

Indigenous Origins of Colonial Institutions*

Luz Marina Arias

Desha Girod

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Abstract

Differences in colonial institutions appear to explain divergent patterns of political and economic development across former colonies. However, the origins of colonial institutions are not well understood. This article hypothesizes that variation in colonial labor institutions can be explained by both pre-colonial indigenous governance and the resource promise of colonies. We derive the hypotheses using a game-theoretic framework that emphasizes constraints facing profit-maximizing colonists. We test the hypotheses using an original dataset of natural resources and labor and tribute institutions from the pre-colonial and colonial periods for 455 sub-national territories in the Americas. The data are consistent with the hypotheses. Existing arguments about the national origin of colonists receive mixed support from the data. The article suggests that political and economic development today is a consequence of both natural resources and indigenous institutions, and therefore predates European colonialism.

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1 Introduction

While colonial institutions appear to explain contemporary development,¹ the origins of colonial institutions and the mechanisms through which institutions persist are not well understood. Colonists encountered much more than a tabula rasa or institutional vacuum as they explored new lands. Colonial expeditions came across rich and diverse indigenous institutions. For example, when Cortés reached the valley of Mexico, he found the Aztec empire, a prosperous and organized society with an agricultural surplus that could sustain a political elite, a religious elite, and an administrative hierarchy. Cortés wrote: “There are many chiefs, all of whom reside in this city, and the country towns contain peasants who are vassals of these lords and each of whom holds his land independently; some have more than others... And there are many poor people who beg from the rich in the streets as the poor do in Spain and in other civilized places,” (Cortés 1986).

The Aztecs lived in “large and intricate polities” (Macleod 2000, p. 5). The Spanish referred to this Mesoamerican *altepetl*, or city-state, as *señorío*. The *altepetl* consisted of a head, the *tlatoani*, surrounded by counselors, the *pipitlin*. The *pipitlin* also served as high-level functionaries (Cline 2000, p. 193) and sometimes governed subunits of the *altepetl* (*calpulli*). Each *calpulli* had its own god and its own hierarchy (Lockhart 1992, p. 16). Elites in the *calpulli* mobilized labor for public works, cultivation of the fields, and religious activities (Cline 2000, p. 194). This hierarchical administrative structure facilitated the transfer of goods and labor to the capital of the empire in the valley of Mexico, and other urban centers.²

In contrast, colonists encountered dispersed settlements, which the Spaniards called *rancherías*, in the region that comprises the present-day sub-national Mexican states of Sonora, Sinaloa, Durango, Chihuahua and Baja California. Indigenous peoples in these settlements subsisted from agriculture, hunting, and gathering. Political organization was decentralized. Headmen or elders (*principales*) provided guidance “...with oratorical skill”

¹See Nunn 2008, Bardhan 2005, Rodrik 2004, Easterly and Levine 2003, Glaeser and Shleifer 2004, Acemoglu et al. 2001, 2002, and Hall and Jones, 1999.

²Furthermore, the peoples of central Mexico had pre-hispanic experiences of conquest (Cline 2000, p. 198). *Altepetl* were in constant competition with each other, which resulted in their frequent restructuration and in the formation of expansive units as a consequence of alliances (Bartolomé 1992, p. 255). For instance, the Aztec Empire consisted of an alliance of three powerful *altepetl*: Tenochtitlan (Mexico), Tlacopan, and Texcoco. This Triple Alliance controlled a far-flung empire in which these three *altepetl* were dominant and all others subordinated to them. “In the period prior to the Spanish conquest all peoples in the Valley [of Mexico] had been subordinated by way of tribute and military service to the tlatoani of Tenochtitlan, Texcoco, or Tacuba” (Gibson 1964, p. 34).

(Deeds 2000, p. 51). Indigenous peoples in these regions did not institutionalize tribute or organize communal labor. Instead, they relied on “bilateral forms of kinship organization” (Deeds 2000, p. 52).

The variation in indigenous institutions raises an important empirical puzzle: How did pre-colonial institutions influence colonists in their colonial institution building? The existing literature emphasizes the role of colonists in the choice of early colonial institutional arrangements. Traditional explanations of different types of colonial institutions emphasize European culture and religion (Weber, 1958), and European legal and economic institutions (la Porta et al. 1997, 1998; Lange et al. 2006). Recent research proposes that colonies with greater indigenous prosperity (i.e. population density, urbanization), and climate and soil suited for crops compelled colonists to build extractive institutions.³ However, the role of indigenous institutions and peoples remains largely unaddressed.⁴

We develop a simple model that explains when and how colonists settled by focusing on the interaction between colonists, indigenous leaders, and labor, which could be indigenous or European.⁵ In so doing, we identify the distinctive role of natural resources and indigenous prosperity in explaining differences in colonial labor institutions. Unlike existing work, we do not focus on the effects of prosperity (i.e. population density or urbanization). We focus on the indigenous institutions that likely supported prosperity before colonists arrived. Specifically, we ask to what extent indigenous peoples organized labor and collected tribute, and how differences in these indigenous forms of governance influenced when colonists settled and what types of labor institutions they built.

We argue that in regions with a very high degree of hierarchy, colonists imitated indigenous governance and reaped profits from the existing structure. However, when colonists found low hierarchy and no resource promise, colonists did not settle at first. When they did settle, they imitated indigenous labor institutions, wherein labor exchange was based on reciprocity and thus laborers received higher compensation for their work. As a result, the same (extractive or wage) labor governance persisted from the pre-colonial to the early colonial periods. In regions with low degree of hierarchy but the potential for natural

³See Acemoglu et al. 2001, 2002b, and Engerman and Sokoloff 1997, 2000, 2006. Acemoglu et al. define extractive institutions as those “where the majority of the population faces a high risk of expropriation and holdup by the government, the ruling elite, or other agents” (2002b, p. 1262).

⁴Africa scholars acknowledge the impact of pre-colonial institutions on economic development (Gennaioli and Rainer 2007, Boone 2003, Engleber 2000; see also Acemoglu et al. 2002a), as do Ertan and Putterman (2007) considering all countries. The question remains whether colonial institutions were new or persisted from indigenous governance practices.

⁵We also consider African labor and discuss how it can be incorporated in the analysis in the theoretical framework.

resource wealth, colonists built more hierarchical labor institutions in order to obtain a higher share of the wealth. Thus, building new institutions was only profitable in regions with high resource wealth, where the prospects of profit offset the cost of building institutions. Furthermore, since regions with more hierarchic governance or resource wealth promised a higher payoff to colonists, we expect that these regions were settled first.

To analyze the influence of indigenous governance institutions and natural resources on colonial labor institutions, we collected original data across 455 subnational zones in the Americas. Our unit of analysis is at the sub-national level to capture fine-grained variation in indigenous and colonial institutions in present-day countries. We focus on the Americas because the Americas offer the cleanest test of our argument. In Africa, the Middle East, and Asia, it is much more difficult to disentangle indigenous from colonists influences on colonial institutions because Europeans traded with indigenous peoples for centuries prior to colonial rule. Europeans might have influenced the indigenous governance institutions that preceded colonial rule in these regions. That is, indigenous governance in these regions could be endogenous to colonial institutions. However, Europeans had not contacted the Americas when they set out on colonial expeditions. Focusing on the Americas, therefore, helps us avoid this endogeneity problem and to offer a relatively clean test of the argument.

Our analysis has implications for several literatures. First, if institutions “rule” when explaining economic and political development,⁶ understanding the mechanisms through which institutions persist seems important. This article contributes to our understanding of the mechanisms behind the persistence of governance institutions by demonstrating that indigenous structures of control influenced colonial institution building.

Second, our analysis is related to the literature on the transfer of institutions. Berkowitz et al. (2003) study the determinants of legal institutions by analyzing the process through which legal institutions were transplanted in the colonies and find that transfers were successful in colonies where the transplant adapted to local conditions or where the population was familiar with the law. Their findings are in line with our argument that the institutions colonists “built” share common elements with the indigenous institutions already in place.

Finally, historical institutionalism holds that institutions persist until challenged by a critical juncture⁷. New institutions that emerge after a critical juncture depend on a constellation of interests, ideas and pre-existing institutions. Consistent with historical institutionalism, we find that the same critical juncture, colonial expansion, had widely different effects on colonial labor institutions throughout the Americas. We find that

⁶See Rodrik et al. 2004.

⁷See Thelen 2004, and Thelen 1999 for a review.

the underlying structure of economic potential that colonists encountered influenced the development of colonial labor institutions in predictable ways.

In the next section, we describe indigenous governance institutions. Then, we then offer a theoretical framework to explain variation in the labor institutions colonists built. Third, we test observable implications of the theory with original data on natural resources and indigenous and colonial institutions. The final section concludes with a discussion of the implications of our study.

2 Indigenous governance institutions

Access to labor was of primary interest to the colonists when settling in the new territories. Labor is essential first for providing food, and also for construction, handicrafts, mining, and other services required by the colonists. Our study focuses on features of the indigenous societies with direct relevance to the actions the colonists took to satisfy their need for labor. The size of the population is relevant, but also the indigenous rules and beliefs governing the exchange of labor and goods.⁸ These rules and beliefs shape the cognitive, informational, coordinative, and normative context for indigenous peoples, and thus facilitated or hindered colonists' ability to use indigenous labor.⁹

Indigenous governance regarding labor and goods exchange can be classified across a continuum where one extreme represents exchange based on reciprocity, and the other extreme represents exchanges based on what we call *hierarchical governance*, that is, asymmetric power relationships and social stratification. Labor requiring the consent of the community is located at one end of the continuum and systematically organized labor drafts at the other end. Similarly, circumstance-specific collection of tribute is located at one extreme and an administrative infrastructure regularly collecting tribute at the other. Indigenous regions with more hierarchic governance had an elite with more control over resources and labor. This control is evident in three areas: surplus, enforcement, and individuals' ability to escape.¹⁰

⁸A certain population density, the presence or absence of intensive agriculture, the specialization of labor, public works, types of political and religious organization, and so on, do not arise independently of each other. We do not seek to deny their relationship but to suggest that some of them have more direct relevance to the actions of the colonists.

⁹For more on the role of institutions as rules and beliefs see Greif 2006, p. 190. di Tella et al. 2007 provide evidence of the influence of economic institutions on the formation of beliefs.

¹⁰For the following description of this characterization we rely primarily on Lockhart and Schwartz (1983), Villamarín and Villamarín (1975), Sanders and Marino (1970), and Greif (2006).

First, in hierarchic regions, the elite consisted of a political authority with an administrative organization and legal and religious system. This social and political differentiation was sustained by economic specialization that allowed for a higher overall productivity and thus food surpluses. A share of the surplus was transferred to the elite in the form of tribute. The elite also had access to labor drafts for public works, the cultivation of their fields, and other services. Economic specialization therefore required social differentiation, and this differentiation received support from the norms, beliefs, and social and political organizations in the region.¹¹ On the contrary, less hierarchic regions had no specialized political or religious authorities mobilizing labor. If labor was organized at all, it is organized on the bases of age and sex. Reciprocity is the basis of exchange.

Second, while communities without hierarchy enforced labor and tribute arrangements with reciprocity and peer-pressure, communities with hierarchy institutionalized authority on a leader who could punish non-compliance.¹²

Third, indigenous peoples in less hierarchic regions were better able to escape from colonists than indigenous peoples of hierarchical regions. Escaping required subsisting apart from a known environment and community. Indigenous peoples that lacked a history of hierarchy were accustomed to moving and adapting to new environments. They could find refuge in the hinterlands because they were relatively more self-sufficient. Escaping was costlier in hierarchic regions because of the specialized set of skills of the indigenous peoples (intensive agriculture, trade, ritual-making). Furthermore, most of the regions featuring hierarchies were located in the highland regions, where escape is costlier than the lowlands. Peoples in the coast and the lowlands could escape colonists by retreating inland.¹³

In the next section we include indigenous hierarchic governance in a game-theoretic analysis. We model the interaction between Colonists, Indigenous Leaders, and Labor. The historical evidence support taking these as the relevant decision makers. Colonists, for example, mattered more to the strategic interaction than the nations they represented. After early experiences in the Caribbean, “the idea of direct crown supervision of overseas expansion (...) faded rapidly in the face of the realities of the Indies” (Lockhart and Schwartz 1983, p. 78). Conquest and colonization was largely carried out by private enterprise and organized on a mercantile basis backed by wealthy Europeans holding charters from their respective crowns. These entrepreneurs, however, relied mostly on their own financial resources. The crowns provided some financial resources at first, but the

¹¹See also Macleod 2000, p. 5-6, and Lockhart 1992, p. 16.

¹²See for instance Greif (2006).

¹³For more on social and geographic factors relating to escape see Service (1955).

contributions were small relative to the overall cost of the enterprise. For example, early explorations in Spanish America were undertaken by the *huestes Indianas*, parties consisting of military men, seamen, religious men for the spiritual care of the soldiers and to intervene in the conversion of the indigenous, and fiscal authorities. The leader of the exploration party would “sport the title captain,” and was invariably a man of standing in the base area (Lockhart and Schwartz 1983, p. 79).¹⁴

Also, Indigenous Leaders historically played an important role in the encounter between the two worlds. In fact, a first tactic by colonists was to identify the local ruler. After years of expeditions, some of the colonization parties included indigenous allies, suggesting the importance of negotiating with indigenous holders of authority. The role and visibility of the indigenous leaders and chiefs varied depending on the indigenous governance institutions. In regions with hierarchies, a political authority and class differentiation were institutionalized and visible, while in regions with less hierarchic governance, political leadership was situation-specific and not as easily identified by outsiders. Not only was the clothing of the ruling class distinguishable from that of the commoners, also “lavish residences, stone-lined tombs, and sumptuary privileges” gave evidence of the status of the elite constituting the political and administrative authority (Zeitlin 1989, p. 32). This is important because the existence of a single, identifiable agent facilitates negotiation and makes enforcing agreements with outsiders more credible.

Laborers are also included as “players” in the strategic interaction that informed Colonist decisions because Laborers represent the bulk of the population. They could respond to Colonist occupation by participating in the colonial project or taking refuge in other areas.

3 Analytic framework

We propose a mechanism that explains differences in colonial labor institutions. We argue that early colonial outcomes in the Americas result from variation in indigenous governance, together with the resource wealth of a region in the eyes of Colonists.

When arriving to new lands, Colonists encountered indigenous peoples in regions with varying degrees of political hierarchy and resource wealth. Colonists chose whether to settle, and if so, whether to imitate existing governance institutions or build new institutions. If Colonists chose to build new institutions, Labor could choose not to comply by fleeing to other regions. If Colonists chose to imitate existing institutions, they had to bargain with

¹⁴See Zavala (1988) for more on the Spanish expeditions and legal instructions for the conquest.

Indigenous Leaders on a division of the total output. We derive hypotheses about whether Colonists chose to settle and how they chose to settle when all players aimed to maximize their individual share of the total output.

When Colonists found hierarchical indigenous governance, they sought to imitate the institutions and reap profits from its existing structure. Colonists could seize much of the existing institutional structure because Indigenous Leaders, who controlled Labor, often bargained with Colonists in order to avoid losing their prerogatives as a result of a Colonist victory in war.

When Colonists found indigenous peoples without hierarchic governance, but the potential for natural resource wealth, Colonists built hierarchical labor institutions in order to obtain the wealth. Building hierarchic institutions is costly because it requires learning, administration and monitoring. Furthermore, indigenous peoples could escape because the region was non-hierarchic. From the Colonist perspective, however, the promise of higher profits offset the cost of building on new institutions.

When Colonists found low hierarchy and no resource promise in a region, Colonists did not settle at first. When they did settle, they imitated indigenous labor institutions, wherein labor exchange was based on reciprocity and thus Laborers received compensation for their work. Colonists imitated the existing labor governance both because the lack of resource promise made building new institutions unprofitable and Laborers could escape.

3.1 Players, actions, timing, and payoffs

Consider a complete information game with three players: Colonists, **C**, Indigenous Leaders, **I**, and Labor, **L**. Colonists first explore a region and observe its indigenous governance institutions, α_0 , and the economic resources and potential of a region, r . Colonists then choose whether to seek permanent settlement. If deciding to settle, colonists can decide whether to imitate the indigenous governance institutions, $\alpha_1 = \alpha = 0$ or build new governance institutions α_1 . Finally, Colonists and Indigenous Leaders bargain a division of the total output. If Colonists decide not to settle, they explore a new region and observe its governance institutions and potential, and, again, choose whether to seek permanent settlement.

Let $Y(r, l)$ be the value of the total output from a region with resource wealth r , and labor l , increasing in both parameters and concave.¹⁵ As explained in section 2, indigenous governance, α_0 , specifies the degree to which labor and tribute exchanges are enforced through political hierarchy and class stratification. A higher α_0 implies more

¹⁵We use L for Labor as players, and l for the role of Labor in the total output. More on this below.

hierarchical indigenous governance, and thus a higher proportion of the output kept by the Indigenous Leaders. Let $\alpha_0 \in (0, 1)$ be the share of the output kept by Indigenous Leaders. Correspondingly, $1 - \alpha_0$ is the share kept by Labor. Thus, indigenous governance, α_0 , specifies the division of the output between Indigenous Leaders and Labor *before* the arrival of Colonists. As such, the parameter α_0 allows us to highlight the role of Indigenous Leaders as intermediaries. Indigenous governance also implies different escape abilities for individuals in society. We incorporate this as a higher outside option for Labor in societies with less hierarchic indigenous governance. In an abuse of notation, we use $u^L(\alpha_0)$, where u^L is the outside option of Labor, a decreasing function of indigenous governance.

If Colonists choose to imitate indigenous institutions, $\alpha_1 = \alpha_0$ and Indigenous Leaders play a role as intermediaries between Colonists and Labor. If instead Colonists choose to build new governance institutions, α_1 , they invest in an administrative hierarchy and new intermediaries—which we also label **I**. Building institutions can increase or decrease the share of the output that Indigenous Leaders are able to keep.

Labor can respond to a change in governance by choosing whether to comply with Colonist rule. If choosing not to comply Labor obtains their outside option $u^L(\alpha_0)$. The response of labor impacts total output: if labor does not comply output falls to $Y(r, 0) = 0$, otherwise output is $Y(r, l)$. We interpret the outside option as migration and death of the existing labor force.¹⁶ If choosing to comply with the change in governance, Labor obtains $(1 - \alpha_1)Y(r, l)$, if Indigenous Leaders and Colonists reach an agreement in bargaining. If the bargaining is not successful, all players obtain their outside option $(u^C, u^I, u^L(\alpha_0))$. If an agreement is reached, Indigenous Leaders keep share of the output $\alpha_1 Y(r, l) - b$ and transfer b to Colonists, where the amount b is determined in a bargaining equilibrium, as will be explained.

We analyze the change in governance institutions and the decision to settle in subsections 3.3 and 3.4, respectively. First, in accordance with backward induction, in the next subsection we analyze the bargaining problem between Colonists and Indigenous Leaders.

3.2 Bargaining

We assume that both Colonists and Indigenous Leaders seek to maximize their fraction of the total output. Colonists sought to profit from the colonies. Profit from the colonies took the form of agricultural surplus, silver, gold, and other ores, and tribute transferred

¹⁶Death is not strictly a choice made by laborers but it will also lead to a fall in output. So in terms of the theoretical framework migration or death are equivalent.

from the indigenous communities to colonists in the form of goods or draft rotary labor (Lockhart and Schwartz 1983, p. 261-62).

To obtain the outcome of the bargaining problem between Colonists and Indigenous Leaders we use the Nash bargaining solution.¹⁷ The Nash solution is an axiomatic approach that describes the bargaining problem by using the information in the utility functions, the bargaining power, and the outside options (or disagreement points) of each player. Let β be the bargaining power of the Colonists; correspondingly, $1 - \beta$ is the bargaining power of Indigenous Leaders.¹⁸ If the surplus is positive, i.e. $\alpha Y(r, l) - u^C - u^I > 0$, the formula under Nash's axiomatic approach prescribes that the surplus is divided according to the bargaining weights: Colonists receive share β and Indigenous Leaders receive share $(1 - \beta)$.¹⁹ In particular, Indigenous Leaders transfer to the Colonists:

$$b = \beta[\alpha_1 Y(r, l) - u^I] + (1 - \beta)u^C.$$

Notice that more hierarchic governance institutions—higher α_1 —implies a higher transfer b to C, since Indigenous Leaders keep more of the total output relative to Labor. Thus, a higher initial α_0 leads to Colonists keeping a higher share of the output, only as a result of with Indigenous Leaders and without the need to change governance institutions. Furthermore, hierarchic governance facilitates negotiation between Indigenous Leaders and Colonists because of the surplus lost to Indigenous Leaders if losing their position of authority.

The alternative to Indigenous Leaders if refusing to reach an agreement with Colonists is to seek refuge elsewhere, outside of their communities, and be in hostility with Colonists. We do not consider a military confrontation as a feasible alternative because the probability of **I** defeating **C** in a military confrontation was small. Colonist military technology at the time was more advanced than that of the indigenous peoples (see Powell, 192, p. 205). Even though some attempted to defeat the Colonists to keep their position of authority

¹⁷This is also known as the Nash cooperative solution, first characterized by Nash (1950).

¹⁸Indigenous Leaders could potentially have more or less bargaining power depending on the form of indigenous governance. To simplify, we assume β does not depend on indigenous governance institutions. Allowing β to depend on indigenous institutions does not change qualitatively our results.

¹⁹A solution that satisfies Nash's four axioms (scale invariance, efficiency, symmetry, and independence of irrelevant alternatives) must maximize the product of players' utilities over the set of feasible payoffs (Krishna and Serrano, 1996). Even though Nash's is a static approach that does not explicitly describe the dynamic strategic interaction in bargaining, Binmore et al. (1986) show that with an appropriate interpretation of the outside options, the limit equilibrium outcome of the explicit strategic characterization coincides with the static Nash solution.

intact, no indigenous group succeeded, and in some cases, Indigenous Leaders sought an agreement with the Colonists preemptively, before Colonists approached them.²⁰

The higher the outside option of Indigenous Leaders, the lower the share of the output kept by Colonists. If Indigenous Leaders in more hierarchic governance institutions have lower outside options, a negotiation between Leaders and Colonists under more hierarchic governance institutions leads to a higher share of the output transferred to Colonists.

Finally, note that if the region has low resource endowments, r , which lead to a low $Y(r, l)$, or if the outside options of Indigenous Leaders or Colonists are large, the surplus is negative and a disagreement results.

3.3 Building institutions

Before bargaining, Colonists choose whether to build new governance institutions, α_1 . Colonists invest in an administrative hierarchy to change the share they are able to obtain of total output to α_1 . This increases the share received by Colonists in the bargaining equilibrium.²¹ Building governance institutions entails an enforcement cost of $e > 0$. Modifying the existing governance institutions involves bargaining, coordination, search, and learning costs (Greif, 2006), plus the administrative cost to effectively implement the policy (Greif, 2008).

As mentioned earlier, a change in governance can induce a response from Labor. If Labor chooses to retreat, total output is zero. For Labor to comply with Colonist rule, the Colonists need to ensure that $(1 - \alpha_1)Y(r, l) \geq u^L(\alpha_0)$. Thus, to maximize their payoff, Colonists choose:

$$\alpha_1^* = 1 - \frac{u^L(\alpha_0)}{Y(r, l)}. \quad (1)$$

Colonists are able to implement a higher α_1 , the lower the outside option of Laborers. That is, in societies where Laborers adapt more easily to migration, and are not part

²⁰After receiving notice of the defeat of the Aztecs in Tenochtitlán, the reigning Zapotec ruler in Tehuantepec, in the Isthmus region in Oaxaca, sent rich gifts and promises of loyalty to Spanish emissaries exploring the highlands of southern, present-day Mexico. See Zeitlin 1989, p. 34.

²¹Historically, there were mainly two types of policies undertaken by Colonists. One sought to recreate the conditions of sedentary societies with well-defined social ranks. These policies were thus aimed at reducing the mobility (ability to escape) of the indigenous peoples through increases in coercion and through changes in the beliefs, norms, and organization of the indigenous labor, or by bringing labor from elsewhere. An example of this is slavery. Other policies also sought to create more sedentary societies but provided positive incentives to labor through wages or better working conditions. Labor governance relied more on equality and reciprocity. Missions and free laborers in some mining centers (called *yanacunas* in Peru), are examples of the latter. In the empirical section we describe in more detail the specific governance forms that we code during colonial times.

of a set of organizations, rules, and beliefs that enforce differentiation (i.e., Labor has a higher outside option), the increase in the share of the output Colonists obtain by changing institutions is lower than if the region had governance hierarchies.²² Colonists can build institutions that extract more, but only to the point that the higher extraction does not hurt output. Notice also that for any initial governance, in a region with a higher resource wealth, more can be extracted because of the higher level of total output.

Assuming an agreement is reached in the bargaining between Colonists and Indigenous Leaders, the payoff to Colonists from building new governance institutions is $\beta[\alpha_1 Y(r, l) - u^I] + (1 - \beta)u^C - e$. The following proposition gives the conditions under which we observe a change in governance in a subgame perfect equilibrium, given that an agreement is reached in the negotiation between Colonists and Indigenous Leaders.

Proposition 1. *If the surplus from bargaining is positive and the following inequality holds:*

$$e \geq \beta[(1 - \alpha_1^*)Y(r, l) - u^L(\alpha_0)], \quad (2)$$

in the subgame perfect equilibrium Colonists imitate indigenous governance institutions. Otherwise, in equilibrium Colonists build new governance institutions α_1^ .*

Proof. The inequality derives from comparing the payoff to Colonists under α_0 to their payoff under α_1^* given that the an agreement is reached in bargaining with Indigenous Leaders. □

Therefore, the decision to build governance institutions depends on the enforcement cost: if the cost relative to the gain in surplus is high, Colonists prefer to imitate indigenous institutions. In this case, colonial labor governance will share institutional elements with indigenous governance. Note from condition 2 above that Colonists choose to imitate indigenous institutions for high values of u^L and for high values of α_0 . That is, in regions with either a very low degree of indigenous hierarchy or a very high degree of indigenous hierarchy we expect to see colonial labor arrangements that feature a similar degree of hierarchy, respectively.

Accordingly, in regions with intermediate levels of hierarchy and with a high resource wealth, the inequality is less likely to hold, and so in those regions we would expect to see labor governance institutions that differ from those in place before the arrival of Colonists.

²²Not only was Indigenous labor used for agriculture, mining, and other economic enterprises, but in many cases Africans or Europeans supplied the necessary labor. Note that bringing outside labor in conditions such that the escape of labor is more difficult can also be interpreted as a low outside option, and was indeed a from of building labor governance institutions undertaken by Colonists. Thus, ‘Labor’ in our analysis need not only refer to Indigenous labor but also to African or European labor.

When Colonists foresee a larger resource wealth, and thus a larger pie from which to obtain a share, the investment in changing institutions to obtain a higher share of the output is profitable.

In summary, we find three possible subgame perfect equilibrium outcomes: (1) If the surplus from an agreement ($\alpha Y(r, l) - u^C - u^I$) is positive and condition 2 holds, Colonists imitate indigenous governance institutions, and there is an agreement between Colonists and Indigenous Leaders; (2) If condition 2 holds but the surplus is negative, Colonists imitate governance institutions and there is *not* an agreement between Colonists and Indigenous Leaders; (3) If the surplus is positive and condition 2 holds, Colonists build new governance institutions and there is an agreement between Colonists and Indigenous Leaders.

3.4 Settlement

We learn from the above analysis that when deciding whether to seek permanent settlement, Colonists make their decision based upon indigenous governance and resource wealth.²³ Regions with hierarchic governance and with high resource wealth promise a higher payoff and facilitate the bargaining with Indigenous Leaders. From the theoretical analysis, thus, we expect that regions with more hierarchic governance and with high resource wealth will be settled first.

The decision of whether to settle depends also on the regions yet to explore: the availability of unexplored regions and the belief about their potential. As settlement in other regions reduced the availability of unexplored areas, or changed the belief about the existence of hierarchic governance and/or resources in the unexplored areas, we expect to see an increase in settlement in regions with less hierarchic governance. Thus, we expect regions with less governance hierarchy to be settled later.

3.5 Testable hypotheses

The above analysis implies specific testable hypothesis regarding the colonist rate of settlement of and the degree to which colonial labor arrangements rely on political hierarchies:

²³There is evidence that upon arrival Colonists inquired about the types of resources and the forms of governance. See, for instance, Villamarín and Villamarín 1999, p 579. Furthermore, Colonists obtained early on an idea of the functioning of each society. They could not understand the detail of all the norms, beliefs and organizations. However, Indigenous Leaders and differentiation were often visible. See also Lockhart and Schwartz 1983, p. 79.

1. Colonists should settle faster in regions with more hierarchic indigenous governance and with high resource wealth than in regions with less hierarchic indigenous governance.
2. In regions with a very high degree of hierarchy or a very low degree of hierarchy we expect to see imitation of indigenous institutions, for a given level of resource wealth. This implies that indigenous governance should predict the form of colonial governance. In regions with more hierarchic indigenous governance we should expect colonial labor arrangements that rely on political hierarchies, and that transfer a higher proportion of the economic surplus to Colonists. In regions without hierarchic indigenous governance, we expect horizontal colonial societies relying on reciprocity and wage labor in labor arrangements.
3. Finally, in regions with high resource wealth we expect to observe Colonists building hierarchic governance institutions. That is, there is strategic complementarity between resource wealth and institutional change.

4 Empirical analysis

We assess the influence of indigenous governance hierarchies and resource wealth on the rate of colonial settlement and on the type of colonial labor institutions. Our analysis requires us to go beyond data in existing quantitative analyses of colonial institutions. First, none of the existing datasets code natural resources available to colonists or pre-colonial indigenous governance institutions. Second, quantitative analyses to date measure colonial institutions indirectly with variables like settler mortality. But countries with similarly high settler mortality, such Mexico and Argentina, consisted of different colonial institutions. While early settlers did not introduce wage labor to Mexico, early settlers introduced wage labor to 43% of Argentina.²⁴

Another limitation of existing data is that the unit of analysis is at the country level. We observe different types of colonial institutions within countries, however. For example, settlers in present-day Argentina established repartimientos and encomiendas in addition to wage labor. Unlike wage laborers, laborers in repartimientos and encomiendas worked without pay. Similarly, colonists in the present-day United States established wage labor, repartimientos, and encomiendas.

To overcome these data limitations, we constructed an original dataset of natural resources, indigenous institutions, and colonial labor institutions for 455 present-day sub-

²⁴The data are discussed below.

national political zones in the Americas. The zones constitute the largest political demarcation within present-day countries (i.e. 33 states in Mexico, 10 provinces and 3 territories in Canada, 9 departments in Bolivia, and so on), and a substantial disaggregation of the national-level data.²⁵ Thus, the unit of analysis for hypothesis testing is each “zone” in the Americas.

The Americas offer the cleanest test of our argument because Europeans had no contact with the region prior to their expeditions. We therefore avoid the endogeneity problem we would face if studying other regions, where previous contact with Europeans might have influenced the European colonial project. By examining colonial institutions directly and at a less aggregated level while avoiding endogeneity problems, we hope to capture the variation in colonial institutions better than existing studies and identify the channels of causality in the process of colonial institutional development. We test our hypotheses across 10 regression models presented here and 32 additional regression models in the Appendix.

4.1 Indigenous governance institutions and resource wealth

Our first independent variable of interest is the pre-colonial indigenous governance hierarchy, the degree of social control by indigenous leaders. Social control can be assessed by the indigenous labor organization and tribute collection in each zone.

We code indigenous labor organization on an ordered 3-point scale. We give a zero to zones with no specialized political or religious institutions that can mobilize labor. If labor is organized at all, it is organized on the bases of age and sex. Reciprocity is the basis of economic exchange. Zones are coded as “1” when they have a political or religious authority that can mobilize communal labor (typically for religious or military purposes). Reciprocity is still part of economic exchange, but there is some asymmetry in political power even if nominal and on the basis of personality. Finally, we coded zones where political or religious authorities systematically organized labor drafts for public works, cultivation of fields, and so on, as “2”. When more than one level of labor organization is present in a zone (this was the case in 11%, 51 out of 455, zones), we code the zone as having the higher level of labor organization.²⁶

As with indigenous labor organization, we code indigenous tribute collection on an ordered three-point scale. Zones with no systematic collection are coded as zero,²⁷ zones with systematic local collection as “1”, and zones with systematic collection linked to an

²⁵The sample in the table is smaller than 455 because of missing data on some of the variables.

²⁶Results hold when coding the zone as having the lowest value.

²⁷That is, there could be some collection for war or other purposes, but the tribute has to be requested each time.

authority external to the tribe as “2”. In 2% of the zones (8 out of 455), we found more than one level of tribute collection and, as with labor organization, we code these zones as having the higher level of tribute collection.²⁸

We code indigenous labor and tribute 50 years before the colonial expedition reached the zone to ensure that colonists did not influence indigenous institutions. Indigenous labor and tribute are positively correlated at 0.67.

Using the data on indigenous labor and tribute, the degree of indigenous governance hierarchy can be separated into three levels: low, medium, and high. Zones with low-level hierarchy (labor = 0 and tribute = 0) consist of societies with no specialization of labor, where some individuals may function as leaders but only for specific roles and under specific circumstances, such as war. Reciprocity is stressed in economic and political exchange. Zones with medium-level hierarchy had political leadership with the ability to obtain labor and resources from the local community on a regular basis, yet with no routine labor draft (labor and tribute were not both zero or 2). Zones with high-level hierarchy consisted of a central authority that operated with intermediary authorities, which administered the relationship between communities and the elite (labor = 2 and tribute = 2).

Figure 1 demonstrates the distribution of indigenous labor organization (Figure 1.A), tribute collection (Figure 1.B), and governance hierarchy (Figure 1.C). While 50% of zones lacked systematic tribute collection, 13% had reciprocity-based labor organization. The two categories overlap in 11% of zones, and the zones in the overlap have low-levels of indigenous governance hierarchy. These zones constitute 20% of the landmass of the Americas.

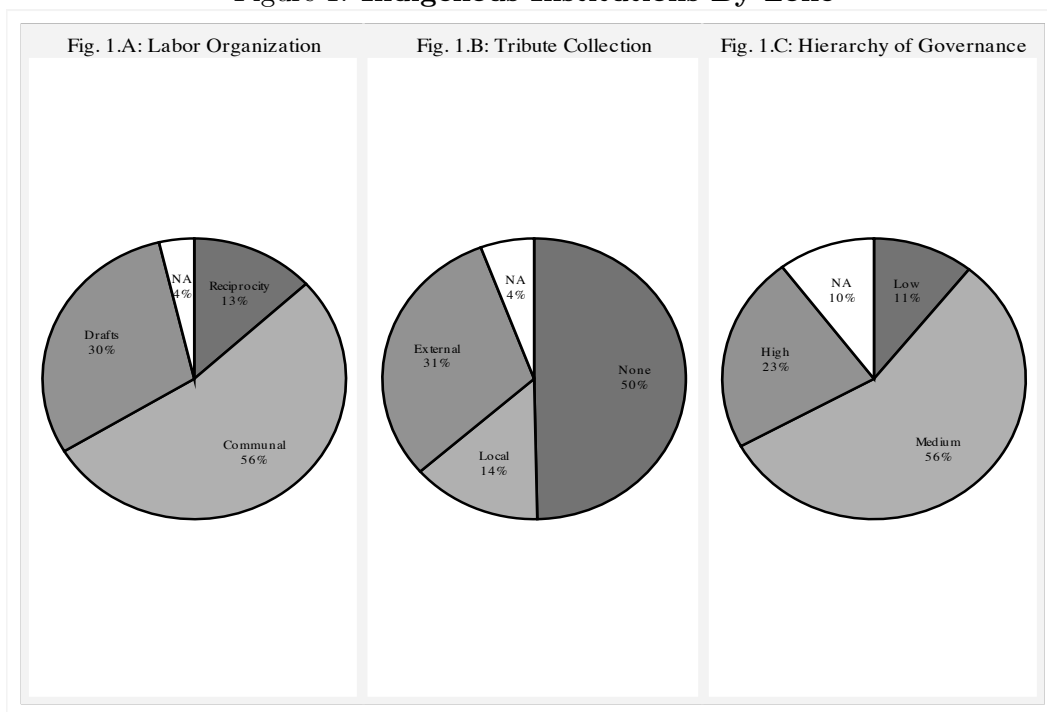
Thirty percent of zones had labor drafts and 31% had external tribute collection. Twenty-three percent of zones overlap between the two and therefore have high-level hierarchy. Zones with high-level hierarchy constitute 9% of the landmass of the Americas.

The vast majority of zones, the remaining 56% , consist of medium-level hierarchy. These zones represent 58% of the landmass. Most of the observations in this category (77%) have communal labor and no systematic tribute collection (labor = 1 and tribute = 0) or communal labor and local tribute collection (labor =1 and tribute = 1). Finally, 10% of zones, mostly small island countries, are missing data on at least one of the two variables, and these represent 13% of the landmass.

The second independent variable of interest in our study is resource wealth. Resources that are highly profitable, such as minerals, agriculture potential (whether land was suitable for cotton, sugar, and so on), and to a lesser extent, timber, should have motivated colonists to settle faster or build more hierarchical labor institutions than less lucrative resources,

²⁸As with labor organization, results hold here when coding the zone as having the lowest value.

Figure 1: Indigenous Institutions By Zone

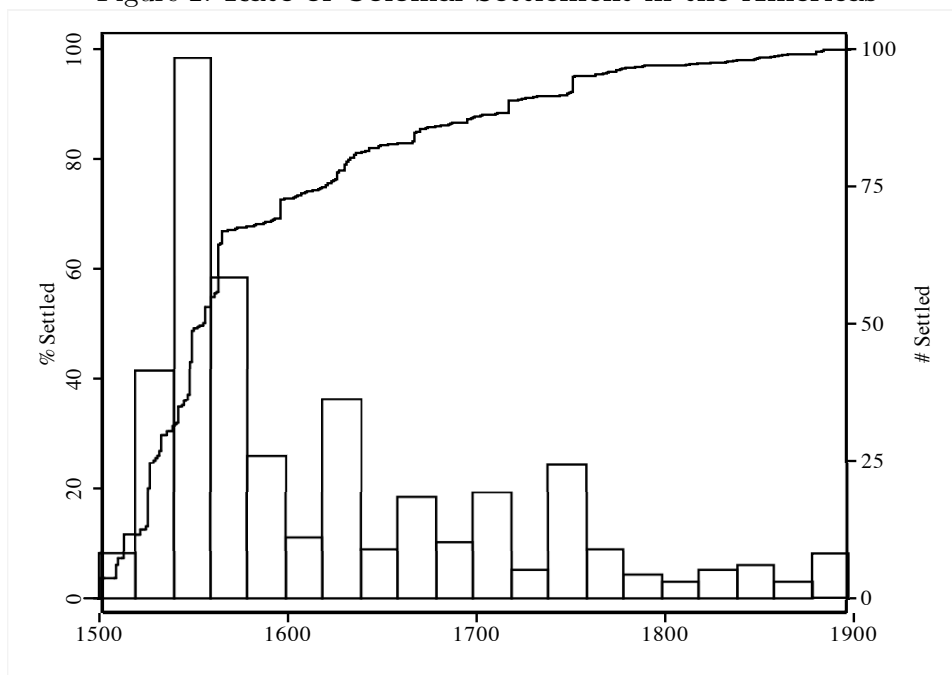


such as furs, fish, and livestock. We code whether any of these resources were available in each zone on the expedition year, regardless of whether the indigenous groups were utilizing these resources. If the specific resource was present, the zone was coded as “1” for the binary variable representing the resource. If the resource was lacking, the zone was coded as zero for the specific resource. Sixty-six percent of the zones had land suitable for cotton, sugar or other crops of interest to colonists, 38% had minerals, 33% had timber, 30% had livestock, 15% had fish, and 12% had furs. The correlation between indigenous governance hierarchy and natural resources is highest for agriculture (0.36), then minerals (0.30), and then timber (0.09). It is nearly zero between the hierarchy levels and either furs, fish, or livestock.

4.2 The Rate of Settlement

We first ask whether indigenous governance hierarchies and resource wealth influence the rate of colonial settlement. The dependent variable is the time span between the first colonial expedition and first settlement. We code the first expedition as the earliest year on record marking the arrival of colonists to the zone, and the first settlement as the arrival of a governor or mayor (whichever is first) to the zone.

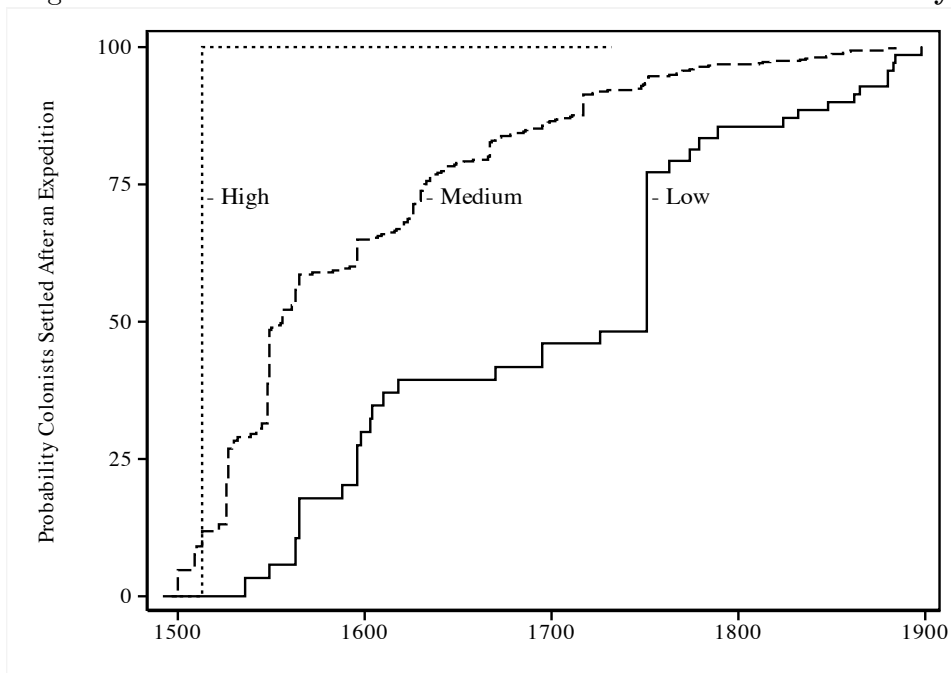
Figure 2: **Rate of Colonial Settlement in the Americas**



Expeditions in the Americas occurred over 333 years, and settlement took almost four centuries, 398 years. Spain launched the first expedition in 1492 and reached the Dominican Republic, Haiti, Cuba and the Bahamas. The United Kingdom launched the last expedition in 1825 into the Yukon province of Canada. The median year of expedition was 1530. On average, colonists settled 81 years following an expedition. The first settlement was in 1500 in the Dominican Republic, and the last was in 1898 in Yukon. The shortest amount of time between expedition and settlement was one year (in Cusco, Peru, for example), and the longest was 360 years (in Tierra Del Fuego, Argentina, for example). By 1550, 28% of the zones were settled. Fifty-five percent of the zones were settled by 1600, 75% by 1700, and 89% by 1800. All zones were settled by 1898. Figure 4.2 demonstrates the distribution of the data.

We expect that colonists settled faster in zones with higher levels of indigenous governance hierarchy. Raw score data appear to support this expectation. Figure 3 uses the Kaplan Meier (1958) nonparametric failure function to display the probability that colonists settled after an expedition in zones with differing levels of governance hierarchy. Settlement occurs fastest (slope is steepest) in zones with high level hierarchy. Settlement occurs less fast in zones with medium level hierarchy, and is slowest in zones with the lowest level hierarchy. The log-rank test for the equality of the function for the three levels

Figure 3: Colonists Settled Faster in Zones with More Hierarchy

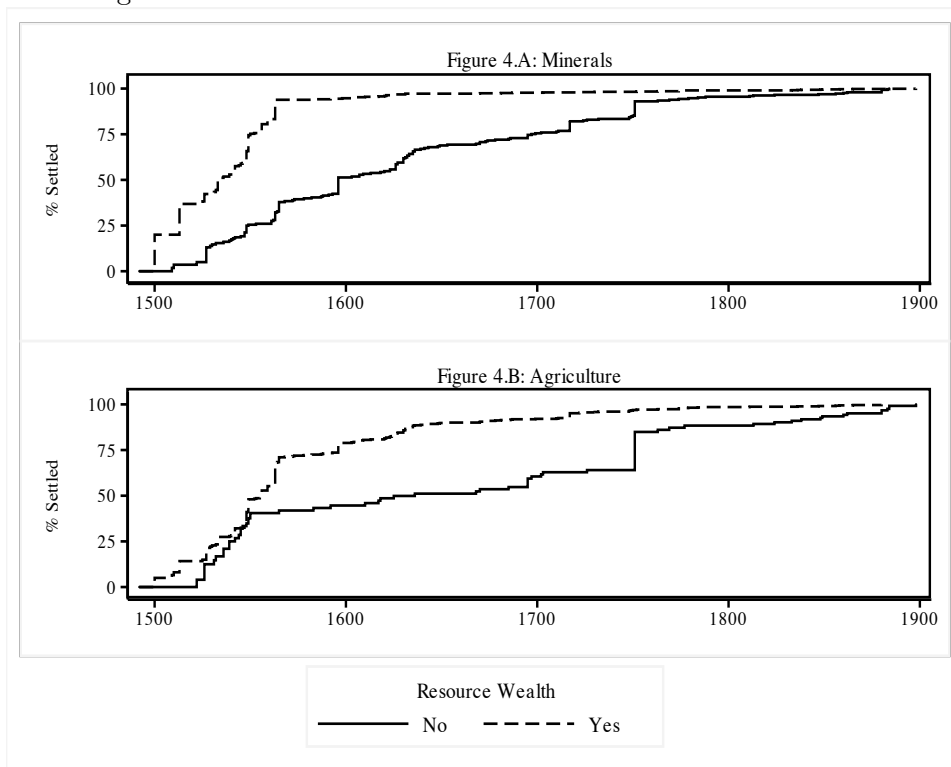


is statistically significant at the 99 percent level. On average, colonists took 22 years to settle in zones with high hierarchy, 88 years to settle in zones with medium-level hierarchy, and 163 years to settle in low-hierarchy regions.²⁹

We also expect that, on average, the promise of resource wealth, especially minerals, agriculture, and to a lesser extent, timber accelerates settlement. Settlement appears to occur faster in zones with minerals than in zones that lack minerals, and it also appears to occur faster in zones with agriculture potential than in zones that lacked agriculture potential. Figure 4 uses the Kaplan Meier nonparametric failure function to demonstrate the likelihood that colonists settled after an expedition in zones with and without minerals (Figure 4.A) and in zones with and without agriculture potential (Figure 4.B). While colonists settle in zones with minerals in 42 years after an expedition on average, colonists settled in regions without minerals in 113 years on average, a difference of 71 years. Similarly, colonists, on average, settle in zones with agriculture potential in 65 years, but in zones without agriculture potential in 141 years, a difference of 76 years. The rate of

²⁹Figure 3 demonstrates that, in the first years of expedition, settlement occurred fast in certain zones that lacked high-level hierarchy. These fast settlements occurred in rich Caribbean countries with medium-level hierarchy where colonists saw the potential for mineral and agriculture wealth.

Figure 4: Resources Affect Rate of Colonial Settlement



settlement is 40 years faster in zones with timber than in zones without timber. Thus, settlement appears to occur faster in zones with resources that were profitable.

Comparatively, settlement does not appear to accelerate as much when other types of resources are present in contrast to when they are absent. The rate of settlement is 25 years faster in zones with fish than in zones that lacked fish, 18 years faster in zones with livestock than in zones without livestock, and 9 years faster in zones with furs than in zones that lacked furs.

While the raw data appear to support the hypotheses that higher governance hierarchy and resource wealth increase the rate of colonial settlement, several factors could confound these relationships. We control for five possible confounding factors. We control for the logarithm of the area of each zone (in square kilometers) to account for the discrepancy in square kilometers across observations.³⁰ We control for the logarithm of distance from the expedition nation of origin to the expedition destination since regions closer to the

³⁰We downloaded spatial data for the Americas at the subnational level from <http://www.gadm.org>. The areas were calculated using the Albers Conical Equal Area Projection.

nation of origin might have received faster settlement.³¹ We also control for the logarithm of elevation³² and mean annual temperature³³ because settler mortality due to diseases might have been less common in regions with higher elevation or lower temperatures.³⁴ Higher settler mortality might have decreased the rate of settlement. Finally, because the Spanish and British were the most prominent settlers in the Americas and might have settled with differing strategies, we code each zone for Spanish expedition and British expedition. We code Spanish expedition as a binary variable where each zone is coded as “1” if its first expedition was Spanish and zero otherwise. We similarly code British expeditions as a binary variable where each zone as “1” if its first expedition came from Great Britain and zero otherwise. Table 1 provides descriptive statistics.

We analyze the influence of increasing indigenous governance hierarchy and the presence of resource wealth on the rate of colonial settlement by modeling the probability of settlement (known as the hazard rate) after an expedition into the zones of the Americas (i). We use a Cox proportional hazards duration model because it is non-parametric, and we cannot assume that settlement increases, decreases or stays constant over time (equation 3):³⁵

$$h(t|X) = h(t)exp\{\beta_1indig_gov_i + \beta_2minerals_i + \beta_3agriculture_i + \beta \times controls + \epsilon_i\} \quad (3)$$

The probability of settlement, represented by the hazard function $h(t|X)$, depends on indigenous governance hierarchy and resource wealth. The model includes a vector of control variables and an error term (ϵ).

4.2.1 Results for rate of settlement

Table 2 demonstrates the influence of indigenous governance on the rate of colonial settlement across the Americas (model 1). The coefficients can be interpreted by calculating them as hazard ratios, or the probability of settlement for each independent variable holding the other variables constant. When an independent variable has a hazard ratio greater

³¹We also downloaded this data from <http://www.gadm.org>

³²The elevation is calculated as the mean elevation for each zone, using the Global Digital Elevation Model (GTOPO30).

³³The data come from Matsuura, Kenji and Cort Willmott. Terrestrial Air Temperature and Precipitation: 1900-2006 Gridded Monthly Time Series, Version 1.01, University of Delaware, <http://climate.geog.udel.edu/climate/>, 2007.

³⁴Data on settler mortality are available for present-day states, not sub-national zones. We nevertheless control for this measure of settler mortality using data from Albouy (2006) and from Acemoglu et al. (2002b). The results remain the same (Appendix Table A1).

³⁵Results stay the same when using a parametric model, the Weibull distribution (Appendix Table A2).

Table 1: **Descriptive Statistics**

Variable	N	Mean	SD	Min	Max
IndigLabor	417	1.18	0.65	0	2
IndigTribute	408	0.81	0.90	0	2
IndigGov	408	1.13	0.60	0	2
Minerals	376	0.46	0.50	0	1
Agriculture	376	0.80	0.40	0	1
Timber	374	0.40	0.49	0	1
Furs	374	0.14	0.35	0	1
Fish	376	0.18	0.38	0	1
Livestock	376	0.37	0.48	0	1
log(Area)	417	9.87	1.85	4.54	14.23
log(Elevation)	417	5.92	1.31	2.30	8.27
Temperature	421	18.79	5.43	4	27
log(Distance)	417	9.10	0.60	2.30	9.77
Spanish Expedition	421	0.84	0.36	0	1
British Expedition	421	0.04	0.20	0	1
Wage Labor	397	0.44	0.50	0	1
Yanaconaje	397	0.09	0.29	0	1
Repartimiento	397	0.25	0.44	0	1
Encomienda	397	0.31	0.46	0	1
Slavery	405	0.23	0.42	0	1

than 1, the independent variable has a positive effect on the dependent variable. When the hazard ratio is less than 1, the independent variable has a negative effect on the dependent variable. In model 1, the hazard ratio of indigenous governance is 2.463. As indigenous governance hierarchy increases, the rate of settlement more than doubles on average. The result is statistically significant at the 99 percent level.³⁶

As expected, resources that are highly profitable accelerated settlement more than other types of resources. Minerals, agriculture potential consistently positively influence the rate of settlement and the effect is statistically significant across specifications. Minerals double the rate of settlement. Agriculture increases it from 49% to 68% depending on the model specification. Timber also increases it from 45% to 56% depending on the model. However, the influence of fish, furs and livestock on the rate of settlement is generally not statistically different from zero.

One might ask whether zones with highly profitable resources and high levels of indigenous governance may increase the rate of settlement most dramatically. These regions may have had the greatest wealth, urbanization, and population densities, when colonists arrived.³⁷ Model 5 includes interaction terms for indigenous governance and mineral wealth, as well as indigenous governance and agriculture. Neither interaction has a statistically significant effect on the rate of settlement.

We find that indigenous governance hierarchy and resource wealth influence the rate of settlement holding five potentially confounding variables constant. There are two important threats to validity, however. First, although the British or Spanish origin of the expedition has no effect on the rate of settlement, certain other colonizers might still have been better equipped to settle than others (France, Netherlands, and so on). Second, over time, colonists might have become better equipped to settle. For example, the United States might have had more technology and know-how to settle its hinterlands in the 1800s than the Spanish in the same hinterlands in the 1500s. Models 2-4 address these threats to validity. Model 2 includes fixed effects for the national origin of every country that launched a first expedition into a zone of the Americas between 1492 and 1898. Model 3 includes fixed effects for each 50-year period from 1450 to 1850. Model 4 includes both sets

³⁶Indigenous governance is measured as an ordinal, three-category variable. The standard deviation of indigenous governance is 0.6, relatively close to one. As a result, we take the liberty to interpret the coefficients in indigenous governance as one unit increases. Results are similar when running the model with separate binary variable for each category of indigenous governance hierarchy (Appendix Table A3). Results are also similar when running the model with indigenous labor organization or indigenous tribute collection instead of indigenous governance hierarchy (Appendix Table A4).

³⁷A control for population is coming soon. We are still coding this.

Table 2: **Indigenous Governance and Resources Accelerate Colonial Settlement**

	Basic Model	Colonist FE	Timing FE	Both FE	Interactions
	(1)	(2)	(3)	(4)	(5)
IndigGov	0.856*** (0.136)	0.888*** (0.135)	0.886*** (0.137)	0.912*** (0.136)	1.059*** (0.245)
Minerals	0.737*** (0.153)	0.712*** (0.155)	0.753*** (0.155)	0.713*** (0.156)	0.519 (0.34)
Agriculture	0.399** (0.164)	0.506*** (0.169)	0.443*** (0.17)	0.524*** (0.172)	0.729** (0.309)
Timber	0.418*** (0.139)	0.445*** (0.14)	0.373*** (0.143)	0.412*** (0.144)	0.461*** (0.143)
Furs	-.155 (0.192)	-.290 (0.198)	-.211 (0.197)	-.340* (0.203)	-.140 (0.193)
Fish	0.336** (0.156)	0.235 (0.165)	0.337** (0.156)	0.202 (0.168)	0.344** (0.158)
Livestock	-.168 (0.13)	-.089 (0.136)	-.175 (0.131)	-.101 (0.136)	-.122 (0.136)
Log(Area)	-.102** (0.042)	-.075* (0.045)	-.098** (0.042)	-.068 (0.046)	-.111*** (0.043)
Log(Elevation)	0.067 (0.055)	0.047 (0.057)	0.045 (0.055)	0.041 (0.056)	0.063 (0.055)
Temperature	0.032** (0.016)	0.049*** (0.019)	0.034** (0.017)	0.051*** (0.019)	0.028* (0.017)
log(Distance)	-.183 (0.115)	0.326* (0.192)	-.078 (0.174)	0.35* (0.19)	-.187 (0.116)
Spanish Expedition	0.232 (0.206)		0.266 (0.218)		0.267 (0.208)
British Expedition	-.174 (0.372)		-.431 (0.382)		-.120 (0.374)
IndigGovXMinerals					0.168 (0.254)
IndigGovXAgriculture					-.391 (0.306)
Obs.	344	344	344	344	344

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

of fixed effects. The results hold in the three additional models and remain statistically significant at the 99 percent level.

4.3 Colonial Institutions

Indigenous governance and resource wealth influence the rate of settlement, but do these variables explain differences in colonial labor institutions? To answer this question, we investigate the influence of indigenous governance across five colonial labor institutions, the dependent variables: *wage labor*, *yanaconaje*, *repartimiento*, *encomienda*, and *slavery* of indigenous peoples. We coded these institutions within fifty years of each expedition.

Wage labor and *yanaconaje* are the least hierarchical colonial labor institutions. Wage labor represents free labor, based on direct, sometimes contractual, agreements between laborer and employer. Wage labor did not involve coercion, quotas or intervention of crown officials, and was present in 40% of the zones in the Americas.³⁸ *Yanaconaje* refers to the situation where indigenous peoples who were not associated with specific communities were in the service of colonists.³⁹ They worked as independent workers, sometimes had more technical training (mining), and could not be forced to move. This form of labor was rare, covering 8% of zones.

Repartimiento, *encomienda*, and slavery of indigenous peoples were far more hierarchical than wage labor or *yanaconaje*. *Repartimiento* was a system of quotas where the colonists had to petition crown officials for workers. The workers were allocated to colonists for set periods of time and not paid for their efforts.⁴⁰ *Repartimientos* were found in 25% of zones. We code *encomienda* when indigenous peoples are specifically assigned to a landowner as unpaid labor or providers of goods. *Encomiendas* appear in 29% of zones. Finally, we code the presence of slavery of indigenous peoples. Colonists maintained indigenous slaves in 20% of zones.

The five institutions can be mapped onto a continuum where wage labor represents the least hierarchical, then *yanaconaje*, *repartimiento*, *encomienda*, and finally slavery of indigenous peoples. The main independent variable of interest is indigenous governance. We expect that zones with higher levels of hierarchy in indigenous governance are less likely to have wage labor or *yanaconaje*, but zones with higher levels of hierarchy in indigenous

³⁸It should be noted, however, that indigenous or other laborers at the time did not constitute a working class in the sense of being dependent solely on wages. Our categorization of colonial labor is based on Villamarín and Villamarín (1975).

³⁹This was the term for them in the Inca empire. In Mexico, they were referred to as *naborías*.

⁴⁰In central Mexico, this was known as *cuatequiltl* and in Ecuador, Peru, and Bolivia, it was known as *mita*.

governance are more likely to have repartimientos, encomiendas, or indigenous slavery, all forms of labor where laborers did not receive payment.

Because a zone can have more than one labor institution, we analyze the influence of increasing indigenous governance hierarchy and resource wealth on the different colonial institutions by modeling the probability of each colonial institution separately in each zone i . We use a logistic (logit) regression, equation 4:

$$\text{logit}(\pi_i) = \beta_0 + \beta_1 \text{indig_gov}_i + \beta_2 \text{minerals}_i + \beta_3 \text{agriculture}_i + \beta \times \text{controls} + \epsilon_i \quad (4)$$

The probability depends on indigenous governance hierarchy and resource wealth. The model includes the same vector of control variables as the duration model and an error term (ϵ).⁴¹

4.3.1 Results for colonial institutions

Consistent with our expectations, we find that a higher level of hierarchy in indigenous governance reduces the probability of wage labor (model 1). The result is statistically significant at the 99 percent level. Higher levels of hierarchy also reduce yanaconaje, but the effect is not statistically significant (model 2). The null effect of institutions on yanaconaje may be explained by the fact that indigenous peoples involved in yanaconaje had fewer exit options than wage laborers. We also find that a higher level of indigenous governance increases the likelihood of repartimiento (model 3), encomienda (model 4), and slavery of indigenous peoples (model 5). These results are significant at the 99 percent confidence level.⁴²

To interpret the logit coefficients in Table 3, it is useful to see the marginal effects of indigenous governance on each dependent variable (figure 5). Based on model 1 in Table 3, the probability of wage labor in zones with low levels of hierarchy is 72%.⁴³ The probability declines to 44% in zones with medium levels of hierarchy, and declines further to 19% in zones with high levels of hierarchy. The probability of yanaconaje when hierarchy is low is 9%. It declines slightly to 5% in zones with medium hierarchy, and it declines further to 3% when the indigenous governance hierarchy level is high.

In contrast to wage labor and yanaconaje, the probability of repartimiento, encomienda and slavery of indigenous peoples increases as indigenous governance hierarchy increases. The probability of repartimiento when hierarchy is low is 2%. It increases in zones with

⁴¹The results also hold controlling for settler mortality (Appendix Tables A5 and A6).

⁴²Results are also similar when running the model with indigenous labor organization or indigenous tribute collection instead of indigenous governance hierarchy (Appendix Table A7 and A8).

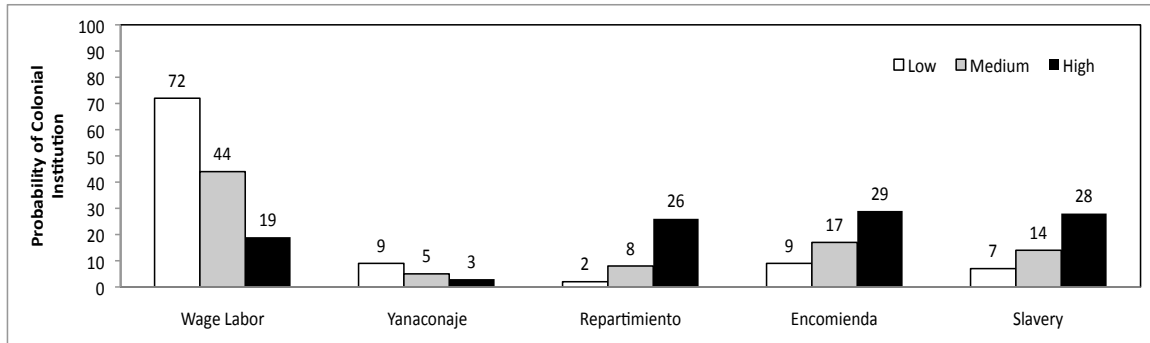
⁴³These estimates were generated using Clarify (King et al 2001).

Table 3: **Indigenous Governance and Resources Affect Colonial Labor**

	Wage Labor	Yanaconaje	Repartimiento	Encomienda	Slavery
	(1)	(2)	(3)	(4)	(5)
IndigGov	-1.231*** (0.281)	-.607 (0.414)	1.461*** (0.369)	0.723*** (0.267)	0.853*** (0.305)
Minerals	-.865** (0.382)	-1.439** (0.6)	0.411 (0.454)	0.58 (0.395)	0.341 (0.398)
Agriculture	-2.004*** (0.419)	2.687** (1.121)	1.328** (0.592)	1.378*** (0.438)	-.431 (0.459)
Timber	0.083 (0.348)	1.187** (0.558)	0.166 (0.469)	-.946** (0.385)	-.842** (0.426)
Furs	0.058 (0.466)	1.880*** (0.716)	0.593 (0.662)	-.770 (0.537)	-1.820*** (0.503)
Fish	0.403 (0.419)	0.211 (0.538)	-.318 (0.545)	-.288 (0.431)	0.702* (0.382)
Livestock	0.819** (0.337)	0.727 (0.499)	-1.057** (0.441)	-.276 (0.345)	1.606*** (0.338)
Log(Area)	0.083 (0.108)	0.112 (0.154)	-.329** (0.142)	-.538*** (0.122)	0.313*** (0.119)
Log(Elevation)	0.128 (0.141)	0.021 (0.205)	0.631*** (0.218)	-.210 (0.147)	0.201 (0.168)
Temperature	-.189*** (0.04)	0.159*** (0.056)	0.264*** (0.055)	-.048 (0.04)	-.076* (0.041)
log(Distance)	-5.305*** (1.443)	-.187 (1.394)	4.833** (2.170)	7.516*** (1.707)	2.480* (1.331)
Spanish Expedition	1.271** (0.542)	2.510*** (0.89)	0.029 (1.007)	2.283** (1.101)	-2.096*** (0.544)
British Expedition	-.302 (0.822)				-.744 (0.748)
Obs.	342	342	342	342	349

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 5: **Effects of Indigenous Governance on Colonial Labor**



medium levels of hierarchy to 8% , and increases to 26% in zones with high levels of hierarchy. Similarly, the probability of encomienda is lowest in zones with low levels of hierarchy, at 9%. It increases with medium levels of hierarchy to 17%, and it increases to 29% with high levels of hierarchy. Finally, as with encomienda and repartimiento, zones with low hierarchy have a 7% probability of indigenous slavery. The probability increases to 14% in zones with medium hierarchy and increases to 28% in zones with high levels of hierarchy. Thus, increasing hierarchy of indigenous governance institutions predicts the presence of colonial institutions that rely on hierarchies and are able to transfer more of the surplus to colonists.

The theory also predicts that zones with the most highly profitable resources, meaning minerals and agriculture potential, are more likely to rely on hierarchies than on wage labor since the cost of building institutions is offset by the potential profit from the resources. Consistent with our expectation, both minerals and agriculture reduce the likelihood of wage labor. The coefficients are consistently negative and statistically significant at conventional levels.

The logit model presented here faces similar threats to validity to the duration model presented above. Some colonists may be inclined to build some institutions over others due to their cultures or crown policies. For example, Table 3 indicates that zones with Spanish expeditions are more likely to have wage labor, yanacanje and encomiendas, but less likely to have indigenous slavery. Spanish settlers may have seized opportunities for yanacanje and encomienda because the Spanish crown outlawed slavery. To ensure these results are not an artifact of the culture or national policies behind different expeditions, we ran the models in Table 3 including fixed effects for all nations of origins involved in

expeditions (Appendix Table A9). The results hold despite the inclusion of these fixed effects.

Combined, these findings support the hypotheses that indigenous governance institutions and resource wealth influence early colonial institution building. When indigenous governance institutions are more hierarchical or when resource wealth is high, colonists settle faster. When indigenous institutions are less hierarchical, colonists build less hierarchical labor institutions. But when institutions are less hierarchical and resource wealth is high, colonists built more hierarchical labor institutions. The hypotheses are supported in the raw data, and after accounting for potentially confounding variables. We find that indigenous governance hierarchy and resource wealth influence the rate of settlement and type of colonial labor institution holding five potentially-confounding variables constant, including fixed effects for the national origin of the expeditions, and including fixed effects for the time period in which the expedition occurred.

5 Conclusion

Our findings suggest that a key determinant of institutional development is the existence of structures that allow the implementation of the chosen policies of those ruling the society. The policy of exploitation was not feasible unless a structure existed or was created to implement such exploitation and harness labor. Labor and tribute institutions already present in the colonized regions in conjunction with the resources these regions offered, influenced the indigenous response to colonial policies, and thus the types of colonial institutional outcomes.

An open question that is beyond the scope of this paper is what are the conditions and processes occurring since early history that led to state-level societies and political hierarchies in some regions of the Americas while not in others. Our findings point to physical geography and the relative abundance of resources valued by specific societies at specific periods in history as key factors leading to institutional divergence.

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Appendix Table A1: **Results Hold Controlling for Settler Mortality**

	Settler Mortality (AJR)	Settler Mortality (Albouy)
	(1)	(2)
IndigGov	0.878*** (0.136)	0.838*** (0.138)
Minerals	0.724*** (0.155)	0.607*** (0.159)
Agriculture	0.528*** (0.169)	0.402** (0.182)
Timber	0.246* (0.143)	0.355** (0.156)
Furs	0.023 (0.2)	-.054 (0.201)
Fish	0.335** (0.163)	0.355** (0.162)
Livestock	-.341** (0.135)	-.378*** (0.137)
Log(Area)	-.167*** (0.047)	-.215*** (0.049)
Log(Elevation)	0.033 (0.058)	0.062 (0.061)
Temperature	0.004 (0.02)	0.04** (0.018)
log(Distance)	-.228** (0.11)	-.205* (0.109)
Spanish Expedition	-.076 (0.229)	0.107 (0.221)
British Expedition	-.357 (0.38)	-.084 (0.373)
log(SettlMort) (AJR)	0.414** (0.166)	
log(SettlMort) (Albouy)		0.003 (0.127)
Obs.	329	322

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A2: **Results Hold Using Weibull Model**

	Basic Model	Colonist FE	Timing FE	Both FE	Interactions
	(1)	(2)	(3)	(4)	(5)
IndigGov	0.865*** (0.135)	0.894*** (0.135)	0.897*** (0.136)	0.924*** (0.136)	0.896*** (0.239)
Minerals	0.767*** (0.149)	0.746*** (0.151)	0.771*** (0.151)	0.752*** (0.153)	0.607* (0.34)
Agriculture	0.445*** (0.158)	0.509*** (0.162)	0.562*** (0.166)	0.599*** (0.167)	0.566* (0.301)
Timber	0.416*** (0.136)	0.411*** (0.138)	0.407*** (0.142)	0.427*** (0.143)	0.428*** (0.141)
Furs	-.178 (0.191)	-.277 (0.196)	-.296 (0.197)	-.399* (0.204)	-.173 (0.192)
Fish	0.242 (0.154)	0.206 (0.161)	0.249 (0.152)	0.181 (0.163)	0.251 (0.155)
Livestock	-.050 (0.124)	-.013 (0.129)	-.078 (0.125)	-.044 (0.129)	-.038 (0.128)
Log(Area)	-.147*** (0.042)	-.129*** (0.046)	-.145*** (0.042)	-.120*** (0.046)	-.148*** (0.043)
Log(Elevation)	0.083 (0.054)	0.063 (0.056)	0.064 (0.054)	0.059 (0.055)	0.08 (0.055)
Temperature	0.012 (0.016)	0.02 (0.018)	0.01 (0.017)	0.019 (0.019)	0.01 (0.016)
log(Distance)	-.136 (0.103)	0.199 (0.182)	0.112 (0.141)	0.26 (0.171)	-.144 (0.104)
Spanish Expedition	0.275 (0.2)		0.275 (0.214)		0.285 (0.202)
British Expedition	-.210 (0.356)		-.574 (0.369)		-.184 (0.358)
IndigGovXMinerals					0.131 (0.254)
IndigGovXAgriculture					-.132 (0.296)
Obs.	344	344	344	344	344

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A3: **Greater Hierarchy Increases the Rate of Settlement**

	Low Hierarchy	Medium Hierarchy	High Hierarchy
	(1)	(2)	(3)
High IndigGov	-.478** (0.194)		
Medium IndigGov		-.385*** (0.128)	
Low IndigGov			1.147*** (0.174)
Minerals	0.856*** (0.152)	0.948*** (0.15)	0.809*** (0.152)
Agriculture	0.586*** (0.168)	0.911*** (0.166)	0.687*** (0.159)
Timber	0.493*** (0.142)	0.408*** (0.14)	0.346** (0.138)
Furs	-.047 (0.196)	0.004 (0.196)	-.103 (0.19)
Fish	0.258* (0.156)	0.275* (0.155)	0.346** (0.156)
Livestock	-.027 (0.13)	-.142 (0.132)	-.269** (0.133)
Log(Area)	-.149*** (0.041)	-.138*** (0.041)	-.093** (0.042)
Log(Elevation)	0.126** (0.054)	0.123** (0.054)	0.069 (0.055)
Temperature	0.018 (0.016)	0.023 (0.016)	0.034** (0.016)
log(Distance)	-.160 (0.118)	-.158 (0.113)	-.185* (0.111)
Spanish Expedition	0.301 (0.208)	0.132 (0.209)	0.079 (0.207)
British Expedition	-.413 (0.376)	-.956** (0.374)	-.702* (0.363)
Obs.	344	344	344

Coefficients reported reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A4: **Hierarchy in Indigenous Labor Tribute and the Rate of Settlement**

	IndigLabor	IndigTribute
	(1)	(2)
IndigLabor	0.675*** (0.114)	
IndigTribute		0.66*** (0.086)
Minerals	0.804*** (0.151)	0.831*** (0.152)
Agriculture	0.488*** (0.16)	0.602*** (0.158)
Timber	0.389*** (0.138)	0.376*** (0.138)
Furs	-.042 (0.189)	-.013 (0.192)
Fish	0.352** (0.156)	0.343** (0.158)
Livestock	-.097 (0.126)	-.231* (0.131)
Log(Area)	-.096** (0.04)	-.088** (0.041)
Log(Elevation)	0.092* (0.054)	0.039 (0.055)
Temperature	0.038** (0.016)	0.062*** (0.017)
log(Distance)	-.177 (0.115)	-.210* (0.11)
Spanish Expedition	0.291 (0.203)	0.099 (0.202)
British Expedition	-.208 (0.378)	-.529 (0.364)
Obs.	351	344

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A5: **Results Hold Controlling for Settler Mortality (AJR)**

	Wage Labor	Yanaconaje	Repartimiento	Encomienda	Slavery
	(1)	(2)	(3)	(4)	(5)
IndigGov	-1.219*** (0.281)	-.918* (0.47)	1.526*** (0.374)	0.709*** (0.274)	0.768** (0.327)
Minerals	-.830** (0.391)	-1.344** (0.627)	0.459 (0.459)	0.531 (0.415)	0.193 (0.438)
Agriculture	-2.034*** (0.425)	2.664** (1.187)	1.321** (0.608)	1.427*** (0.447)	-.630 (0.491)
Timber	0.185 (0.361)	1.229** (0.605)	0.154 (0.485)	-1.103*** (0.398)	-1.009** (0.462)
Furs	-.091 (0.498)	2.195*** (0.8)	0.471 (0.645)	-.508 (0.588)	-1.365** (0.542)
Fish	0.445 (0.422)	0.437 (0.586)	-.318 (0.557)	-.287 (0.439)	0.772* (0.408)
Livestock	0.792** (0.342)	0.923 (0.566)	-.889* (0.455)	-.475 (0.364)	1.608*** (0.369)
Log(Area)	0.057 (0.113)	0.401** (0.2)	-.376** (0.148)	-.549*** (0.127)	0.376*** (0.132)
Log(Elevation)	0.185 (0.147)	0.063 (0.237)	0.653*** (0.226)	-.278* (0.157)	0.155 (0.171)
Temperature	-.136*** (0.051)	-.059 (0.088)	0.353*** (0.075)	-.134*** (0.051)	-.266*** (0.062)
log(Distance)	-5.689*** (1.485)	2.831 (2.426)	3.019 (2.231)	7.622*** (1.877)	3.146** (1.437)
Spanish Expedition	1.672*** (0.605)	1.447 (1.070)	0.761 (1.066)	1.882 (1.193)	-3.754*** (0.762)
British Expedition	-.335 (0.834)				-.404 (0.868)
log(SettlMort) (AJR)	-.680 (0.421)	2.653*** (0.98)	-1.296** (0.648)	1.283*** (0.494)	2.718*** (0.653)
Obs.	337	337	337	337	344

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A6: **Results Hold Controlling for Settler Mortality (Albouy)**

	Wage Labor	Yanaconaje	Repartimiento	Encomienda	Slavery
	(1)	(2)	(3)	(4)	(5)
IndigGov	-1.352*** (0.292)	-.931* (0.476)	1.398*** (0.374)	0.842*** (0.282)	0.893*** (0.329)
Minerals	-.742* (0.41)	-1.488** (0.656)	0.244 (0.472)	0.508 (0.428)	0.328 (0.433)
Agriculture	-1.247*** (0.462)	1.896 (1.195)	1.686* (0.893)	0.814* (0.495)	-.752 (0.497)
Timber	-.218 (0.402)	1.417** (0.645)	0.327 (0.493)	-1.009** (0.426)	-.938** (0.452)
Furs	-.537 (0.524)	2.359*** (0.827)	0.586 (0.658)	-.447 (0.562)	-1.412*** (0.528)
Fish	0.619 (0.438)	0.389 (0.589)	-.352 (0.549)	-.304 (0.432)	0.693* (0.391)
Livestock	1.139*** (0.357)	0.831 (0.569)	-.983** (0.448)	-.606* (0.359)	1.519*** (0.354)
Log(Area)	0.165 (0.121)	0.377* (0.201)	-.371** (0.146)	-.608*** (0.129)	0.357*** (0.126)
Log(Elevation)	0.216 (0.151)	0.079 (0.239)	0.628*** (0.22)	-.275* (0.156)	0.138 (0.17)
Temperature	-.182*** (0.044)	-.064 (0.09)	0.279*** (0.057)	-.076* (0.042)	-.183*** (0.056)
log(Distance)	-5.292*** (1.514)	2.668 (2.458)	3.523 (2.323)	6.085*** (1.800)	2.679* (1.385)
Spanish Expedition	1.596*** (0.581)	1.411 (1.101)	0.405 (1.044)	1.901* (1.123)	-3.050*** (0.659)
British Expedition	-.770 (0.846)				-.472 (0.802)
log(SettlMort) (Albouy)	-.714*** (0.25)	2.807*** (1.028)	-.445 (0.342)	0.558** (0.268)	1.712*** (0.517)
Obs.	330	330	330	330	337

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A7: **Hierarchy in Indigenous Labor and Colonial Labor**

	Wage Labor	Yanaconaje	Repartimiento	Encomienda	Slavery
	(1)	(2)	(3)	(4)	(5)
IndigLabor	-.942*** (0.241)	-.494 (0.374)	1.161*** (0.338)	0.586** (0.253)	0.717*** (0.275)
Minerals	-.920** (0.368)	-1.487** (0.596)	0.778* (0.444)	0.62 (0.384)	0.378 (0.389)
Agriculture	-2.085*** (0.407)	2.608** (1.112)	1.532*** (0.587)	1.449*** (0.432)	-.341 (0.446)
Timber	0.156 (0.34)	1.188** (0.569)	-.109 (0.459)	-1.016*** (0.38)	-.916** (0.418)
Furs	-.138 (0.455)	1.877*** (0.705)	0.585 (0.651)	-.615 (0.53)	-1.765*** (0.498)
Fish	0.333 (0.417)	0.259 (0.542)	-.382 (0.534)	-.213 (0.426)	0.752** (0.382)
Livestock	0.693** (0.321)	0.631 (0.494)	-.816* (0.423)	-.269 (0.341)	1.688*** (0.335)
Log(Area)	0.095 (0.107)	0.09 (0.154)	-.319** (0.134)	-.574*** (0.121)	0.295** (0.118)
Log(Elevation)	0.102 (0.138)	0.008 (0.201)	0.566*** (0.204)	-.195 (0.145)	0.23 (0.165)
Temperature	-.199*** (0.04)	0.151*** (0.057)	0.27*** (0.054)	-.045 (0.04)	-.074* (0.041)
log(Distance)	-5.736*** (1.439)	-.221 (1.179)	5.742*** (2.137)	8.237*** (1.757)	2.736** (1.334)
Spanish Expedition	1.311** (0.543)	2.250** (0.924)	0.019 (1.018)	1.446 (1.098)	-2.156*** (0.542)
British Expedition	-.339 (0.82)				-.698 (0.754)
Obs.	348	333	333	333	355

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A8: **Hierarchy in Indigenous Tribute and Colonial Labor**

	Wage Labor	Yanaconaje	Repartimiento	Encomienda	Slavery
	(1)	(2)	(3)	(4)	(5)
IndigTribute	-.847*** (0.192)	-.650** (0.292)	1.555*** (0.314)	0.195 (0.166)	1.210*** (0.246)
Minerals	-1.126*** (0.38)	-1.531** (0.606)	0.619 (0.453)	0.822** (0.385)	0.397 (0.414)
Agriculture	-2.398*** (0.421)	2.564** (1.076)	1.911*** (0.635)	1.657*** (0.426)	-.493 (0.468)
Timber	-.021 (0.347)	1.219** (0.563)	0.227 (0.498)	-1.016*** (0.386)	-.584 (0.45)
Furs	-.055 (0.472)	1.924*** (0.686)	0.657 (0.653)	-.568 (0.535)	-2.060*** (0.523)
Fish	0.486 (0.414)	0.189 (0.565)	-.311 (0.58)	-.192 (0.423)	0.574 (0.402)
Livestock	0.762** (0.333)	0.807 (0.515)	-.923** (0.456)	-.277 (0.343)	2.007*** (0.385)
Log(Area)	0.069 (0.108)	0.084 (0.159)	-.302** (0.144)	-.563*** (0.12)	0.411*** (0.126)
Log(Elevation)	0.163 (0.145)	0.078 (0.212)	0.408* (0.215)	-.174 (0.147)	0.046 (0.167)
Temperature	-.226*** (0.042)	0.121** (0.059)	0.357*** (0.067)	-.046 (0.04)	-.053 (0.043)
log(Distance)	-5.154*** (1.424)	-.203 (1.075)	3.049 (2.270)	7.717*** (1.716)	2.899** (1.415)
Spanish Expedition	1.331** (0.543)	2.594*** (0.992)	-.406 (1.048)	1.560 (1.101)	-2.467*** (0.571)
British Expedition	-.335 (0.816)				-.643 (0.754)
Obs.	342	327	327	327	349

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix Table A9: Results Hold with Colonist Origin Fixed Effects

	Wage Labor	Yanaconaje	Repartimiento	Encomienda	Slavery
	(1)	(2)	(3)	(4)	(5)
IndigGov	-1.385*** (0.297)	-.678 (0.421)	1.435*** (0.373)	0.663** (0.27)	0.708** (0.316)
Minerals	-.846** (0.391)	-1.339** (0.6)	0.445 (0.458)	0.617 (0.395)	0.554 (0.422)
Agriculture	-2.122*** (0.439)	2.631** (1.140)	1.320** (0.594)	1.360*** (0.439)	-.479 (0.459)
Timber	-.044 (0.366)	1.100* (0.57)	0.135 (0.473)	-.967** (0.384)	-1.285*** (0.463)
Furs	0.367 (0.491)	2.106*** (0.752)	0.679 (0.685)	-.612 (0.551)	-1.176** (0.515)
Fish	0.594 (0.467)	0.425 (0.58)	-.225 (0.569)	-.166 (0.438)	1.404*** (0.442)
Livestock	0.735** (0.362)	0.597 (0.518)	-1.126** (0.46)	-.359 (0.349)	1.106*** (0.366)
Log(Area)	-.015 (0.12)	0.055 (0.165)	-.344** (0.144)	-.572*** (0.124)	0.036 (0.137)
Log(Elevation)	0.124 (0.144)	0.011 (0.209)	0.614*** (0.218)	-.213 (0.146)	0.084 (0.179)
Temperature	-.226*** (0.05)	0.134** (0.061)	0.254*** (0.057)	-.061 (0.041)	-.219*** (0.056)
log(Distance)	-5.379*** (1.466)	-.571 (2.138)	4.899** (2.184)	7.593*** (1.734)	3.135** (1.419)
Spanish Expedition	0.142 (0.895)	1.825* (1.108)	-.283 (1.117)	0.339 (1.306)	-5.595*** (1.024)
British Expedition	-1.731 (1.249)				-5.449*** (1.351)
Obs.	336	308	308	308	343

Coefficients reported with standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.