Labor Coercion and the Accumulation of Human Capital*

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Abstract: This paper examines the effect of labor coercion on human capital accumulation. We first develop a model of human capital accumulation in which coercion depresses both the relative wage of unskilled labor and public educational expenditures. If unskilled labor's wage declines sufficiently, increasing the return to schooling, workers may demand more education than in the case without coercion. We then use micro data from Puerto Rico, where unskilled laborers were forced to work for landowners during 1849-1874. Using variation in municipality-level suitability for coffee cultivation and international coffee prices, we estimate the response of schooling to exogenous increases in relative demand for unskilled labor in regimes with and without coercion. Under coercion, public expenditure on education fell with no decrease in literacy, consistent with an increase in the skill premium. Following the abolition of coercion in 1874, literacy declined in response to similar increases in demand for unskilled labor.

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I. Introduction

Throughout history, many types of labor arrangement have involved the use of coercion – the threat or use of force to compel workers to enter into an employment relationship. Slavery was a common way of organizing labor in plantation economies throughout the Americas and has been the focus of economic historians for many years.[1] Other forms of forced labor, such as debt peonage and the state-sanctioned forced recruitment of laborers, also played an important role in the hacienda system found in Latin America during the colonial and post-colonial periods.[2] Episodes of coercion are not confined to the historical record: they have persisted in many forms across both industrialized and developing countries throughout the twentieth century (Andrees and Belser 2009).

While the conditions determining the degree and precise form of coercion have been studied extensively, in particular the role of international trade, less is known about the consequences of coercion for economic development.[3] Scholars have argued that coercive labor institutions could lead to socially inefficient outcomes as they involve a costly transfer of resources away from workers (e.g., Engerman and Sokoloff 1997; Coatsworth 1999; Conning 2004; Acemoglu and Wolitzky 2010). Consistent with these arguments, empirical studies have found a negative relationship between the historical prevalence of coercion and measures of current economic development such as income and levels of education.[4] In contrast, less analysis has been devoted to identifying the empirical mechanisms that may lead to limited educational human capital accumulation. It is difficult to understate the importance of this channel given that it is arguably one of the most prominent determinants of development in the modern period (e.g., Galor 2005). This paper provides empirical evidence of the consequence of labor coercion for individuals' education decisions in the context of increasing commodity export trade.

To inform our empirical analysis and formalize ideas, we first develop a simple general equilibrium model of the public provision of education, coercion of unskilled workers, and workers' human capital accumulation decisions in a small open economy. In the absence of coercion, a commodity boom affects the equilibrium amount of educational attainment through changes in both the public provision of educational driven by government tax revenue (supply) and in the skill premium (demand).

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[1] E.g., Mintz (1969); Fogel and Engerman (1974); Wright (1978); Lockhart and Schwartz (1983).

[2] E.g., McCreery (1994); Alston, Mattiace and Nonnenmacher (2009); Dell (2010). See Acemoglu and Wolitzky (2010) for a broader discussion of the prevalence of forced labor throughout history.

[3] In a seminal study, Evsey Domar (1970) argued that the incentives to coerce workers would increase significantly as the result of a rise in (shadow) wages. Consequently, if export commodity booms increase the relative demand for unskilled labor, this provides a strong link between periods of increased international trade and episodes of labor market coercion. Empirical evidence in the context of U.S. slavery (e.g., Fogel and Engerman 1974; Goldin 1976; Wright 1978; 1986), European serfdom (Postan 1944; North and Thomas 1973; Brenner 1976), and 19th century Britain (Naidu and Yuchtman 2009) is generally consistent with this view. A well-developed literature also documents the deterioration of labor institutions in parts of Latin America during the period of globalization in the late nineteenth century (e.g., Coatsworth 1974; Katz 1974).

[4] For evidence on incomes per capita across U.S. states and counties, see Mitchener and McLean (2003) and Lagerlöf (2005), respectively. For evidence across British colonies in the Caribbean, see Nunn (2008). For evidence on incomes and schooling levels across coffee economies in the Caribbean basin, see Nugent and Robinson (2005).

We then introduce a coercive regime in which an elite-controlled government reallocates resources from educational public goods and into the enforcement of coercive labor regulations, allowing landowners to pay below-market wages to unskilled workers. With coercion, equilibrium educational attainment is determined in addition by diminished spending on educational public goods balanced against an increased skill premium, with the latter coming from lower wages of unskilled workers.[5] If the skill premium effect dominates, this can induce workers to *accumulate* human capital in the face of a rising price of the commodity relative to periods in which coercion did not occur.

The empirical content of the theory relies on the availability of exogenous variation in the relative demand for unskilled labor and in local government resources *in regimes with and without legally-sanctioned labor coercion*, and thus imposes demanding requirements for its empirical validation. We take advantage of a unique setting that provides the opportunity to examine these relationships. Specifically, 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 abolition of this legislation after 1874. We use micro data on cohorts of individuals across municipalities, exploiting variation in the suitability of coffee cultivation across municipalities and in coffee prices over time to identify exogenous shifts in unskilled labor demand and local government resources and to examine the extent to which the predictions of the theoretical model are supported.

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 decline in the provision of public primary schools relative to the non-coercive period. Consequently, coercion correlated with lower educational public good provision. However, we also find that during the coercive period increased coffee prices had no effect on individuals' literacy rates in coffee growing regions. In contrast, after the abolition of coercion in 1874, similar changes in coffee prices reduced literacy rates by 12 percent as the relative return to remaining unskilled increased, consistent with a diminished skill premium dominating increased educational spending. These results suggest that the abolition of coercion had important consequences, eliminating landowners' ability to extract unskilled workers' income but also reducing laborers' incentive to accumulate human capital as the abolition of coercion against unskilled workers lowered the relative wage of skilled workers. As such our empirical results are consistent with the mechanisms explored in the theory.

[5] 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.

The research design and the richness of the data also allow us to distinguish our explanation for educational outcomes from various competing explanations. We do so by exploiting variation in the suitability for coffee cultivation across otherwise similar municipalities. First, from a purely technological perspective, there are disincentives to establish coffee plantation economies, as there are constant (or even decreasing) returns to scale in coffee cultivation.[6] Second, using unique land ownership distribution data, we show that coffee region municipalities did not experience a disproportionately greater degree of concentration of land ownership relative to the comparison group of municipalities. Thus, the evidence is inconsistent with the traditional factor endowments-economic inequality hypothesis.[7] We also present evidence that rules out other explanations for our results, such as differences in natives' and immigrants' sorting patterns across regions, in transportation cost changes and other technological improvements, and alternate consequences of the establishment of a coercive political system. In summary, our findings emphasize changes in relative wages coming from variation in coffee prices and the incentive of elites to create and maintain a coercive labor regime as the main mechanism affecting workers' incentives to accumulate human capital in explaining patterns of literacy and schooling provision.

While our finding of increased human capital accumulation coincident with coercion might seem perverse and surprising, we believe it is intuitive, consistent with the literature, and can be easily rationalized by standard economic theory. Recent contributions find a strong and negative relationship between the prevalence of historical coercive institutions and long-run levels of human capital accumulation (e.g., Engerman and Sokoloff 1997; Acemoglu et al. 2008; Gallego 2010; Martínez-Fritscher and Musacchio 2010). However, as emphasized by Domar (1970), labor coercion is more likely to exist in regions that experience high unskilled labor demand. To the extent that these regions possess fixed (e.g., geographic) characteristics that encourage specialization in the production of unskilled labor-intensive crops, regions that experience episodic coercion should also experience a higher demand for unskilled labor, and consequently, lower demand for education. During episodes of coercion, the relationship can be partially mitigated due to the lower wages faced by unskilled workers.

The paper is structured as follows: Section II describes the historical background and context. Section III presents our theoretical framework. Section IV describes 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, and Section VII concludes.

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[6] See Berry and Cline (1979), Binswanger and Ronsezweig (1986) and Binswanger, Deininger, and Feder (1986).

[7] The factor endowments hypothesis asserts that certain geographic endowments could have generated the incentives for the establishment of plantation economies, and that the resulting differences in economic inequality would influence the development of labor and other economic institutions. For a discussion, see Engerman and Sokoloff (1997), Engerman, Mariscal, and Sokoloff (2002), Acemoglu and Robinson (2005), and Galor, Moav, and Vollrath (2009).

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 exports from Puerto Rico (P.R.) (Topic 1998).[8] 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. During 1871-1881, P.R. 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.[9] 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 were produced in Brazil. As the dominant producer in the world during the period (Bates 1997), Brazil's exports influenced significant variation in international coffee prices throughout this period (Figure 1, Panel B). In contrast, exports from P.R. constituted less than 4 percent of world exports allowing us to consider international coffee prices as exogenous to P.R.'s production.

Figure 1, Panel A shows that coffee exports *lag* coffee prices. This is not surprising as coffee trees require five to seven years after planting to achieve a high yield. This can also be shown quantitatively as the relationship between coffee prices and coffee exports is positive and significant at a lag of four to six years. To establish this relationship, Table II presents estimates of models that use the lagged structure of coffee prices to predict Puerto Rico coffee exports for the period 1846-1898. In a model including prices in periods [t, $t - 6$] separately, the elasticity from the annual coffee price in year [$t - 6$] has the strongest and most predictive power, with an estimated exports-price elasticity of 1.14 (significant at the 10 percent level, column 1). Estimates from parsimonious models that collapse recent past [t, $t - 3$] and more distant past [$t - 4$, $t - 6$] prices indicate that the price elasticity for distant past

[8] 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.

[9] Coffee exports constituted approximately three quarters of total exports from Puerto Rico, whereas sugar during this time period constituted only 20 percent of total exports (Dietz 1986).

prices is in the 1.31-1.33 range and statistically significant at conventional confidence levels (columns 2-3). We incorporate this timing in our empirical analysis (see Section IV.B).

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.[10] 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 rainfall precipitation map of Puerto Rico using estimates from data for the years 1971-2000 (National Weather Service 2007). Average annual rainfall 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 rainfall 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 rainfall averages, the West-Central region surpasses this threshold during the month of October, whereas rainfall 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 ºF and 66.7 ºF, respectively).[11] Apart from differences in rainfall 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).[12]

These rainfall 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 rainfall levels and the extent of coffee cultivation is quite strong. 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 rainfall and coffee cultivation is strongly positive.[13] While Las Marias and Maricao are outliers, all results are robust to their exclusion. This quantitative evidence is corroborated by historical accounts of differences in coffee cultivation due to rainfall and temperature differences across

[10] 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

[11] This difference is significant at 95 percent confidence, Table 1, Panel A.

[12] 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).

[13] 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.

municipalities (Bergad 1983; Cabrera Collazo 1988; Picó 1987; 2007; Seda Prado 1996). Further, Figure 2, Panels A and B, show a strong and positive relationship between contemporary rainfall as reported by the National Weather Service and historical coffee cultivation as reported by Bergad (1983).

Table 2 documents that this relationship is robust to conditioning on other geographic factors. The unconditional relationship between rainfall 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 4). 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 6). 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 [14]

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*".[15] 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).

A significant proportion of all adult males were categorized as *jornaleros*. Based on the population census of 1867, at the peak of the coercive labor regime, on average 9 percent of the overall

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

[15] 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.

population of these municipalities was classified as subject to the *libreta* system – this represented approximately 35 percent of the adult male population.[16]

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 another coffee growing municipality, 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]." Consequently, significant heterogeneity in enforcement of these measures is observed.

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 the five central municipalities for which data is available.[17] 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 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).

[16] This figure is based on a back-of-the-envelope calculation on the proportion of the overall adult male (16-70 years old) population in these municipalities in 1867 of 25.7 percent, based on the population distribution data from the census of 1887. Since approximately 9 percent of the overall population was classified as *jornalero*, they constituted approximately 35 percent of adult males of working age.

[17] See the Data Appendix (online) for details of the construction of the libreta sanctioning measures.

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.[18] Using binary responses for 16 central region municipalities for which data is available, 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.[19] 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.

Despite the coffee elites' opposition to the derogation of the *jornalero* legislation, the provincial government eliminated the state-sanctioned coercive labor regime in 1874. This was primarily in response to concerns about political unrest throughout the remaining Spanish colonies in the Caribbean including the unsuccessful *Grito de Lares* in Puerto Rico and the Cuban Ten Years' War. Additionally, provincial authorities and the national elite believed that Puerto Rico was under an increasing threat of invasion by the U.S. and that the prevalence of various forms of state-sanctioned coercive measures (i.e., the jornalero legislation, slavery) could be seen as justification for American intervention.[20] Although these forms of state-sanctioned coercion were abolished during this period, other forms such as debt bondage and shared tenancy continued throughout the rest of the nineteenth century (Picó 1979; Bergad 1986).

There is evidence of substantial nominal 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.[21] 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.

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[18] 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).

[19] 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.

[20] This belief partially came from Spanish perceptions regarding national beliefs of the United States following the Union victory in the American civil war. See Chapter 4 in Figueroa (2005) for a detailed summary of the history of labor reform during the period 1868-1873.

[21] These nominal modal monthly wage rate figures are based on evidence from various hacienda records in Buitrago (1976) and Bergad (1983).

II.B. Municipal Governments Institutions and the Provision of Public Primary Schooling[22]

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.

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.

The local government executive throughout the period was composed of mayors ('alcaldes ordinarios') and council members ('regidores').[23] 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. While local authorities had control over how government revenue was spent, they did not control its level as local property tax rates were set by provincial authorities. These property tax revenues were the main source of income for each municipality.

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. The central government then instituted a number of reforms to promote the establishment of a public primary school system.[24] However, although guidelines from the central government outlined 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

[22] 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).

[23] 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. 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.

[24] 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.

primary schools across municipalities during the last third of the nineteenth century.[25] 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 and formalize ideas, we develop a general equilibrium model of labor market coercion of unskilled workers, public provision of education, and workers' human capital accumulation in a small open economy. Section III.A describes a model without coercion in which potential students weigh the returns from schooling against the opportunity cost of not working as an unskilled worker during matriculation. In addition, government expenditures directly affect the quality of education. If a commodity boom affects both relative wages and government tax revenue, equilibrium educational attainment is determined by the interaction of these demand and supply side factors, respectively.

Section III.B describes a regime in which the government devotes resources to coercive labor regulations that reduce wages paid to unskilled laborers thus increasing the skill premium. Under reasonable parameter values for this time period, our model is also consistent with educational attainment falling by less in response to rising coffee prices than in the non-coercive period due to a higher skill premium and a greater incentive to invest in human capital. However, spending on educational capital increases more in the non-coercive regime than with coercion.

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

The three factors of production are unskilled labor (U), skilled labor (S), and land (L) with factor prices w_u, w_s, and r, respectively. We include the two types of labor so as to discretize the human capital accumulation decision. Land is included because of the importance of land rents in government tax revenue from which education and coercion were financed.[26] While total population size is exogenous and fixed, 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. Individuals are born each period t and live for two periods. We define a household as two generations co-existing at a given time t: one youth (0) and one adult (1). In the following period, the adult dies, the youth becomes an adult, and a new youth 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 in each period t such that the total population at any period is $N_t = N_{0,t} + N_{1,t}$. The total number of unskilled workers is equal to the

[25] See Osuna (1949), De la Rosa Martínez (1980), Colón Ramírez (1994) for detailed accounts.
[26] The budget data collected by the authors indicates that property taxes were the main source of local government revenue.

number of unskilled youth and unskilled adults such that $U_t = U_{0,t} + U_{1,t}$. The number of skilled workers is equal to the number of adults who invested in human capital as youth $S_t = E_{1,t}$. Finally, $E_{0,t}$ is the number of students such that the total population is $N_t = U_t + S_t + E_{0,t}$.

Determination of Factor Prices

Motivated by the fact that Puerto Rico is a small open economy, we assume for simplicity that there are three goods, one of which is coffee, whose prices are set on world markets. With an equal number of factors as goods, no factor intensity reversals, and all goods being produced, exogenous goods prices determine factor prices that are insensitive to domestic conditions. Appendix B derives explicit conditions under which an increase in coffee prices leads to increase in both land rents and the relative wage of unskilled labor. 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).[27]

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 and complementarity between factors. The effectiveness of a worker, as measured by skill per worker, is denoted by $q_t = Q_t/E_{0,t} = f(k_t)$ where $k_t = K_t/E_{0,t}$. The wage that each physical skilled worker earns as an adult at time t is comprised of the wage per effective skilled worker ($w_{s,t}$) and the number of effective skilled workers each physical skilled worker comprises [$f(k_{t-1})$]. Educational capital depreciates fully each period.

The government maximizes the sum of landowners' utility and skilled workers' altruistic utility, which are both linear in income given an exogenous linear tax rate on land, τ. This is motivated by the fact that landowners and skilled workers were given the right to vote and they comprised the entirety of the legislative body. Consequently the government maximizes following function with respect to

[27] Some of the model's complexity arises because there are three goods and three factors. A more tractable model with two goods and two factors would clearly deliver the demand side responses in the presence and absence of labor coercion, but would obscure local elites and their capabilities to engage in the enforcement of labor coercion. In addition, if taxes came from skilled workers, this model would have the counterfactual implication that tax revenue fell with coffee prices increasing as skilled wages must fall if unskilled wages rise in a two-factor two –good model (Jones and Scheinkman 1977).

educational capital (K_t) at time t subject to the constraint that spending can not exceed tax revenue $\tau r_t L$, where β is the exogenous discount factor and $E_t[\bullet]$ is the expectations operator:

$$(1-\tau)r_t L + w_{s,t} f(k_{t-1}) E_{1,t} + \beta E_t[w_{s,t+1} f(k_t) E_{0,t}].$$ [28]

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

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

Household Educational Decisions

The altruistic adult in the household chooses the youth's education level to maximize the youth's lifetime income. The choice is discrete – the youth either attends school or does not. If the youth does not go to school, he earns the unskilled wage for two periods. If the child attends school, he 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 as workers will never enter school in the final period of life because they die before the returns are realized. The key tradeoff for households' human capital accumulation decision is that education brings a higher but deferred wage. At the time of birth, the present discounted value of the stream of payments to a skilled worker is $\beta E_t[w_{s,t+1} f(k_t)]$. Because education is a public good, its only cost is the stream of forgone unskilled wages $w_{u,t} + \beta E_t[w_{u,t+1}]$. We 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.[29] In equilibrium, the stream of payments to a skilled worker equals the stream of forgone unskilled wages. This leads to the following *educational indifference condition*: [30]

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

As the relative wage of skilled workers increases, the return to education increases, reducing the educational capital per worker k_t for a given level of aggregate investment K_t. For a given set of factor prices, the tax revenue and equilibrium skill per worker conditions [equations (2) and (3)] determine equilibrium values of K_t and k_t which determine the equilibrium level of $E_{0,t}$, and, subsequently $E_{1,t+1}$.

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

This section considers the impact of an increase in coffee prices on educational attainment and educational capital spending as determined by changes in factor prices – an increase in both land rents

[28] Including landowners income as a discounted stream produces identical results.
[29] All agents are risk neutral such that uncertainty plays no role. In addition, we have studied the time path of coffee prices during the period and find that they are well represented by a random walk – the point estimate on a model with multiple lags is 0.996 (standard error = 0.167).

and the relative wage of unskilled labor. Based on equation (2), educational capital provision rises ($K \uparrow$) with tax revenue in response to increasing land income. From equation (3), equilibrium educational capital per student rises ($k \uparrow$) as the unskilled-skilled wage gap narrows. The equilibrium change in E is ambiguous. On one hand, 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 (3), suppressing time subscripts, and combining them to deliver:

$$\hat{E} = \hat{r} - \frac{1}{\varepsilon_{f(k),k}}\left[\hat{w}_u - \hat{w}_s\right] \tag{4}$$

where $\varepsilon_{f(k),k}$ is the elasticity of $f(k)$ with respect to k.

This expression is useful as it decomposes changes in educational attainment into "supply" and "demand" effects. On the supply side, higher land rents increase tax revenue and educational capital increasing the effectiveness of an education. On the demand side, the incentive to obtain an education declines as the skill premium falls. The latter case provides a simple model of how increased coffee prices can lead to falling educational attainment. As this is consistent with contemporary evidence (e.g., Soares, Kruger, and Berthelon 2006; Kruger 2007) and with our empirical evidence that educational attainment fell in response to rising coffee prices in the non-coercive regime, we maintain the assumption of the demand side dominating in the non-coercive case 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 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 subject to the budget constraint $\tau r_t L = V_t + K_t$

Motivated by the discussion in Section II.B, we assume that unskilled laborers can work for a landowner under a coercive contract, or attempt to breach this contract and work in some household production at the market-clearing wage. Given an attempt at breaching the contract, the laborer is caught with probability $\pi(V)$ in which case they are imprisoned for a period with a payoff that we normalize to zero. With probability $1 - \pi(V)$ such an attempt is successful, in which case the worker earns the non-coercive wage w_u. Greater coercive capital expenditures increase the probability that laborers in breach of the law are caught, but this is subject to decreasing marginal effectiveness [$\pi'(V) > 0$, $\pi''(V) < 0$]. Coercive capital fully depreciates at the end of each time period. Because unskilled workers are necessary in the

production process of all goods produced, they are paid a wage that is incentive compatible for them to supply labor $w_c \equiv (1 - \pi(V))w_u$.[31] Consequently, the educational indifference condition becomes:

$$f(k_t) = \frac{\left(1-\pi\left(V_t\right)\right)w_{u,t}}{w_{s,t}}\left[\frac{1+\beta}{\beta}\right]. \tag{5}$$

Analogous to the case without coercion, the government maximizes the utility of landowners and the altruistic utility of skilled workers:[32]

$$(1 - \tau)r_tL + \pi(V_t)w_{u,t}U_{1,t} + w_{s,t}f(k_{t-1})E_{1,t} + \beta E_t[w_{s,t+1}f(k_t)E_{0,t}]. \tag{6}$$

The first term reflects landowners' after-tax income. The second term reflects the value of coerced adult unskilled income that is reallocated to landowners. 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.[33] This objective function is maximized with respect to *current* coercive (V_t) and educational (K_t) expenditures subject to the budget constraint $\tau r_tL = V_t + K_t$.[34]

Maximizing the constrained objective function yields a first order condition relating expenditures on educational and coercive capital where we suppress time subscripts:

$$\pi'(V)w_uU = \beta w_sf'(k), \tag{7}$$

such that the marginal return to coercion equals the discounted marginal return to educational capital. A stationary equilibrium where $E_{1,t} = E_{1,t+1}$ can be solved recursively given that exogenous world prices determine a unique vector of equilibrium factor prices. Online Appendix B discusses the existence, uniqueness, and stability of the stationary equilibrium.

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[31] More generally, any coercive wage $w_c(w_u,V)$ that satisfies $\partial w_c(w_u,V)/\partial w_u > 0$, $\partial w_c(w_u,V)/V < 0$, and $\partial w_c^2(w_u,V)/\partial V\partial w_u < 0$ yields identical results. This cross-partial restriction captures the idea that the marginal return to coercion for the elites is increasing in the shadow wage of unskilled labor, consistent with Domar (1970).

[32] We depart from median voter-determined policy models because they have stark and counterfactual implications. For example, if the median voter is a landowner all tax revenue will go towards coercive activity. Allowing for the government objective function to 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 nearly identical results 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 2009). Although this mechanism may be at play, the short-run price variations should not induce large incentives for 21 year later franchise adjustments based on a voting age of 21.

[33] Even if allowed, there will be no coercion of skilled workers 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.

[34] 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.

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

Combining the new educational indifference condition [equation (5)] and the government budget constraint, we can derive the response of educational attainment to a change in coffee prices under the coercive regime:

$$\hat{E} = \underbrace{\left(\frac{\tau r L}{K}\right)\hat{r} - \frac{1}{\varepsilon_{f(k),k}}\left(\hat{w}_u - \hat{w}_s\right)}_{A} + \underbrace{\frac{V}{K}\left[\underbrace{\left(\frac{K}{V}\right)\left(\frac{-\varepsilon_{(1-\pi(V)),V}}{\varepsilon_{f(k),k}}\right)}_{c.a.} - \underbrace{1}_{e.q.}\right]}_{B}\hat{V}, \tag{8}$$

where $\varepsilon_{(1-\pi(V)),V}<0$ is the elasticity of the coercive wage with respect to coercion holding the shadow wage constant. Although V is still an endogenous variable, equation (8) is illustrative. The first term (A) is nearly identical to the no-coercion case. Educational attainment is increasing in the land rental rate as tax revenue allows for more educational capital but is declining in the relative wage of unskilled labor as the opportunity cost of matriculation 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 reduces expenditures on educational capital and thereby diminishes the effectiveness of and the incentive to obtain an education. 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. Online Appendix B discusses this calibration in detail and shows that, for reasonable parameter values and historical data for this episode, 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 while acknowledging that the educational quality effect might dominate in other cases.

To see how equilibrium educational attainment changes in response to an increase in coffee prices filtered through changes in factor prices, we combine equations (7) and (8) to obtain an expression for changes in educational attainment as a function of changes in (shadow) factor prices:

$$\hat{E} = \underbrace{\frac{1}{\kappa}\left[\left(\frac{\tau r L}{K}\right)\hat{r} - \frac{1}{\varepsilon_{f(k),k}}\left(\hat{w}_u - \hat{w}_s\right)\right]}_{A} + \underbrace{\alpha_0}_{B}\hat{r} + \underbrace{\alpha_1\left(\hat{w}_u - \hat{w}_s\right)}_{C} \tag{9}$$

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

Relative to the no-coercion case, coercion leads to the presence of the additional terms (*B*) and (*C*). Term (*B*) represents increased land tax revenue leading to greater coercion and increased efforts to avoid this coercion. Term (*C*) represents how an increased relative wage of unskilled labor provides greater incentive for government coercion, leading to increased avoidance through education. This is consistent with Domar (1970) who argues that increases wages for unskilled workers, due to scarcity, lead to greater returns to slavery and serfdom through cost savings. 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.

Whether educational capital *K* rises or falls in response to higher coffee prices is generally ambiguous. However it increases less than in the case without coercion in which all additional tax revenue is spent on educational capital. *K* correlates positively with *r* as increases in government tax revenue have a positive income effect. *K* correlates negatively with ($\widehat{w}_u - \widehat{w}_s$) through a price effect in which increased unskilled wages increase the incentive for coercion and dampens the government's desire to supply *K*. Whether *K* rises or falls in response to these forces is determined by the sum of these effects and is ambiguous. See Online Appendix B for a thorough derivation and discussion of these results.

Main Elements of the Model

Element 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.

Element 2. In a coercive regime, the provision of education may increase or decrease ($K\uparrow\downarrow$) and will be strictly less than in the case without coercion as some of the government budget is allocated to coercion. The change in equilibrium educational attainment will be *strictly greater than* 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 century.

We link individuals' personal information to data on the municipality where they would have been eligible to enter school for school-eligible cohorts throughout the 1854-1891 period, under the assumption that the municipality where the individual resided was the same as where he or she made the schooling decision.[35] Table 3, Panel A, row 1 reports an average literacy rate of 18.6 percent in this population (ages 25-62 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 data also reports information on the individual's gender, ethnicity, and ancestry.[36]

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 (preceding the expansion of the coffee sector), 1866, 1876-77 (during the coercive period), and 1897 (post-coercion period). Although 1876-1877 was not in the coercive period, we classify the school data with the coercive period, as we expect the stock of schools not to change dramatically within two years following the abolition of the *jornalero* law. 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 a small 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

[35] We exclude individuals of ages 24 and younger as of 1910, as their literacy outcomes could have been influenced by the U.S. educational reforms of 1898 onwards. See Bobonis and Toro (2007) for details.
[36] See the Data Appendix (online) for more details including a discussion of measurement error issues, self-reported literacy and age misreporting in particular.
[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), 0.40 schools per thousand children would imply 4 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.

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 rainfall to those in municipalities with lower rainfall 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 cohorts entering school following an increase in coffee prices, we estimate the following model:

$$y_{icm} = \theta P^{C}_{c\text{-}k} * R_m + \beta_1 R_m + \beta_2 X_{icm} + \gamma\, P^{C}_{c\text{-}k} + \alpha_{(m)} + \varepsilon_{icm}, \qquad (10)$$

where y_{imc} is a literacy indicator for individual i in school-entry cohort c in municipality m; $P^{C}_{c\text{-}k}$ denotes the international price of coffee k years preceding the individual's school-entry decision at the earliest possible age of entry, six years old; R_m is the municipality-specific continuous measure of average annual rainfall; 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. 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.[39] Estimating equation (10) separately for school-age cohorts in the coercive and non-coercive regimes allows us to test elements 1 and 2 of our theoretical framework.[40]

Because coffee trees require five to seven years after planting to achieve a high yield, any surge in coffee exports follows an increase in coffee prices by approximately this number of years (see Section II.A). To incorporate this timing into the variation in relative demand for unskilled and skilled labor, we

[39] 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 $P^{C}_{c\text{-}6} * G_m$ variable. Unfortunately, we do not have period-municipality-specific measures of coffee cultivation, and thus cannot perform this alternative empirical approach.

[40] Since other forms of labor coercion such as debt bondage and shared tenancy continued throughout the rest of the nineteenth century, we can only make inferences regarding the consequences of this relationship in periods of and in the absence of the state-sanctioned *jornalero* legislation.

use average coffee prices 4-6 years preceding the individual's primary school enrollment decision (denoted as $P^{C}_{\{c-4,c-6\}}$) as our main explanatory variable of interest. Although coffee prices (contemporaneous or lagged) might not matter only at age 6, since children could delay school entry, drop out of school and start working at a later age, or go (back) to school once the coffee boom was over, this specification captures the reduced form effect on the acquisition of literacy skills taking into account individuals' school entry/exit decisions given labor market conditions at the initial time of potential entry.

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

$$y_{mt} = \theta_P Post\_coercion_t * R_m + \theta_C Coercion_t * R_m + \beta_1 R_m + \beta_2 X_m + \gamma_t + \alpha_{(m)} + \varepsilon_{mt}, \qquad (11)$$

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, 1876-1877; and 1897); X_m are the remaining municipality-level geographic controls; γ_t are period fixed effects; and ε_{mt} is 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 rainfall 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 rainfall 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 fertility and mortality rates (i.e., crude birth and death rates in 1828) and baseline differences in public school provision were quite similar during the first half of the century (for the former see Table 1, Panel C; for the latter, see Section VI.B). 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. We assess potential threats to the validity of our assumptions in the alternative explanations section (Section VI).

V. Empirical Results

V.A. Adult Literacy

This section presents evidence on the relationship between coffee prices and individuals' levels of literacy across higher and lower rainfall municipalities in each of the labor regimes. We start the discussion with a graphical analysis to shed light on the patterns in the data. Figure 5, Panel A displays literacy rates by cohort for municipalities above and below median annual rainfall levels. During the

coercive regime, cohort literacy rates in the high rainfall municipalities are on average 2.7 percentage points lower (16 percent; p-value = 0.10) than those in below median rainfall municipalities, consistent with the existence of a lower skill premium in coffee growing municipalities. In contrast, for post-labor market liberalization cohorts, literacy rates are on average 9.2 percentage points lower (36 percent; p-value < 0.001) for individuals in high rainfall municipalities. This suggests a substantial decrease in the skill premium following the labor reform.

We then examine the relationship between international coffee prices and individuals' levels of literacy across higher and lower rainfall municipalities in each of the labor regimes. We do this generalizing the empirical model (10) presented above, where we allow each cohort to have a (smoothed) potential effect, as follows:

$$y_{icm} = \alpha_m + \gamma_c + \sum_c (R_m \times d_c)\theta_c + \varepsilon_{icm}, \tag{12}$$

where d_c is a variable that indicates whether the individual is in the birth cohort group 1848, 1849,…, 1885; 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 four to *six years preceding the individuals' school entry decision* (P^C_{c-6}), 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.

Panel B of Figure 5 illustrates the cohort-specific rainfall correlation estimates (θ_c) from equation (12) (with 95 percent confidence intervals in dashed lines). The birth cohort of 1868, age 6 in 1874 and therefore the last facing 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 1868. 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 arguments.

Table 4 provides regression-based evidence of the relationships depicted in Figure 5, Panel B using estimation based on equations (10). Columns 1-3 and 4-6 report estimates for school-age cohorts in the coercive and non-coercive regimes (respectively) pooling all cohorts for a given regime and

[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).

estimating an expression for each group. Columns 1 and 2 show estimates of θ for school-age cohorts during the coercive regime using the $P^{C}_{\{c-4,c-6\}}$ coffee price measure. These effects are positive, small, and statistically indistinguishable from zero. The point estimate of the specification excluding geographic controls and municipality fixed effects (column 1) implies that a one standard deviation increase in coffee prices induced a 0.03 percentage point (1.7 percent, from a mean of 15.6 percent) higher literacy rate in municipalities with 10 in. higher annual rainfall levels. The preferred municipality fixed effects estimate (column 3) implies a smaller positive response of 0.02 percentage point (1.5 percent).

In contrast to cohorts during the coercive regime, estimates of θ are negative and significantly different from zero at conventional confidence levels among school-age cohorts during the non-coercive regime. The point estimate of these specifications (with and without municipality fixed effects) imply that a one standard deviation increase in coffee prices six years preceding the individuals' school entry induced a 0.9-1.0 percentage points (approximately 4.8 percent) reduction in literacy rate in municipalities with 10 in. higher annual rainfall levels. The differential effect across regimes is large – it implies that coercion induced an increase in literacy of 1.2 percentage points (5.9 percent) following a one standard deviation increase in coffee prices six years preceding the individuals' school entry (in municipalities with 10 in. higher annual rainfall levels) (bottom row). Given the differences in rainfall of approximately 20 inches across coffee and non-coffee central municipalities, these point estimates imply significant *relative increases* in literacy rates as a response to unskilled labor demand shocks preceding the liberalization of labor markets in 1874.[42]

It is useful to think about the socio-economic background of the marginal individuals whose schooling decisions would have been influenced by changes in coffee prices, both during and following the abolition of the coercive labor regime. Although we do not have direct information on the socio-economic background of each individual to be able to determine this, we can make an assessment based on ancillary information. Given the high degree of inequality in land ownership among landowners (Gini = 0.75), and the high proportion of landless households as of the 1890s (70 percent), it would be appropriate to consider that the children of very small landowners – those likely to also become *jornaleros*, but to also have an alternative option (i.e., work in their own farm) apart from working as laborers in large landowner farms were those most affected by the hypothesized changes.

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 nor

[42] To assess whether age heaping leads to bias in our estimates, as a robustness check we estimate models based on equation (10) that include indicator variables for individuals of reported ages 25, 30, 35, …, 60. We find qualitatively and quantitatively similar results (available from the authors upon request).

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 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 in the two types of municipality 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 with no significant difference. In contrast, in the coercive coffee boom years 1867 and 1876, there is a significantly 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 (11). 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 1867, 1876-1877, and 1898. 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; this reduces 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 1876-1877 (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

[43] 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.

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 six alternate hypotheses, test our underlying assumptions, and present evidence that rules out each of the alternate explanations. In addition, we also show that they do not affect our estimate of the coefficients of interest for the coercive regime. 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) the consequences of the establishment of a coercive political system, (5) technological and economic changes that may depend on geographic factors correlated with rainfall, and (6) competition from the Puerto Rican sugar industry.

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

The geographic sorting of the population during the non-coercive period provides an 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 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 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). We can also 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, race, and native ancestry that might proxy for unobserved differences in the demand for education across high and low rainfall municipalities. We do this by estimating variants of the empirical model (12), where we allow each cohort to have a (smoothed) potential effect on the predetermined variable:

$$x_{icm} = \alpha_m^{PRE} + \gamma_c^{PRE} + \sum_c (R_m \times d_c)\theta_C^{PRE} + \nu_{icm}\,, \tag{13}$$

where x_{icm} is the predetermined indicator variable (i.e. female gender, non-white individual, native father) 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 c possessed characteristic x in a municipality m 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 (13); Panels A, B, and C report the correlation for females, non-white individuals, and individuals with native-born fathers, respectively. There is no clear relationship between changes in the proportion of female individuals across school entry cohorts and changes in coffee price six years earlier 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. There is also no evidence of sorting based on parental ancestry. 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.[45]

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).[46] Such

[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. Obviously, we cannot determine whether there is geographic sorting based on the returns to literacy or other unobserved characteristics of the individuals correlated with their literacy status.

[45] 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 Online Appendix Tables A1, columns 4-5, and A2, columns 5-6).

[46] 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).

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 6, row 1). 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 6, row 2). 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.

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 (i.e., Engerman and Sokoloff 1997; for a survey see Nunn 2008). 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; not reported in the tables). 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 6). There is no correlation between the overall land

Gini coefficient and annual rainfall levels (row 3).[47] 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 (row 4). The correlation between the proportion of landless households in 1899 and annual rainfall is small, negative, and statistically indistinguishable from zero (row 5).[48] 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 jurisdictions (e.g., Acemoglu et al. 2008; Nunn 2008). Moreover, using models analogous to equation (10) for the sub-sample of municipalities with 1890s land ownership data and controlling for the overall land ownership Gini coefficient and its interaction with the price of coffee, we find similar estimates of the coffee-price literacy relationship (see Table 7, row 1). The estimates are robust to the use of the landowners' land ownership Gini coefficient measure (see Online Appendix Tables A1, columns 1-3).[49] These pieces of evidence are inconsistent with economic inequality as the mechanism explaining these effects.

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

[47] 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 6, columns 5 and 6).

[48] 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 6, column 11).

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

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.

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.[50] 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).[51] 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.[52] Using this data we find no evidence of a greater presence of repressive forces in higher rainfall municipalities (Table 6, rows 6-8).

We also estimate models analogous to (10) sequentially allowing for additional interaction terms between the coffee price and these coercive apparatus variables (Table 7, rows 2-4). The point estimates on the coffee price – rainfall interaction for the sample of post-coercive period cohorts are in the [-0.064, -0.066] percentage points range (statistically significant at 99 percent confidence), whereas those for the sample of coercive period cohorts in the [0.017, 0.022] 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.

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

[50] 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.

[51] 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. In addition, the eligibility requirement had the intention of promoting the selection of individuals that supported the conservative regime.

[52] See the Data Appendix (online) for a detailed description of the construction of these variables.

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 (10) 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 7, rows 5-7). The point estimates on the coffee price – rainfall interaction for the sample of post-coercive period cohorts are in the [-0.064, -0.066] percentage points range (each significant at 99 percent confidence), whereas those for the sample of coercive period cohorts in the [0.012, 0.020] range. All are quantitatively similar to those reported above for both the coercive period and post-coercive period cohorts and the differential response across regimes is significant at least at the 15 percent level. These robustness checks help to mitigate possible concerns that the evidence is consistent with broader technological or economic change effects that may be correlated with rainfall or other geographic characteristics.

Competition for Unskilled Labor from the Puerto Rican Sugar Industry

The model and the empirical evidence up to now have neglected the Puerto Rican sugar industry for various reasons. From a technological perspective, the sugar industry faces incentives to establish plantation economies, as there are increasing returns to scale in sugar cane cultivation and processing. Including these could lead to the confounding of the mechanisms discussed in the paper with those of the land inequality-factor endowments hypothesis. Also, municipalities specializing in sugar were primarily in coastal areas and possessed different geographic, technological, or economic characteristics, making them non-comparable to those municipalities located in the central highlands. For these reasons, we have excluded coastal municipalities from the analysis.

We could also be concerned that competition between coffee producers and sugar producers for scarce unskilled labor may have been important during this time period. However, the sugar industry suffered a relative decline during the second half of the nineteenth century and thus may not have been a strong source of competition for the unskilled laborers employed in the coffee industry.[53] To address this concern, we estimate models analogous to (10) including an interaction term between the average rainfall in the municipality and the price of sugar 1-3 years preceding the individuals' primary school enrollment decisions (Table 7, row 8).[54] All are quantitatively similar to those reported above for both the coercive period and post-coercive period cohorts. These robustness checks help to mitigate possible concerns that the evidence is consistent with this source of competition for unskilled laborers across the coffee and sugar sectors.

[53] For a detailed discussion of the size of the sugar and coffee sectors in P.R. throughout the nineteenth century, see Dietz (1986).
[54] Sugar is an annual crop that has at least one growing cycle per year, justifying this lag structure.

VII. Conclusion

This paper studies whether changes in the incentive for elites to enforce coercive labor institutions affected individuals' human capital accumulation decisions during coffee booms throughout the second half of the nineteenth century in Puerto Rico. We find that, under a coercive labor regime, local governments in coffee growing regions allocated more resources to the enforcement of coercive measures arguably with the goal of depressing the realized wage of unskilled labor. While this reduced the public provision (supply) of education, it also, surprisingly, induced workers to demand significantly more schooling leading to no change in the equilibrium amount of educational attainment in response to rising coffee prices. Following the abolition of these coercive measures in 1874, rising coffee prices correlated with declining literacy rates, consistent with a "resource curse" in which individuals' perceived opportunity cost of schooling increases during commodity booms. These results are broadly 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).

A number of questions remain that we view as being fertile fields for future work. First, our finding of a perverse impact of labor coercion on the incentive to accumulate human capital is consistent within our theoretical framework under conditions in which coercion avoidance dominates educational quality. Since our model suggests that either effect can dominate, examining episodes in which the latter effect dominates, and identifying conditions leading to this outcome may be a fruitful endeavor. Second, because we do not formally examine 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. Third, our work does not explore whether labor market coercion has persistent effects on the incentives for agents to specialize in activities that may or may not be conducive to long-run economic development. For instance, whether these institutions (i.e., the General Laborers' Law) promoted specialization in unskilled labor-intensive activities (i.e., coffee), to the extent that this led to negative long-run economic performance, remains an open question. These and their implications for levels of human development remain important topics for future research.

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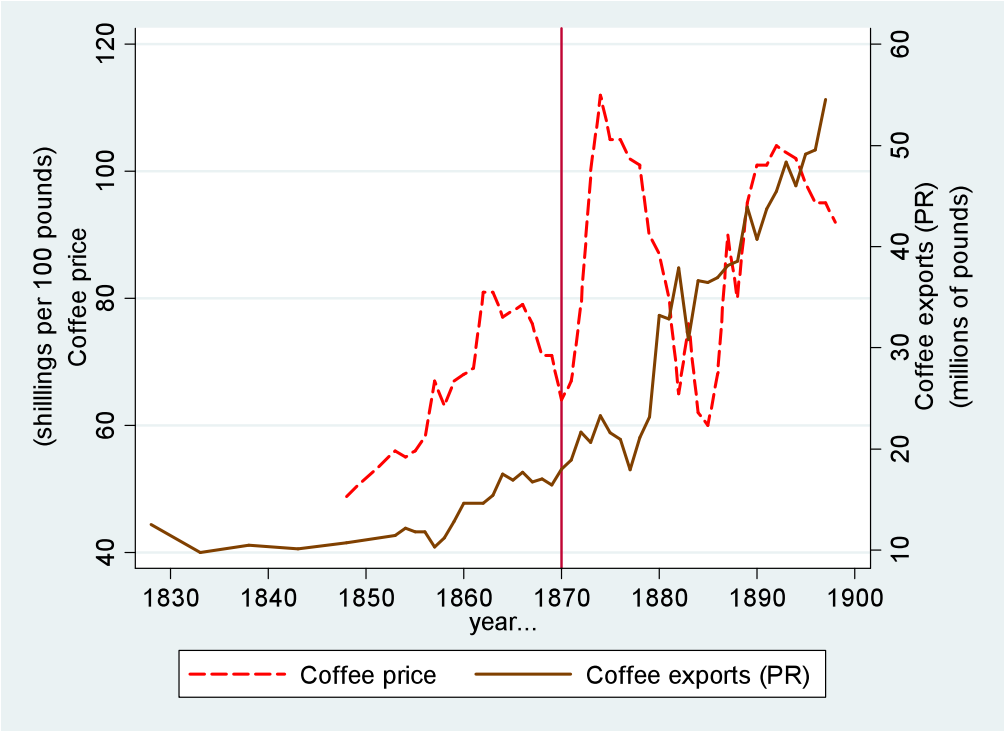
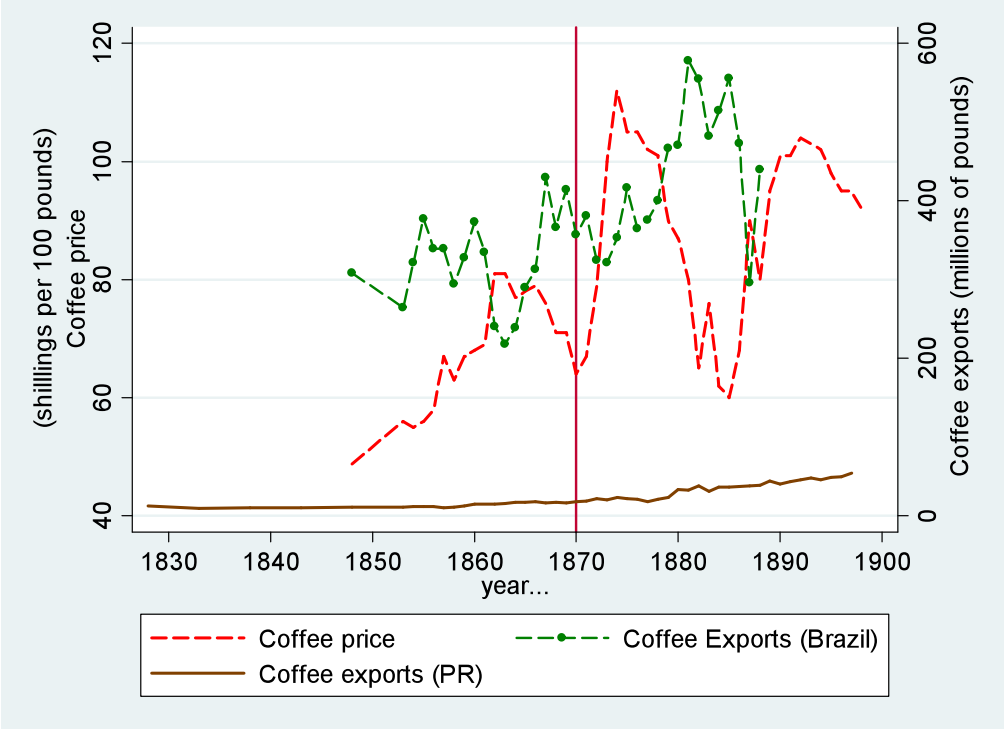
Figure 1: Volume of P.R. Coffee Exports and International Coffee Prices, 1825-1897

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



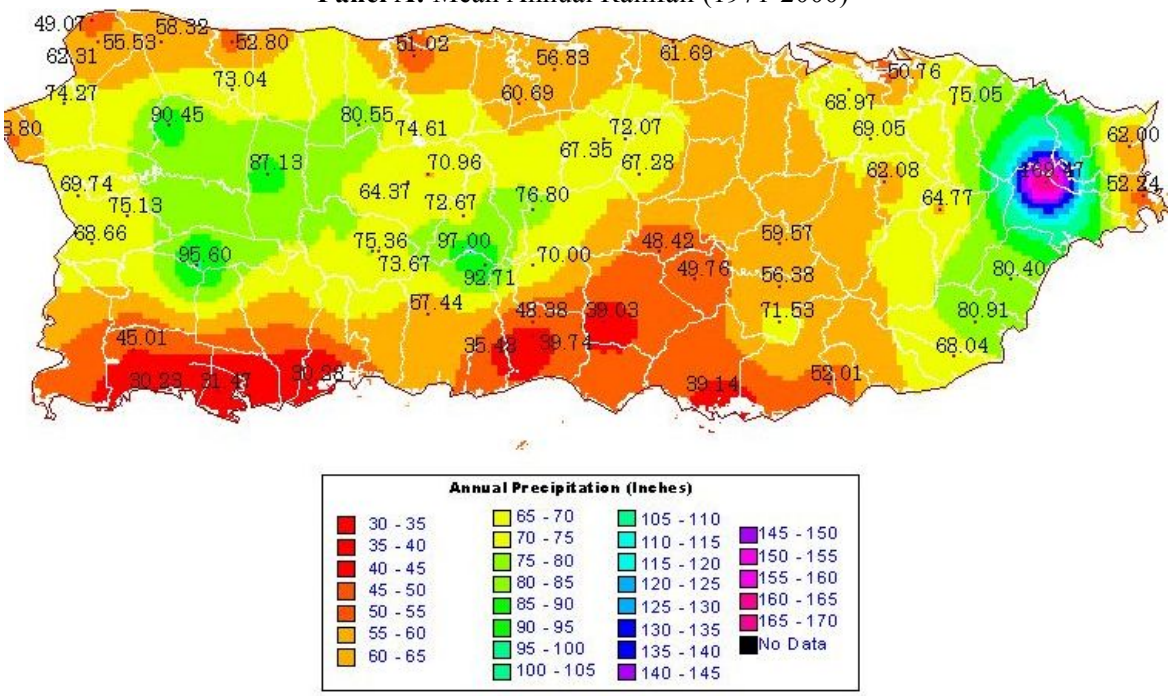
Panel B: Coffee Prices and Trends in Brazil and P.R. Coffee Exports



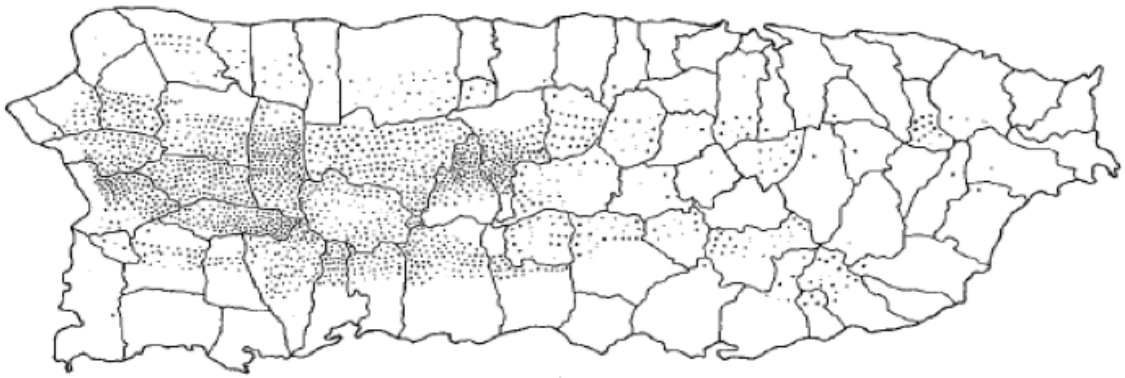
Sources: Coffee exports data – *Boletín Histórico de Puerto Rico,* volume 5, p. 300, averages for the years 1828-32, 1833-37, 1838-42, 1843-47, and 1848-52, available in Dietz (1986); Puerto Rico, Intendencia General de Hacienda, *Balanza Mercantil*, for the years 1853-1860; *Estadística General*, for 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: Geographic Distribution of Mean Annual Rainfall (1971-2000) and Coffee Cultivation (1935) in Puerto Rico

Panel A: Mean Annual Rainfall (1971-2000)



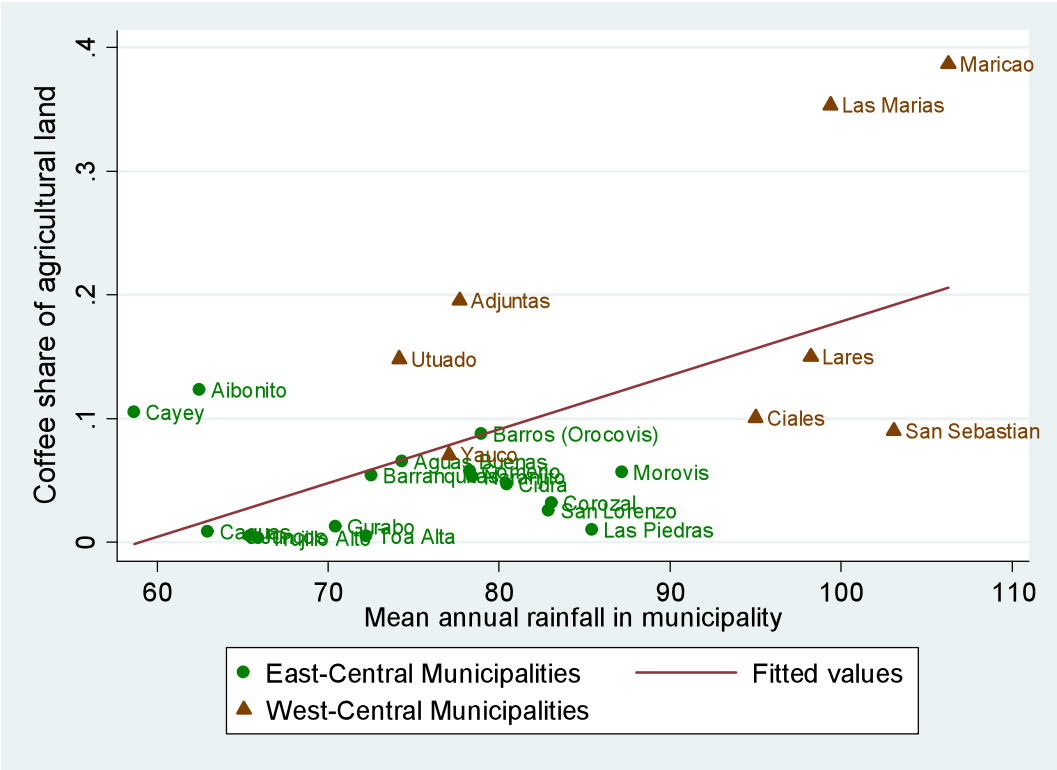
Panel B: Coffee Cultivation (1935)



Notes: In Panel B, each dot represents 100 cuerdas (1 cuerda = 0.97 acres)

Sources: National Weather Service (2007) for Panel A and Bergad (1983), p. xxvii from Roberts (1941) for Panel B.

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

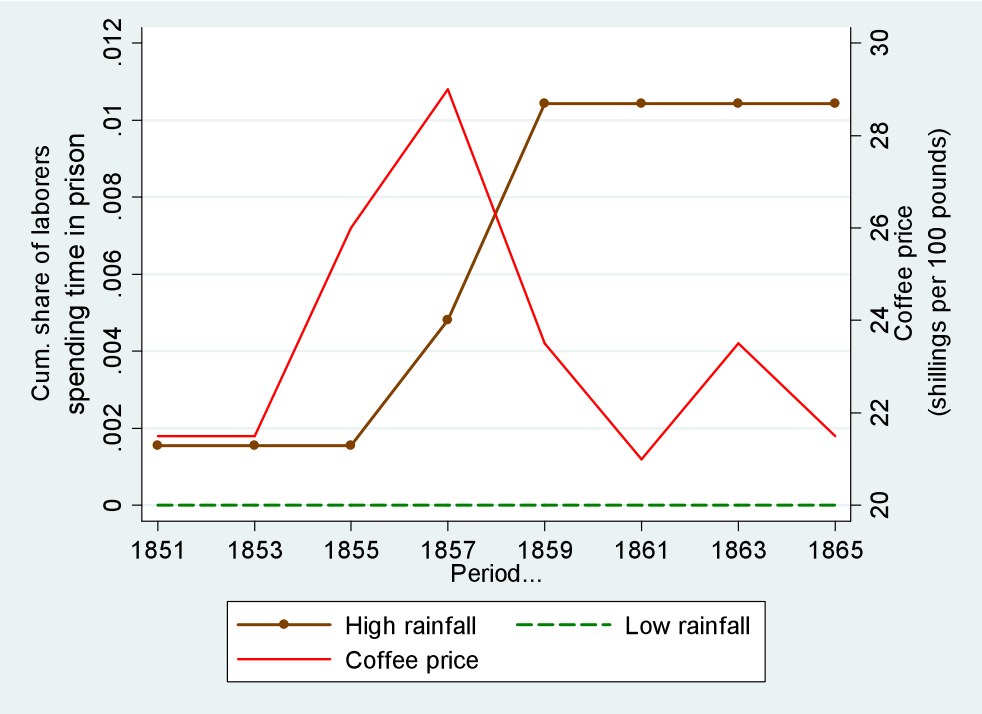


Notes: Each (green) circle represents a municipality. Plotted are residuals (adjusted by sample means) from multivariate regression which condition on the following geographic variables: mean annual maximum and minimum temperatures, mean altitude, mean degree of ruggedness (gradient), and distance to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

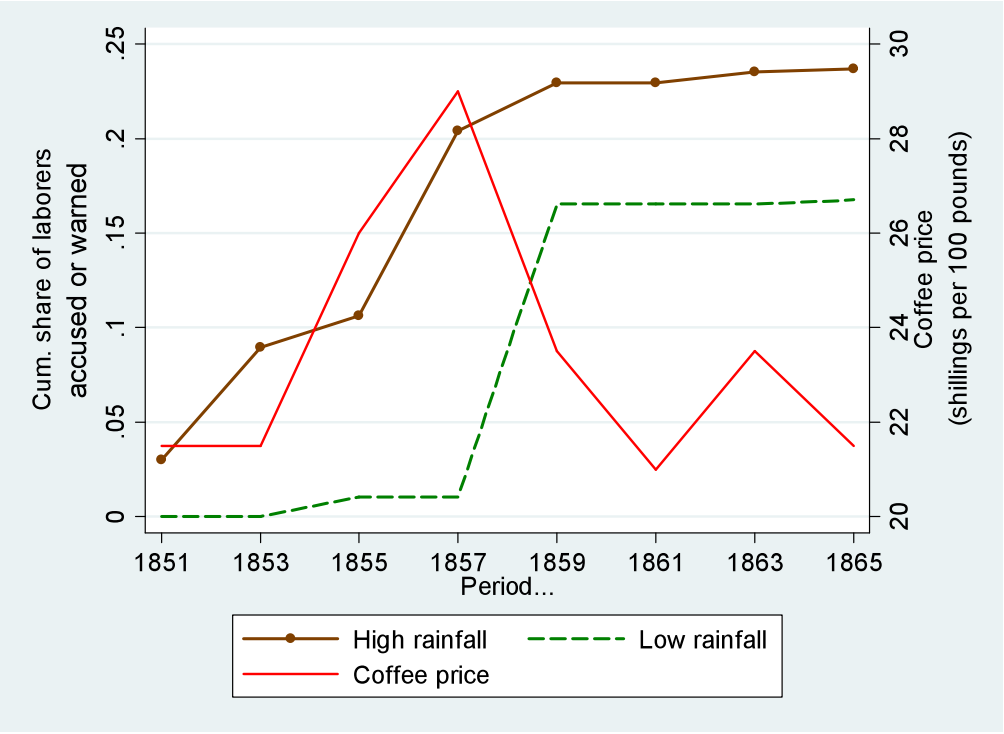
Source: Author's calculations from Carroll (1899) and Roberts (1941). See the data appendix for details on the construction of the variables.

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

Panel A: Cumulative Share of Laborers Spending Time in Prison



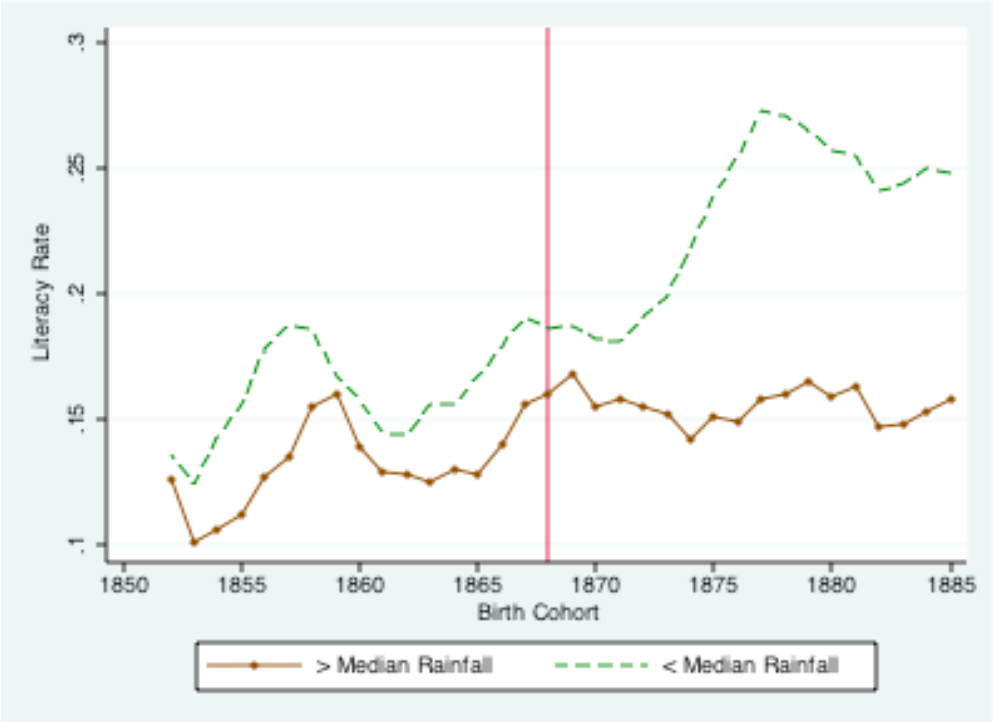
Panel B: Cumulative Share of Laborers Accused of or Warned against Vagrancy



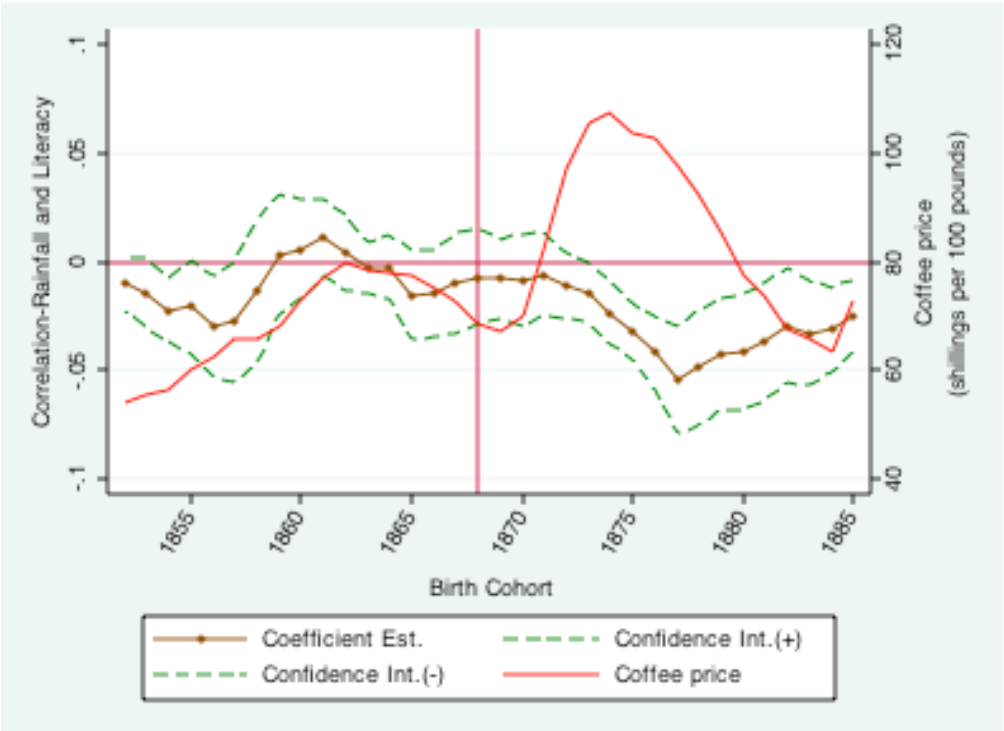
Notes: The figures depict the cumulative share of laborers ('jornaleros') reported to be spending time in prison (Panel A) and accused or warned of being punished for not abiding by the coercive labor regulations (Panel B) in municipalities with above average (solid brown line with circles) and below 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

Panel A: Literacy Rates by Cohort Group and Average Annual Rainfall Levels

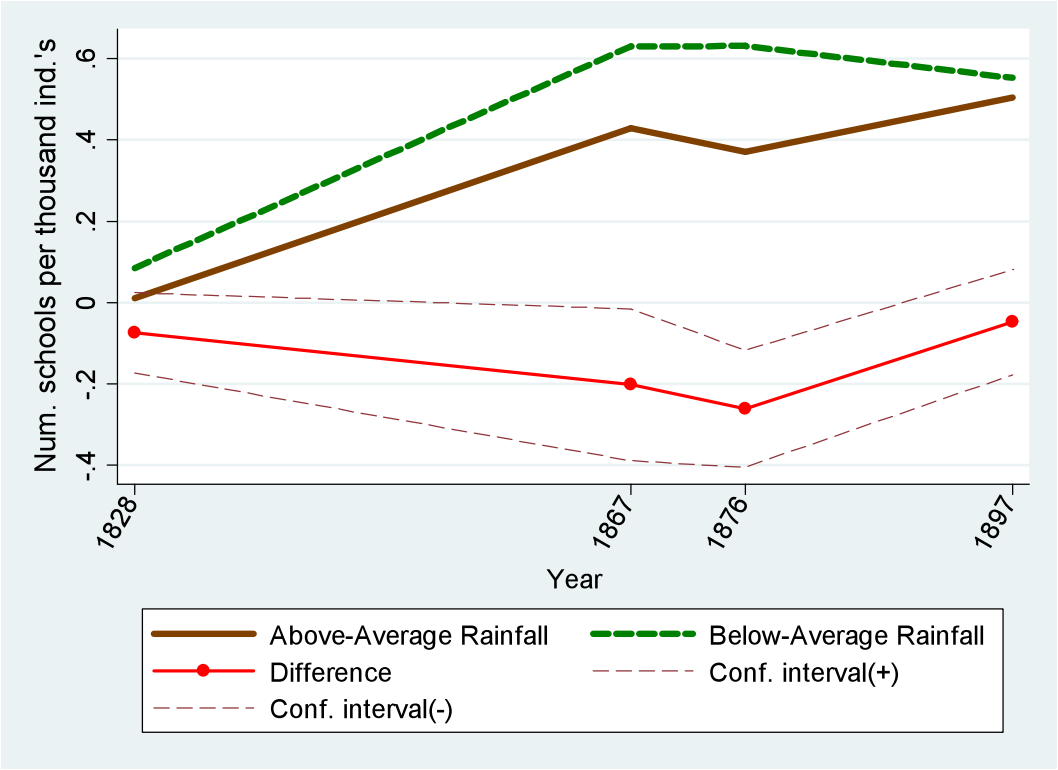


Panel B: Coefficients - Interaction of Cohort Group Indicators and Average Annual Rainfall Levels



Notes: Panel A – birth cohort-specific literacy rates by (5-year moving averages), by above median and below median average annual rainfall levels. Panel B - 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

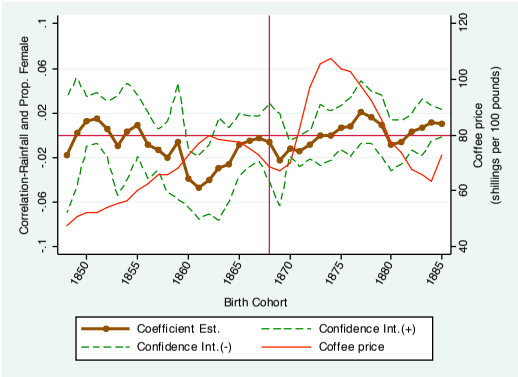


Notes: Panel A depicts trends in number of public primary schools per thousand individuals for the above average (solid brown line) and below average (dashed green line) annual rainfall municipalities; mean differences coefficient estimates from OLS regressions, depicted in the solid red line with circles,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

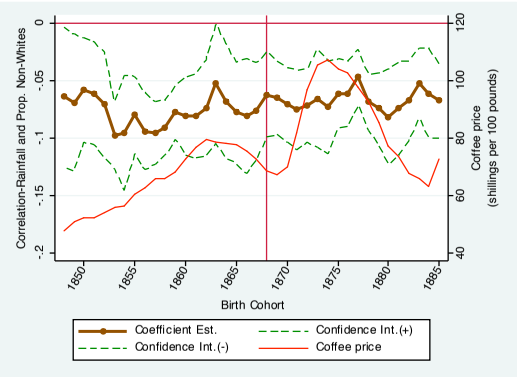
Figure 7: Differences in Pre-Determined Observable Characteristics across Cohorts in Municipalities with Varying Rainfall Levels

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

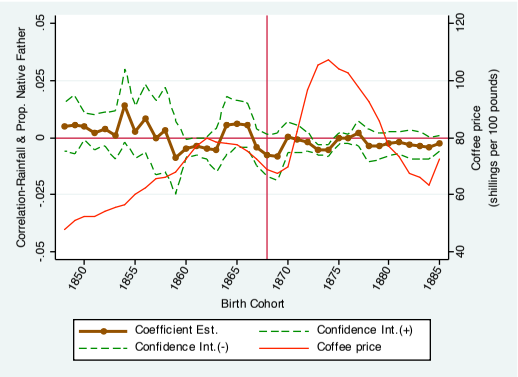
Panel A: Proportion Female



Panel B: Proportion Non-White



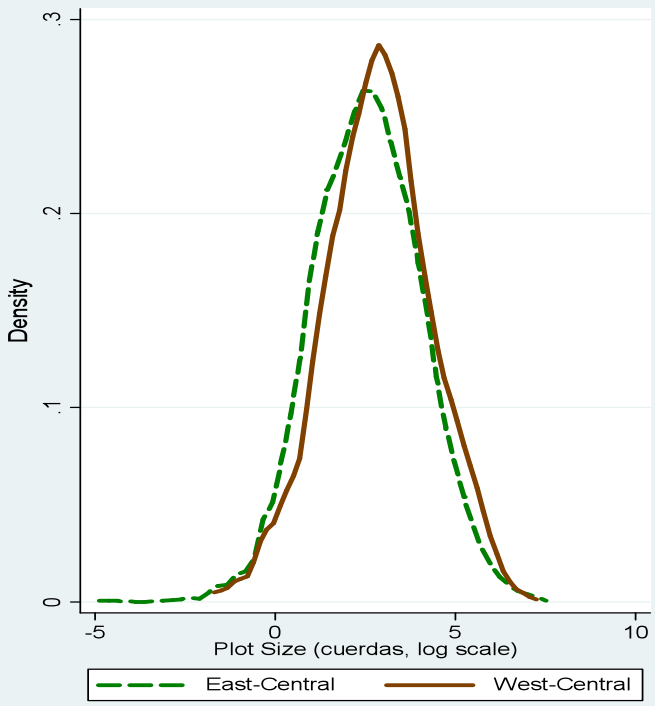
Panel C: Proportion Native Father



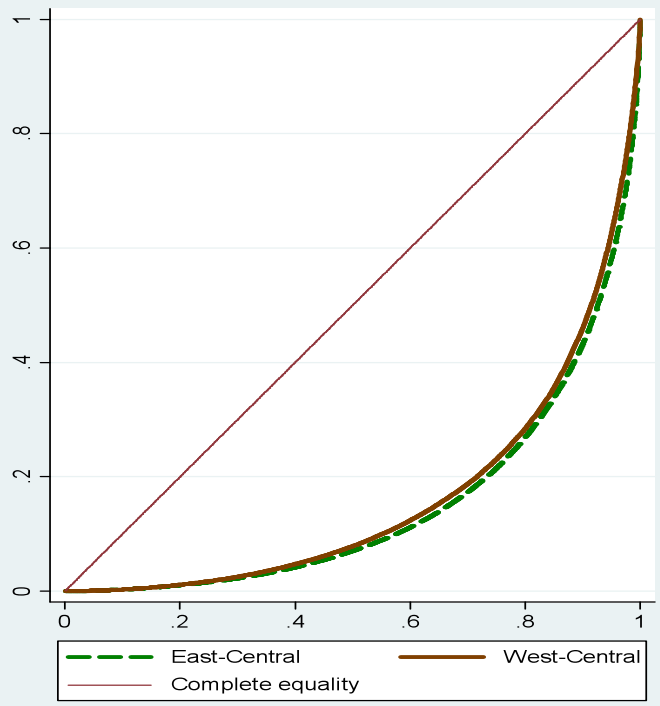
Notes: Values of parameter estimates of cohort-specific correlation with mean annual rainfall in municipality, from OLS regressions and their 95 percent confidence intervals are presented. (Robust standard errors; disturbance terms are allowed to be correlated within municipality, but not across municipalities).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

Dependent variables:	ln [Coffee exports (PR)] [millions of pounds]			Share of agricultural land under coffee cultivation, year 1896		
Sample:	Years 1846 - 1898			All central municipalities		
	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)
ln[Coffee price [t]]	0.83					
	(0.65)					
ln[Coffee price [t − 1]]	0.28					
	(1.04)					
ln[Coffee price [t − 2]]	-0.56					
	(0.86)					
ln[Coffee price [t − 3]]	0.20					
	(0.92)					
ln[Coffee price [t − 4]]	0.13					
	(1.01)					
ln[Coffee price [t − 5]]	0.20					
	(0.91)					
ln[Coffee price [t − 6]]	1.14*					
	(0.60)					
ln[Avg. coffee price [t, t − 3]]		0.56				
		(0.41)				
ln[Avg. coffee price [t − 1, t − 3]]			0.43			
			(0.44)			
ln[Avg. coffee price [t − 4, t − 6]]		1.31***	1.33***			
		(0.36)	(0.40)			
Average annual rainfall (in. x 10)				0.044***	0.044**	0.038**
				(0.019)	(0.017)	(0.018)
Average maximum temperature					-0.009	-0.003
					(0.006)	(0.007)
Average minimum temperature					-0.010	-0.008
					(0.006)	(0.007)
Average altitude (m)						0.000
						(0.000)
Average land gradient (º)						0.006
						(0.008)
Distance to port (km)						0.001
						(0.003)
Mean of dep. variable	-	-	-	0.090	0.090	0.090
Observations	47	47	47	25	25	25

Notes: Heteroskedasticity-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 (1)	Coercive Period Cohorts (2)	Post-coercive Period Cohorts (3)	Difference (3) - (2) (4)
Panel A: 1910 Census of Population PUMS Data				
Adult Literacy Rate	0.186	0.156	0.199	0.043 (0.108)
Age (in 1910)	37.6	50.4	32.0	-18.5 (0.1)
Gender (Female = 1, Male = 0)	0.50	0.50	0.50	0.00 (0.01)
Ethnicity (Black/Mulatto = 1, Other = 0)	0.27	0.27	0.26	0.00 (0.01)
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 across individuals for Panel A and across municipalities in Panel B 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 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) * Avg. coffee price 4-6 years preceding primary school enrollment decision	0.018	0.017	0.016	-0.066***	-0.065***	-0.065***
	(0.033)	(0.033)	(0.031)	(0.018)	(0.018)	(0.018)
Avg. coffee price 4-6 years preceding primary school enrollment decision	-0.410	-0.405	-0.409	0.576***	0.566***	0.571***
	(0.308)	(0.309)	(0.297)	(0.141)	(0.140)	(0.139)
Demographic controls	Yes	Yes	Yes	Yes	Yes	Yes
Geographic controls	No	Yes	No	No	Yes	No
Municipality fixed effects	No	No	Yes	No	No	Yes
Δ*Literacy from 1SD*(*Coffee price*)**10 in. rain*	*0.003*	*0.002*	*0.002*	*-0.010*	*-0.009*	*-0.009*
Differential effect for post-coercion cohort [from pooled regression]				-0.083**	-0.081**	-0.080**
				(0.036)	(0.036)	(0.034)
Δ*Literacy from 1SD*(*Coffee price*)**10 in. rain*				*-0.012*	*-0.012*	*-0.012*
Mean of dependent variable	0.156	0.156	0.156	0.199	0.199	0.199
N	4749	4749	4749	10760	10760	10760
R-squared	0.09	0.09	0.10	0.07	0.08	0.09

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; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Demographic controls include linear and quadratic terms on age (in 1910), female gender, black/mulatto, and native-father indicators. 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 Alternate Hypotheses – Correlations with Annual Rainfall Levels

Dependent variables:	Coefficient Estimate on Avg. rainfall (in. x 10)			Mean of dep. variable	N
	OLS (1)	OLS (2)	OLS (3)	(4)	(5)
Adult foreigners' literacy rate, 1899	0.006	0.002	-	0.86	23
	(0.014)	(0.002)			
Native adult males' literacy rate, 1899	-0.013**	-0.013**	-	0.24	23
	(0.005)	(0.005)			
Overall land ownership Gini, 1890s	0.009	-0.002	-	0.92	19
	(0.074)	(0.008)			
Landed HHs land ownership Gini, 1890s	0.028	0.009	-	0.75	19
	(0.017)	(0.021)			
Share of landed households, year 1899	-0.003	-0.026	-0.022	0.70 / 0.69	23 / 19
	(0.020)	(0.021)	(0.028)		
Num. of Provincial Civil Guard Units, 187	-0.050	-0.058	-	0.92	22
	(0.072)	(0.147)			
Share of Volunteer Guard Unit, 1886	-0.017	-0.039	-	0.70	22
	(0.061)	(0.083)			
Volunteer Guard Headquarters, 1886	0.009	0.012	-	0.09	22
	(0.030)	(0.076)			
Geographic controls	No	Yes	Yes		

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 7: Robustness Tests of the Effects of the Coffee Boom on Literacy Rates

	Dependent variable: Individual's literacy (1/0) indicator					
	Coef. Est. Avg. rainfall × Coffee price [4-6 years lag]	$\Delta Literacy$ $f\ rom$ $1SD(P_c)$	Coef. Est. Avg. rainfall × Coffee price [4-6 years lag]	$\Delta Literacy$ $f\ rom$ $1SD(P_c)$	Δ Effect for post-coercion cohorts	$\Delta Literacy$ $f\ rom$ $1SD(P_c)$
Sample:	Coercion period cohorts		Post-coercion period cohorts			
Additonal control variable:						
	(1)	(2)	(3)	(4)	(5)	(6)
Coffee price 6 years preceding primary school enr. decision ×						
Overall Land Gini Coefficient, 1890s	0.007	*0.001*	-0.060***	*-0.009*	-0.065*	*-0.009*
	(0.030)		(0.016)		(0.032)	
Num. Provincial Civil Guard units (n x 10) (1876)	0.017	*0.002*	-0.066***	*-0.010*	-0.083**	*-0.012*
	(0.032)		(0.017)		(0.034)	
Share of Volunteer Guard Unit in Mun. (1886)	0.022	*0.003*	-0.064***	*-0.009*	-0.086**	*-0.013*
	(0.033)		(0.018)		(0.037)	
Volunteer Guard Headquarters in Mun. (1886)	0.017	*0.002*	-0.065***	*-0.009*	-0.082**	*-0.012*
	(0.034)		(0.017)		(0.036)	
Mean altitude (m. x 10)	0.012	*0.002*	-0.065***	*-0.009*	-0.076	*-0.011*
	(0.041)		(0.018)		(0.049)	
Mean land gradient (°)	0.020	*0.003*	-0.064***	*-0.009*	-0.083*	*-0.012*
	(0.040)		(0.015)		(0.043)	
Distance to port (km)	0.020	*0.003*	-0.066***	*-0.010*	-0.085**	*-0.012*
	(0.033)		(0.017)		(0.034)	
Avg. rainfall (in. x 10) × Avg. sugar price 1-3 years pre. pr. school enrollment decision	0.008	*0.001*	-0.096***	*-0.014*	-0.103***	*-0.015*
	(0.031)		(0.018)		(0.036)	
Geographic controls	No		No			
Municipality fixed effects	Yes		Yes			
Mean of dependent variable	0.156		0.199			
N Municipalities[a]	22		22			
N Individuals[b]	4749		10760			

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; significantly different from zero at (*) 90%, (**) 95%, (***) 99% confidence. Demographic controls are female gender, black/mulatto, and native-born indicators, as well as linear and quadratic terms on age (in 1910). a,b = the number of municipalities (individuals) in the overall landownership Gini coefficient-Coffee price interaction specification is 18 (9,720 and 4,256 in the post-coercion and coercive period samples, respectively).