we believe that this shows that we do not need pathological beliefs to general a fall in K when E is constant in equilibrium.

Figure 1: Volume of P.R. Coffee Exports and International Coffee Prices, 1825-1897

Panel A: Coffee Prices and Trends in P.R. Coffee Exports

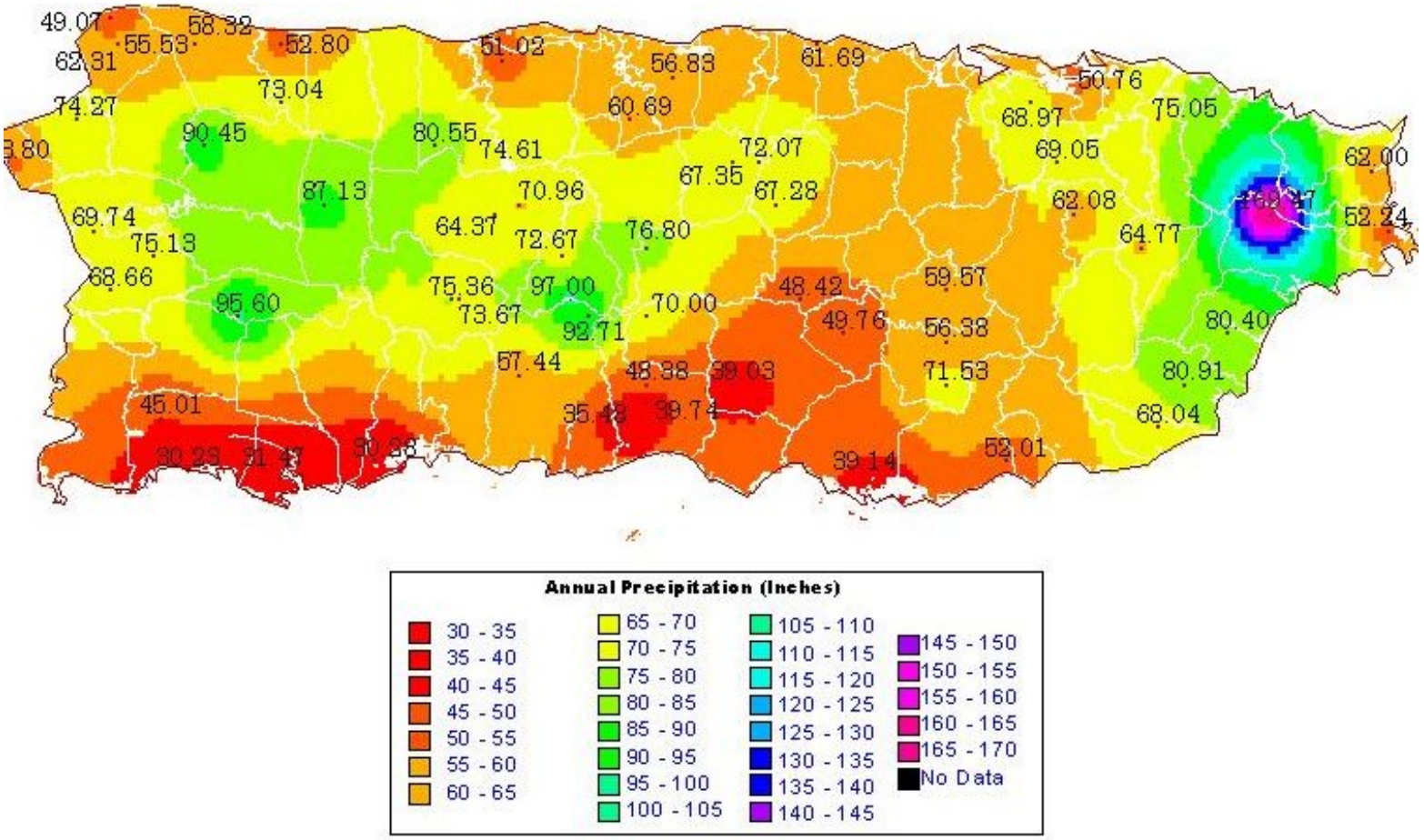


Panel B: Coffee Prices and Trends in Brazil and P.R. Coffee Exports



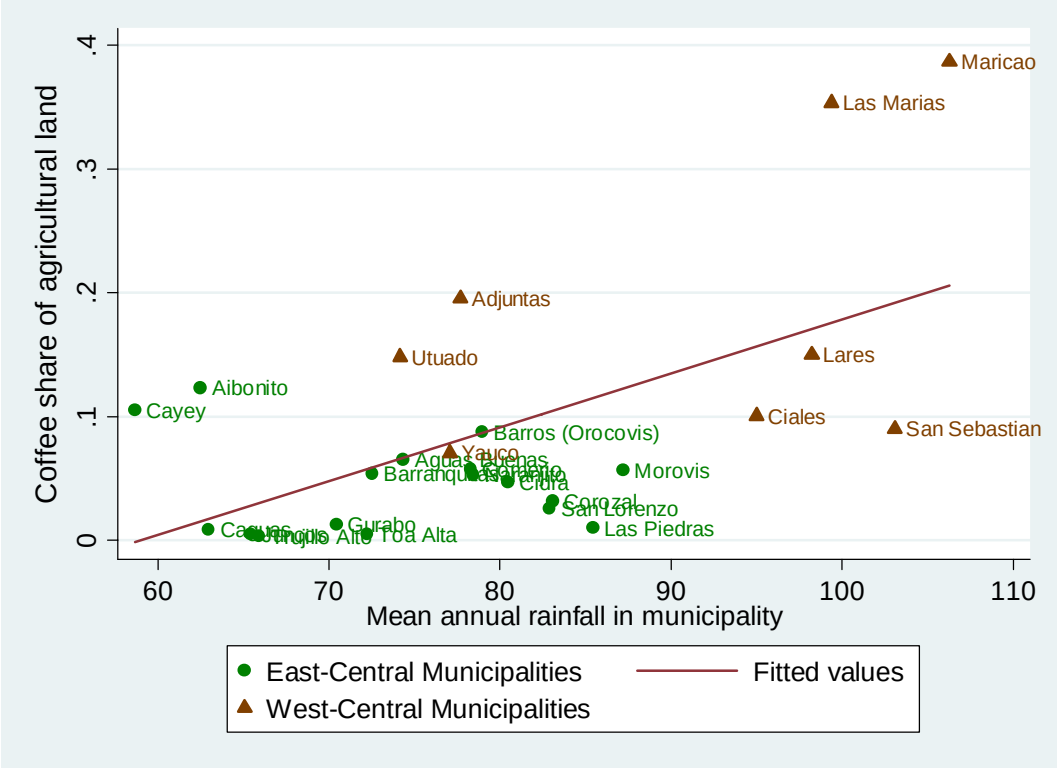
Sources: Coffee exports data – *Boletín Histórico de Puerto Rico,* volume 5, p. 300, averages for the years 1828-32, 1833-37, 1838-42, 1843-47, and 1848-52, available in Dietz (1986); Puerto Rico, Intendencia General de Hacienda, *Balanza Mercantil*, for the years 1853-1860; *Estadística General*, for the years 1862-1898, in Bergad (1983). Wholesale export prices for coffee (quoted in the UK) are taken from Sauerbeck (1886, 1893, 1909). See the data appendix for details.

Figure 2: Mean Annual Precipitation, 1971-2000



Source: National Weather Service (2007).

Figure 3: Mean Annual Precipitation Levels and Coffee Cultivation, Year 1896

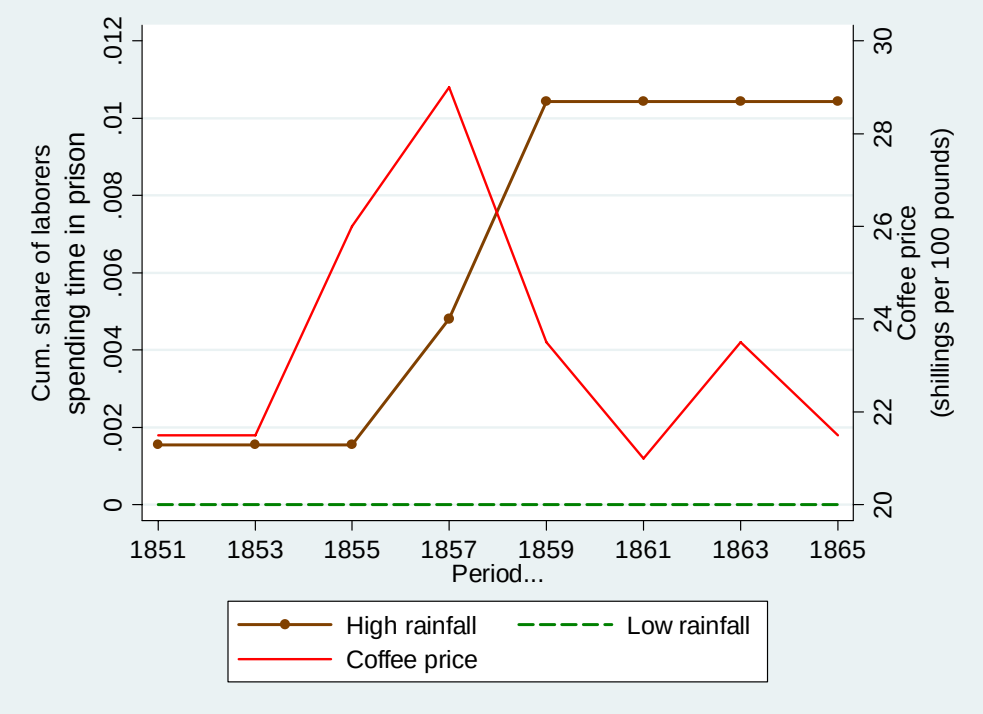


Notes: Each (green) circle represents a municipality. Plotted are residuals (adjusted by sample means) from multivariate regression which condition on the following geographic variables: mean annual maximum and minimum temperatures, mean altitude, mean degree of ruggedness (gradient), and distance to the nearest port municipality. Linear fit from OLS regression shown in solid line.

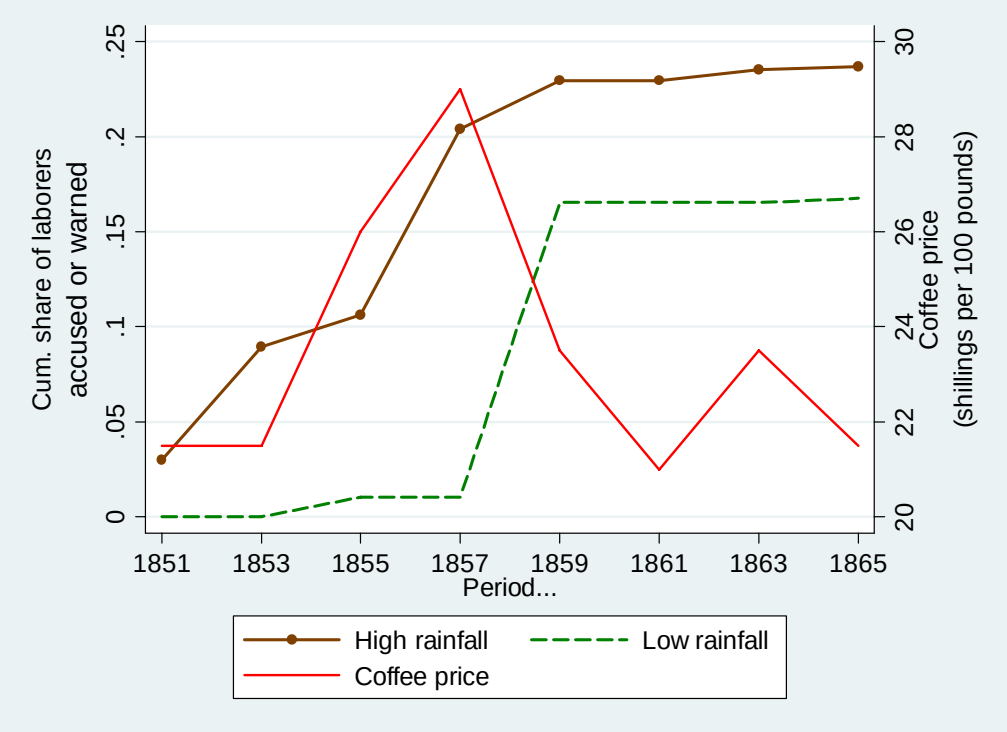
Source: Author's calculations from Carroll (1899) and Roberts (1941). See the data appendix for details on the construction of the variables.

Figure 4: Trends in Enforcement of General Laborers' Law, 1851-1867

Panel A: Cumulative Share of Laborers Spending Time in Prison



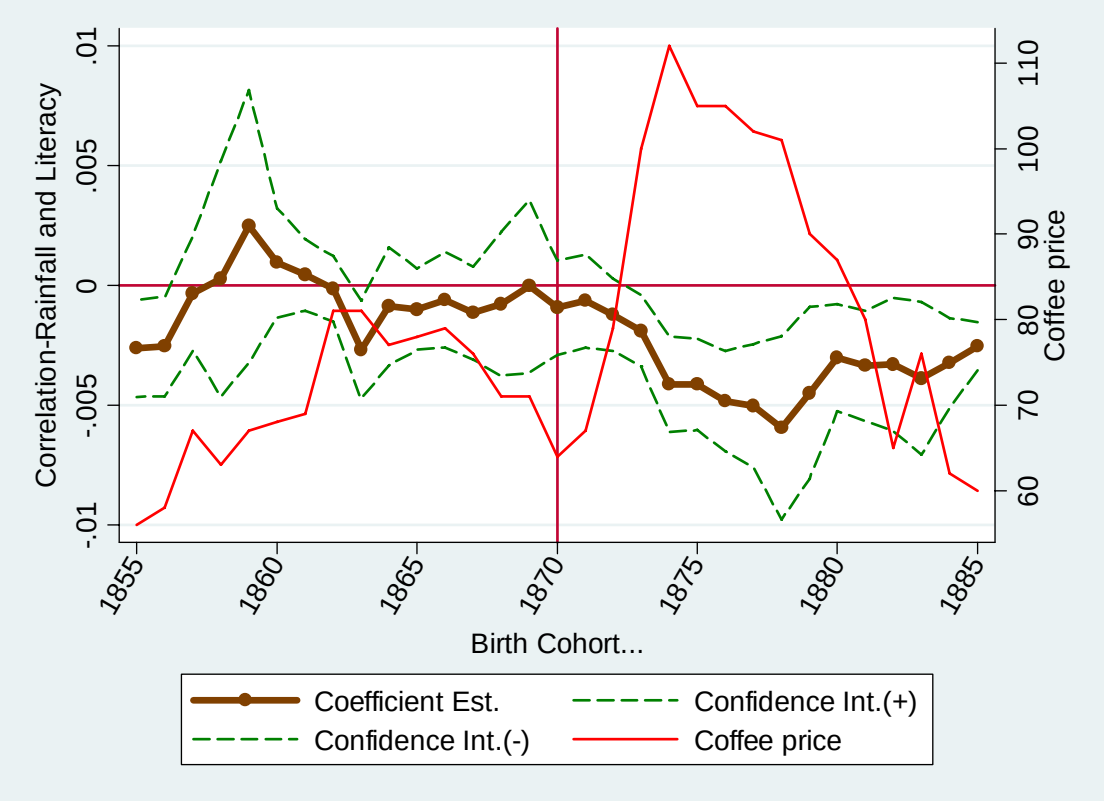
Panel B: Cumulative Share of Laborers Accused of or Warned against Vagrancy



Notes: The figures depict the cumulative share of laborers ('jornaleros') reported to be spending time in prison (Panel A) and accused or warned of being punished for not abiding by the coercive labor regulations (Panel B) in municipalities with above average (solid brown line with circles) and below average (dashed green line) annual rainfall levels. International coffee prices depicted in a solid red line.
Sources: Authors' calculations from Córdova (1831-33), and Gaceta de Puerto Rico (1868a).

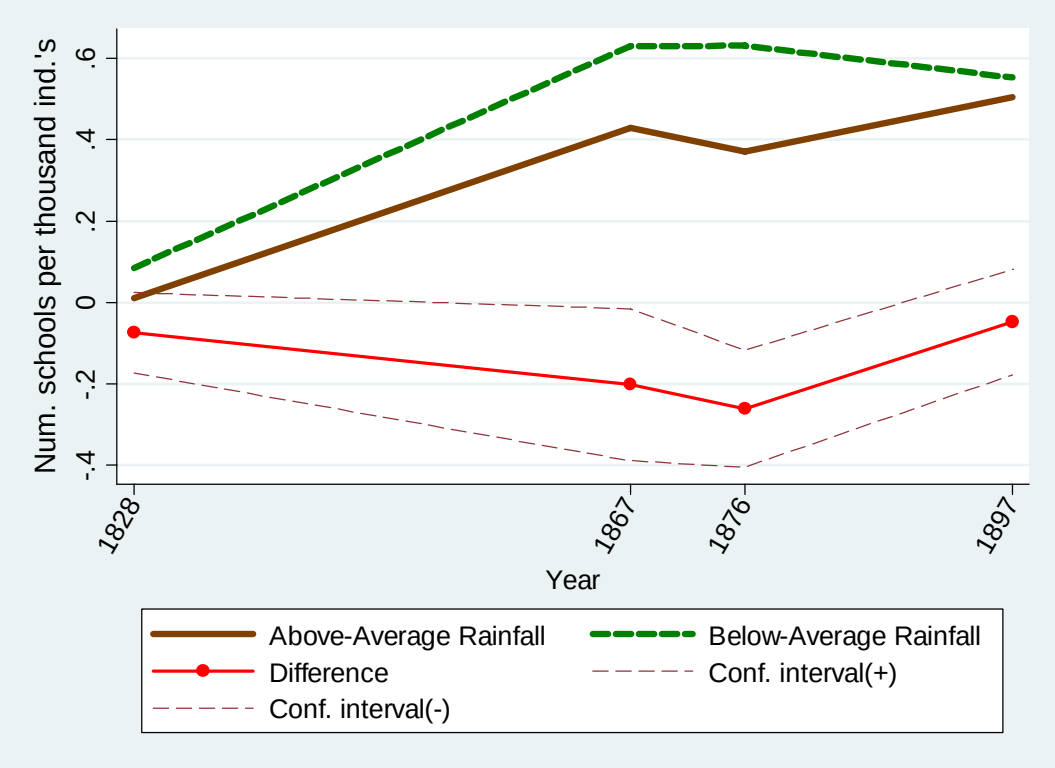
Figure 5: Literacy Rates Differences across Municipalities with Varying Rainfall Levels

Coefficients-Interaction of Cohort Group Indicators and the Municipality-Level Average Annual Rainfall Levels



Notes: Values of parameter estimates of cohort-specific correlation with mean annual rainfall in municipality, from OLS regressions and their 95 percent confidence intervals are presented. (Robust standard errors; disturbance terms are allowed to be correlated within municipality, but not across municipalities). Specification includes municipality and year of birth indicator variables.

Figure 6: Trends in number of schools per capita throughout the 19th century

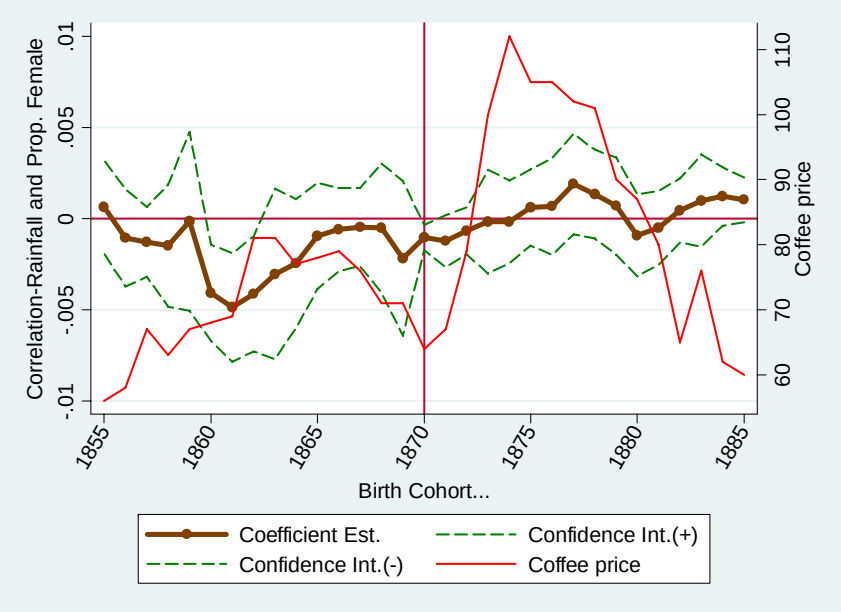


Notes: Panel A depicts trends in number of public primary schools per thousand individuals for the above average (solid brown line) and below average (dashed green line) annual rainfall municipalities; mean differences coefficient estimates from OLS regressions, depicted in the solid red line with circles, and their 95 percent confidence intervals, depicted in thin dashed lines.

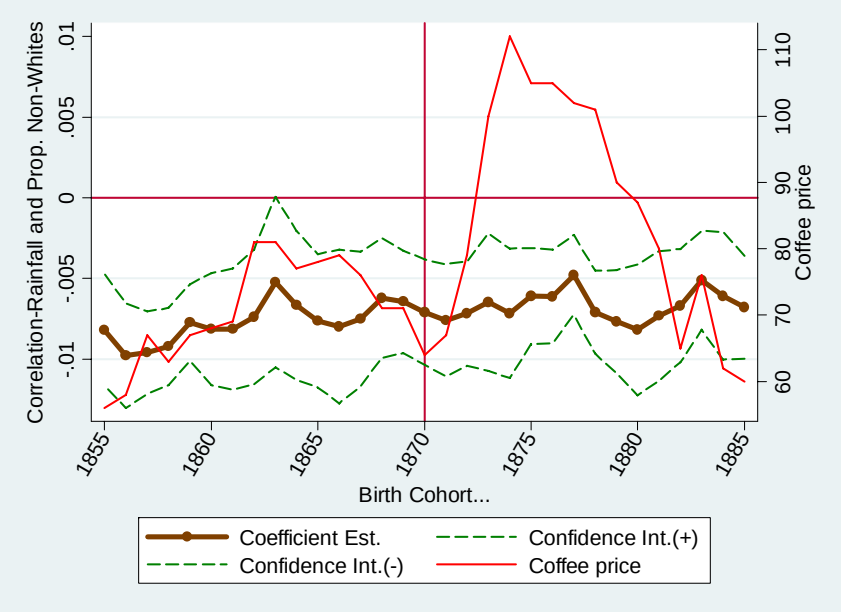
Figure 7: Differences in Pre-Determined Observable Characteristics across Cohorts in Municipalities with Varying Rainfall Levels

Coefficients-Interaction of Cohort Group Indicators and the Municipality-Level Average Annual Rainfall Levels

Panel A: Proportion Female



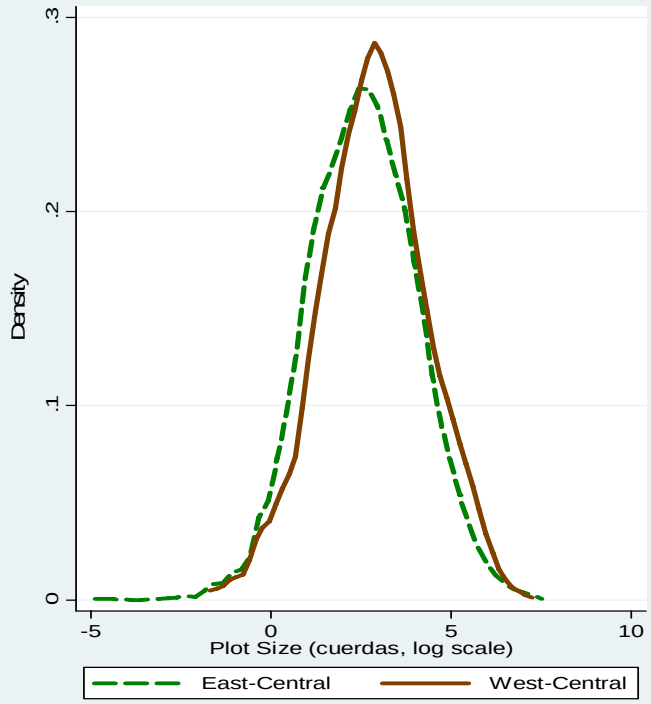
Panel B: Proportion Non-White



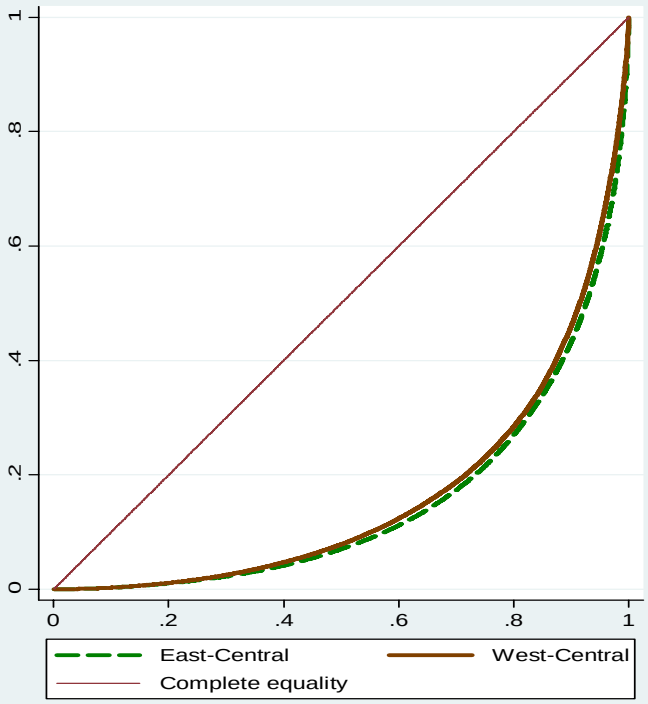
Notes: Values of parameter estimates of cohort-specific correlation with mean annual rainfall in municipality, from OLS regressions and their 95 percent confidence intervals are presented. (Robust standard errors; disturbance terms are allowed to be correlated within municipality, but not across municipalities). Specification includes municipality and year of birth indicator variables.

Figure 8: Distribution of Landholdings across Regions, 1890s

Panel A: Non-parametric kernel densities



Panel B: Lorenz Curves



Notes: Panel A figures present non-parametric kernel density estimates of the distribution of individual land ownership using an Epanechnikov kernel. Panel B presents Lorenz curve of land ownership distribution for each region (coffee region = solid brown line; food crops region = dashed green line). Data are samples from land cadastres for municipalities in West-Central and East-Central regions, varying years (1891-1894).

Table 1: Geographic, Economic and Demographic Characteristics, Mid-Nineteenth Century

	West-Central (Coffee) Region (1)	East-Central (Food crops) Region (2)	Difference (Std. Error) (3)	Corr. with mean annual rainfall (Std. Error) (4)
Panel A: Geographic Characteristics				
Average annual rainfall, 1899-1928 (in.)	90.2	74.1	16.1***	-
			(4.2)	
Average altitude (meters)	436.4	331.8	104.7	0.636
			(73.7)	(2.797)
Average land gradient (degrees)	17.6	14.4	3.2**	0.061
			(1.3)	(0.054)
Average maximum temperature, 1950-2000 (ºF)	82.9	84.0	-1.2	0.045
			(1.3)	(0.051)
Average minimum temperature, 1950-2000 (ºF)	63.2	66.7	-3.5***	-0.034
			(0.7)	(0.038)
Distance to nearest port (km)	24.4	26.0	-1.6	0.036
			(2.8)	(0.108)
Panel B: Coffee Cultivation & Production, Year 1828				
Coffee production (quintales)/ land unit (cuerda)	0.071	0.034	0.037	0.000
			(0.032)	(0.001)
Number of coffee mills	0.40	0.06	0.34	0.020**
			(0.24)	(0.009)
Wealth per capita	94.9	109.3	-14.4	0.403
			(14.8)	(0.813)
Value of production per capita	9.5	6.0	3.4	0.040
			(1.6)	(0.070)
Panel C: Socio-Economic and Demographic Characteristics, Year 1828				
Sharecroppers share of the populaion	0.08	0.13	-0.05	-0.0007
			(0.03)	(0.0018)
Slaves as share of total population	0.08	0.08	0.00	-0.0030***
			(0.02)	(0.0006)
Free blacks or mulattos as share of the pop.	0.33	0.35	-0.02	-0.0069
			(0.07)	(0.0032)
Free blacks as share of the population	0.05	0.07	-0.02	-0.0013
			(0.02)	(0.0011)
White pop. share of the total population	0.51	0.44	0.07	0.0156***
			(0.08)	(0.0034)
Crude Birth Rate	57.8	54.6	3.2	0.12
			(7.5)	(0.30)
Crude Death Rate	23.1	23.2	-0.1	0.08
			(3.3)	(0.13)

Notes: Standard errors in parentheses; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. See the data description section and the data appendix for detailed descriptions of the construction of variables used in the analysis.

Table 2: Precipitation Levels and Coffee Cultivation in Year 1896

Dependent variable:	Share of agricultural land under coffee cultivation, year 1896						
Sample:	Overall	Overall	Overall	Overall	Overall	Land Ownership	Land Ownership
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)	OLS (7)
Average annual rainfall (in. x 10)	0.044***	0.044**	0.038**	0.038**	0.040*	0.032	0.034
	(0.019)	(0.017)	(0.017)	(0.018)	(0.020)	(0.021)	(0.0244)
Average maximum temperature		-0.009	-0.003	-0.003	-0.003		-0.007
		(0.006)	(0.008)	(0.007)	(0.007)		(0.008)
Average minimum temperature		-0.010	-0.007	-0.008	-0.008		-0.002
		(0.006)	(0.006)	(0.007)	(0.007)		(0.008)
Average altitude (m)			0.000	0.000	0.000		
			(0.000)	(0.000)	(0.000)		
Average land gradient (°)			0.006	0.006	0.006		0.003
			(0.008)	(0.008)	(0.008)		(0.007)
Distance to port (km)				0.001	0.001		-0.001
				(0.003)	(0.003)		(0.002)
Black / mulatto population share, 1899					0.005		
					(0.081)		
Mean of dep. variable	0.0898	0.0898	0.0898	0.0898	0.0898	0.0895	0.0895
Observations	25	25	25	25	25	20	20

Notes: Robust standard errors in parentheses; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. See the data description section and the data appendix for detailed descriptions of the construction of variables used in the analysis.

Table 3: Descriptive Statistics

	All Cohorts	Coercive Period Cohorts	Post-coercive Period Cohorts
Panel A: 1910 Census of Population PUMS Data			
Adult Literacy Rate	0.178	0.145	0.198
Age (in 1910)	36.5 [8.9]	46.4 [5.4]	30.7 [4.3]
Gender (Female = 1, Male = 0)	0.50	0.49	0.51
Ethnicity (Black/Mulatto = 1, Other = 0)	0.27	0.27	0.27
Panel B: Primary School Provision and Other Government Measures			
Num. of public primary schools per 1,000 individuals	0.406 [0.276]	-	-
Jornalero Share of Population, Year 1867	0.093 [0.054]	-	-
Share of Volunteer Guard Company in Mun.,Year 1886	0.69 [0.30]	-	-
Volunteer Guard Company Headquarters, Year 1886	0.087 [0.288]	-	-
Number of Units in Provincial Civil Guard, Year 1876	10.27 [15.05]	-	-

Notes: Standard deviation in brackets. See the data description section and the data appendix for detailed descriptions of the construction of variables used in the analysis.

Table 4: The Effects of the Coffee Boom on Literacy Rates

Dependent variable:	Individual's literacy (1/0) indicator								
Sample:	All	All	All	Males	Females	All Coercion Period Cohorts		All Post-Coercion Period Cohorts	
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)	OLS (7)	OLS (8)	OLS (9)
Avg. rainfall (in. x 10) * Post-coercion cohort	-0.0227***	-0.0227***	-0.0220***	-0.0286**	-0.0147**				
	(0.0053)	(0.0053)	(0.0051)	(0.0103)	(0.0049)				
Avg. rainfall (in. x 10) * Coffee price six years preceding primary school enrollment decision						0.00010	0.00005	-0.00067**	-0.00069***
						(0.00046)	(0.00045)	(0.00025)	(0.00024)
Average annual rainfall (in. x 10)	-0.0181*	-0.0156							
	(0.0090)	(0.0117)							
Coffee price six years preceding primary school enrollment decision						0.00021	0.00064	0.00675***	0.00690***
						(0.00358)	(0.00345)	(0.00208)	(0.00203)
Demographic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographic controls	No	Yes	No	No	No	Yes	No	Yes	No
Municipality fixed effects	No	No	Yes	Yes	Yes	No	Yes	No	Yes
*ΔLiteracy from 1SD(Coffee price)*10 in. rain*						*0.017*	*0.009*	*-0.012*	*-0.012*
Mean of dependent variable	0.178	0.178	0.178	0.229	0.128	0.145	0.145	0.198	0.198
N	14532	14532	14532	7227	7305	5421	5421	9111	9111
R-squared	0.05	0.05	0.06	0.05	0.04	0.05	0.05	0.05	0.05

Notes: Coefficient estimates from OLS regressions are reported. Robust standard errors in parentheses; disturbance terms are allowed to be correlated across all individuals within a municipality but not across municipalities; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Demographic controls include 25-29, 30-39, and 40-49 years (in 1910) age group indicators (or the appropriate subset for period-specific cohort regressions), as well as a female gender indicator, a black/mulatto indicator, and a native-born indicator. Geographic controls are the mean maximum and minimum annual temperature, mean altitude, mean land gradient, and distance to nearest port for each municipality.

Table 5: The Effects of the Coffee Boom on Public Primary School Provision

Dependent variable:	Number of schools per capita in municipality						
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)	OLS (7)
Avg. rainfall (in. x 10) * Year 1867 / 1876 / 1897	-0.075***	-0.071***			-0.066***	-0.067**	
	(0.021)	(0.022)			(0.022)	(0.026)	
Avg. rainfall (in. x 10) * Year 1867			-0.084**	-0.082**			-0.082*
			(0.036)	(0.037)			(0.042)
Avg. rainfall (in. x 10) * Year 1876			-0.130***	-0.118***			-0.120**
			(0.038)	(0.038)			(0.047)
Avg. rainfall (in. x 10) * Year 1897			-0.026	-0.023			-0.018
			(0.026)	(0.026)			(0.032)
Average annual rainfall (in. x 10)	-0.011	-0.012	-0.011	-0.010	0.011		
	(0.019)	(0.027)	(0.019)	(0.028)	(0.018)		
Black/Mulatto Pop. Share, Year 1899					0.441**		
					(0.159)		
Period indicators	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographic controls	No	Yes	No	Yes	Yes	No	No
Municipality fixed effects	No	No	No	No	No	Yes	Yes
Rainfall (1867) & rainfall (1876) joint significance F-test p-value			0.001	0.002			0.009
Mean of dependent variable	0.406	0.406	0.406	0.406	0.406	0.406	0.406
N	86	86	86	86	86	86	86
R-squared	0.65	0.70	0.67	0.72	0.73	0.79	0.81

Notes: Coefficient estimates from OLS regressions are reported. Robust standard errors in parentheses; disturbance terms are allowed to be correlated within municipalities over time but not across municipalities; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Geographic controls are the mean maximum and minimum annual temperature, mean altitude, mean land gradient, and distance to nearest port for each municipality.

Table 6: Tests of Geographic Sorting – Composition Effects

Dependent variable:	Female individual ind. (1/0)		Non-white individual ind. (1/0)		Cohort size (logs)	
Sample:	All Post-Coercion Period Cohorts		All Post-Coercion Period Cohorts		All Post-Coercion Period Cohorts	
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)
Avg. rainfall (in. x 10) *						
Coffee price six years preceding	-0.00021	-0.00020	0.00001	-0.00004	-0.0003	-0.0003
primary school enrollment decision	(0.00023)	(0.00023)	(0.00019)	(0.00019)	(0.0007)	(0.0007)
Coffee price six years preceding	0.0017	0.0016	-0.0004	-0.0001	-0.002	-0.002
primary school enrollment decision	(0.0018)	(0.0018)	(0.0014)	(0.0014)	(0.006)	(0.006)
Other demographic controls	Yes	Yes	Yes	Yes	Yes	Yes
Geographic controls	Yes	No	Yes	No	Yes	No
Municipality fixed effects	No	Yes	No	Yes	No	Yes
Δ*Effect from 1SD(Coffee price)*10 in. rain*	*-0.004*	*-0.004*	*0.000*	*-0.001*	*-0.0052*	*-0.0053*
Mean of dependent variable	0.502	0.502	0.267	0.267	-	-
N	9111	9111	9111	9111	329	329
R-squared	0.001	0.002	0.075	0.095	0.213	0.358

Notes: Coefficient estimates from OLS regressions are reported. Standard errors in parentheses; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Geographic controls are the mean maximum temperature, mean minimum temperature, mean altitude, mean land gradient, and distance to nearest port for each municipality. Demographic controls for columns (1-2) include a 25-29 years (in 1910) age group indicator, a black/mulatto indicator, and a native-born indicator; in columns (3-4), these include the 25-29 years (in 1910) age group indicator, a native-born indicator, as well as a female gender indicator; in columns (5-6), these are the proportion of (i) females in the cohort, (ii) blacks/mulattos in the cohort, and (iii) native-born individuals in the cohort.

Table 7: Tests of Alternate Hypotheses – Correlations with Annual Rainfall Levels

Dependent variable:	Adult foreigners' literacy rate, year 1899		Native adult males' literacy rate, year 1899		Overall Land Ownership Gini, 1890s		Landed HHs Land Ownership Gini, 1890s		Share of Landless Households, year 1899		
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)	OLS (7)	OLS (8)	OLS (9)	OLS (10)	OLS (11)
Avg. rainfall (in. x 10)	0.0055	0.0021	-0.013**	-0.013**	0.009	-0.002	0.028	0.009	-0.003	-0.026	-0.0222
	(0.0137)	(0.0016)	(0.005)	(0.005)	(0.074)	(0.008)	(0.017)	(0.021)	(0.020)	(0.021)	(0.0275)
Geographic controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	Yes
Mean of dep. variable	0.86	0.86	0.24	0.24	0.92	0.92	0.75	0.75	0.70	0.70	0.69
Observations	23	23	23	23	19	19	19	19	23	23	19
R-squared	0.008	0.32	0.24	0.62	0.07	0.56	0.14	0.45	0.001	0.43	0.3945

Notes: Coefficient estimates from OLS regressions are reported. Standard errors in parentheses; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Geographic controls are the mean maximum temperature, mean minimum temperature, mean altitude, mean land gradient, and distance to nearest port for each municipality.

Table 8: Robustness Tests of the Effects of the Coffee Boom on Literacy Rates

	Dependent variable: Individual's literacy (1/0) indicator					
Additonal control variable:	Coefficient estimates on:			Coefficient estimates on:		
Interaction with coffee price six years preceding primary school enrollment decision	Avg. rainfall (in. x 10) * Coffee price 6 years prec. school enroll. decision	Additional control variable	Δ*Literacy from 1SD* ($Price_c$)* *10 in. rain*	Avg. rainfall (in. x 10) * Coffee price 6 years prec. school enroll. decision	Additional control variable	Δ*Literacy from 1SD* ($Price_c$)* *10 in. rain*
	----- Post-coercion period cohorts -----			----- Coercion period cohorts -----		
	(1)	(2)	(3)	(4)	(5)	(6)
Mean altitude (m. x 10)	-0.00068**	0.00001	*-0.012*	0.00005	-0.00003	*0.001*
	(0.00025)	(0.00002)		(0.00044)	(0.00003)	
Mean land gradient (º)	-0.00067***	-0.00008	*-0.012*	0.00008	-0.00013	*0.002*
	(0.00021)	(0.00012)		(0.00046)	(0.00018)	
Distance to port (km)	-0.00071***	0.00004	*-0.013*	0.00001	0.00006	*0.000*
	(0.00021)	(0.00004)		(0.00046)	(0.00006)	
Num. Provincial Civil Guard units (n x 10) (1876)	-0.00071***	-0.00017***	*-0.013*	0.00007	0.00011	*0.001*
	(0.00022)	(0.00005)		(0.00045)	(0.00011)	
Share of Volunteer Guard Unit in Mun. (1886)	-0.00067**	0.00050	*-0.012*	0.00005	-0.00017	*0.001*
	(0.00024)	(0.00117)		(0.00043)	(0.00157)	
Volunteer Guard Headquarters in Mun. (1886)	-0.00070***	-0.00080	*-0.012*	0.00006	0.00083	*0.001*
	(0.00023)	(0.00056)		(0.00046)	(0.00077)	
Geographic controls		No			No	
Municipality fixed effects		Yes			Yes	
Mean of dependent variable		0.198			0.145	
N Municipalities		22			22	
N Individuals		9111			5421	

Notes: Coefficient estimates from OLS regressions are reported. Robust standard errors in parentheses; disturbance terms are allowed to be correlated across all individuals within a municipality but not across municipalities; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Demographic controls include a female gender indicator, a black/mulatto indicator, a native-born indicator, and the relevant age group controls (a 25-29 years (in 1910) age group indicator for the post-coercive period sample, and 30-39 and 40-49 years (in 1910) age group indicators for the coercive period sample).

Table A1: Robustness Tests of the Effects of the Coffee Boom on Literacy Rates

Dependent variable:	Individual's literacy (1/0) indicator				
Sample:	Municipalities with Land Ineq. Measures			Municipalities with Baseline School Data	
	(1)	(2)	(3)	(4)	(5)
Panel A: Post-Coercion Cohorts Average Effect					
Avg. rainfall (in. x 10) * Post-coercion cohort	-0.0265***	-0.0243***	-0.0230***	-0.0224***	-0.0221***
	(0.0049)	(0.0060)	(0.0057)	(0.0063)	(0.0063)
Average annual rainfall (in. x 10)	-0.0092	-0.0108	-0.0198	-0.0182	-0.0184
	(0.0103)	(0.0118)	(0.0135)	(0.0138)	(0.0133)
Geographic controls	Yes	Yes	Yes	Yes	Yes
Municipality fixed effects	No	No	No	No	No
Panel B: Post-Coercion Cohorts Average Effect					
Avg. rainfall (in. x 10) * Post-coercion cohort	-0.0258***	-0.0235***	-0.0222***	-0.0217***	-0.0215***
	(0.0048)	(0.0057)	(0.0054)	(0.0061)	(0.0061)
Geographic controls	No	No	No	No	No
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Panel C: Additional Controls for All Specifications					
Demographic controls	Yes	Yes	Yes	Yes	Yes
Landowner Gini & Post-coercion cohort interaction	Yes	No	No	No	No
Overall Gini & Post-coercion cohort interaction	No	Yes	No	No	No
1828 Num. schools per capita & Post-coercion cohort interaction	No	No	No	Yes	No
N Municipalities	18	18	18	20	20
N Individuals (Panels A & B)	13098	13098	13098	12855	12855

Notes: Coefficient estimates from OLS regressions are reported. Robust standard errors in parentheses; disturbance terms are allowed to be correlated across all individuals within a municipality but not across municipalities; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Demographic controls include 25-29, 30-39, and 40-49 years (in 1910) age group indicators as well as a female gender indicator, a black/mulatto indicator, and a native-born indicator. Geographic controls are the mean maximum and minimum annual temperature, mean altitude, mean land gradient, and distance to nearest port for each municipality.

Table A1: Robustness Tests of the Effects of the Coffee Boom on Literacy Rates (cont.)

Dependent variable:	Individual's literacy (1/0) indicator				
Sample:	Municipalities with Land Ineq. Measures			Municipalities with Baseline School Data	
	(1)	(2)	(3)	(4)	(5)
Panel D: Post-Coercion Cohorts Coffee Price Effect					
Avg. rainfall (in. x 10) * Coffee price six years preceding primary school enrollment decision	-0.00062***	-0.00062**	-0.00064**	-0.00072**	-0.00070**
	(0.00020)	(0.00022)	(0.00023)	(0.00032)	(0.00030)
Geographic controls	No	No	No	No	No
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
*ΔLiteracy from 1SD(Coffee price)*10 in. rain*	*-0.011*	*-0.011*	*-0.011*	*-0.013*	*-0.012*
Panel E: Coercion Cohorts Coffee Price Effect					
Avg. rainfall (in. x 10) * Coffee price six years preceding primary school enrollment decision	-0.00001	-0.00001	-0.00005	-0.00003	-0.00001
	(0.00045)	(0.00044)	(0.00043)	(0.00052)	(0.00054)
Geographic controls	No	No	No	No	No
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
*ΔLiteracy from 1SD(Coffee price)*10 in. rain*	*0.000*	*0.000*	*-0.001*	*0.000*	*0.000*
Panel F: Additional Controls for All Specifications					
Demographic controls	Yes	Yes	Yes	Yes	Yes
Landowner Gini * Coffee Price interaction	Yes	No	No	No	No
Overall Gini * Coffee Price interaction	No	Yes	No	No	No
1828 Num. schools per capita * Coffee price interaction	No	No	No	Yes	No
N Municipalities	18	18	18	20	20
N Individuals (Panel D)	8206	8206	8206	8075	8075
N Individuals (Panel E)	4892	4892	4892	4780	4780

Notes: Coefficient estimates from OLS regressions are reported. Robust standard errors in parentheses; disturbance terms are allowed to be correlated across all individuals within a municipality but not across municipalities; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Demographic controls include a female gender indicator, a black/mulatto indicator, a native-born indicator, and the relevant age group controls (a 25-29 years (in 1910) age group indicator for the post-coercive period sample, and 30-39 and 40-49 years (in 1910) age group indicators for the coercive period sample).

Table A2: Robustness Tests of the Effects of the Coffee Boom on Public Primary School Provision

Dependent variable:	Coefficient Estimate on Avg. rainfall (in. x 10) * Post-Period indicator					
Sample:	All Mun.	Gini Mun.	Gini Mun.	Gini Mun.	Schools Mun.	Schools Mun.
	(1)	(2)	(3)	(4)	(5)	(6)
Geographic controls	-0.065***	-0.048**	-0.045**	-0.062**	-0.077***	-0.068***
	(0.023)	(0.018)	(0.018)	(0.025)	(0.021)	(0.024)
Municipality Fixed Effects	-0.072**	-0.050**	-0.053***	-0.064**	-0.078***	-0.071**
	(0.027)	(0.019)	(0.018)	(0.027)	(0.023)	(0.026)
Landowners Gini & Young cohort interaction		Yes	No	No		
Overall Gini & Young cohort interaction		No	Yes	No		
1828 Num. schools p.c. & Young cohort interaction					Yes	No
N Municipalities	23	19	19	19	21	21
N Observations	86	72	72	72	80	80

Notes: Each coefficient estimate is from a separate regression. Coefficient estimates from OLS regressions are reported. Robust standard errors in parentheses; disturbance terms are allowed to be correlated across all individuals within a municipality but not across municipalities; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Geographic controls are the mean maximum and minimum annual temperature, mean altitude, mean land gradient, and distance to nearest port for each municipality.