Fiscal Legibility and State Development: Evidence from Colonial Mexico*

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Abstract

We examine how fiscal legibility, the ability of a central government to observe local economic conditions for the purposes of taxation, shapes political centralization. When a ruler is unable to observe economic conditions, it can be preferable to grant autonomy to local intermediaries in charge of tax collection to encourage better performance. As a ruler's ability to observe local conditions improves, so does the monitoring and accurate sanctioning of underperforming intermediaries. This enables the ruler to tighten control over tax collection, retain more revenue, and establish a more direct state presence. This shift also encourages the ruler to invest in further enhancing fiscal legibility over the longer term. We present a dynamic principal-agent model to illustrate this argument and provide empirical support for the theory using subnational panel data on local political institutions in colonial Mexico. We focus on the effects of a technological innovation that drastically improved the Spanish Crown's ability to observe local economic production: the introduction of the patio process to refine silver. We show that the transition to direct rule differentially increased in mining districts following this technological innovation and that these areas saw greater investments in improving state informational capacity over the long term.

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1. Introduction

Capable and centralized states tend to deliver better economic and political outcomes for the citizenry over the long term (e.g. Boone 1994; Mamdani 1996; Lange 2004; Gennaioli and Rainer 2007; Michalopoulos and Papaioannou 2013; Osafo-Kwaako and Robinson 2013; Dincecco and Katz 2014). However, building state capacity is costly, and many central authorities lack the willingness or ability to seize political control from local elites in the periphery. Despite the potential long-term benefits of political centralization, central authorities often rely on indirect forms of rule that allow local elites to retain considerable political and even military autonomy from the center. These arrangements offer a number of advantages for central rulers, allowing them to extend political authority and extract at least some revenue from areas that are distant, underdeveloped, or even physically impenetrable (e.g. Gerring et al. 2011; Garfias and Sellars n.d.).

When will a central ruler benefit from transitioning to more direct forms of rule? A crucial consideration is the state's level of fiscal legibility: the ability of central authorities to independently observe, measure, and assess specific populations, their wealth, and activities for the purposes of taxation and social control (e.g., Kain and Baigent 1992; Scott 1998; Lee and Zhang 2017). This type of informational capacity allows rulers to contend with "exceptionally complex, illegible, and local social practices [...] and [create] a standard grid whereby [they can] be centrally recorded and monitored" (Scott 1998, p. 2). Where the state is unable to observe local conditions, it can be advantageous to delegate the task of controlling and administering territory to regional elites who have better access to information about the local environment (e.g., Levi 1988; Balán et al. 2021). However, reliance on local authorities is costly, and usually requires the central government to sacrifice both revenue and decision-making autonomy as part of the bargain with provincial elites. As central authorities gain the ability to independently monitor and police activity across the territory, the bargaining power of local potentates declines, and the state can exert greater control over these intermediaries and the population as a whole.

Like other dimensions of state capacity, building fiscal legibility is difficult, costly, and constrained

by geographic, social, technological, political, and other factors. In this paper, we examine how an exogenous shift in fiscal legibility — a sudden increase in the state's ability to directly observe local economic conditions — influences state centralization, the division of resources between local elites and the central government, and the central government's incentive to invest in further enhance legibility over the longer term.

We develop a dynamic principal-agent model to illustrate how the optimal contract for a ruler to offer intermediaries depends on the existing quality of independent information on local conditions available to central authorities. When the ruler is unable to observe economic conditions in the periphery, and thus to monitor local intermediaries, exerting tight control over them becomes prohibitively costly. It is thus preferable to encourage their effort in revenue collection exclusively via high compensation through indirect forms of rule. Under indirect rule, the ruler has little incentive to invest in improving future legibility: intermediaries' effort is encouraged only through high compensation, so a marginal improvement in the ruler's ability to monitor shirking provides no short-term benefit. This can lock peripheral areas into an equilibrium of low fiscal legibility and indirect rule over the long term.

If fiscal legibility exogenously improves, however, it becomes easier for central authorities to identify whether a decline in tax revenue is due to poor conditions or poor intermediary effort. This enables the ruler to centralize control and credibly threaten to dismiss intermediaries who shirk on their duties. Incorporating a threat of dismissal under more direct forms of rule pushes intermediaries to exert effort under less generous compensation schemes, and allows the ruler to retain more revenue for the central government. Direct rule, in turn, encourages central authorities to invest in improving fiscal legibility in a district over time. As it becomes easier to identify when intermediaries are shirking, the ruler can retain a greater share of the surplus through exerting tighter control over officials. An exogenous increase in legibility can therefore encourage political centralization and state development over the longer term.

We provide empirical support for the theory using subnational data on state centralization in colonial Mexico around the time of a major technological innovation in silver mining. In the early years of colonial rule, the Spanish Crown relied on the *encomienda*, an institution of indirect rule through which elites were granted broad rights to extract tribute and labor in exchange for maintaining local political order and collecting revenue for the government (e.g., Zavala 1973; Knight 2002; García Martínez 2011). Over time, the Crown sought to centralize authority, replacing *encomiendas* with *corregimientos*, an institution of direct rule through which local intermediaries were hired and fired by the center and paid a set wage. The timing of this transition differed across space. Some areas moved to direct rule within a generation of the Conquest, while others remained in *encomienda* for the duration of the colonial period.

We examine the short- and longer-term effects of an exogenous increase in fiscal legibility in silver mining districts on the trajectory of state centralization. During the 1550s, the patio process, a technology to refine silver, was discovered. This technique relied on mercury amalgamation to extract pure silver from mined ores, reducing the cost of processing the silver sulfides common to the Americas (Brading and Cross 1972; Bakewell 1984; Guerrero 2017). A key advantage for the Crown was that the new amalgamation process produced silver using mercury in a well-known ratio. Because mercury was only produced at scale in a handful of locations worldwide — and not in Mexico — the Crown was able to rapidly institute and enforce a monopoly over the sale and distribution of this important input. This gave central authorities a direct and reliable new way to observe fluctuations in mining production and the nearby local economy. The patio process and its reliance on state-provided mercury became to the legibility of local production what "surnames and the rolls of names that they generated were to the legibility of the population" and "what uniform measurement and the cadastral map were to the legibility of real property." (Scott 1998, p. 80).

Using a differences-in-differences empirical strategy, we show that this sudden increase in fiscal legibility in mining districts led to an acceleration in political centralization. Following the introduction of the patio process in the 1550s, the proportion of *encomiendas* that transitioned to

direct rule was around 15 percentage points higher in mining relative to non-mining districts and relative to before the widespread use of silver amalgamation. This result is robust across numerous empirical specifications. The implied effect is substantively large, corresponding to two-thirds of a within-district standard deviation in direct rule over the period of analysis. Consistent with our theory, we further show that the effect of this legibility shock was greater in areas where authorities would have had less prior access to information about fluctuations in economic production and lower where the threat of rebellion would have increased the transition cost of moving to direct rule. We present indirect evidence suggesting that the differential acceleration in centralization in mining areas can be traced to the increase in fiscal legibility after the introduction of the patio process, as opposed to higher revenue potential, by examining large revenue shocks to another important commodity, cochineal dye, which increased the profitability of production but did not affect the observability of economic activity and thus did not lead to political centralization.

We finally present evidence on an important prediction that emerges from our model: an exogenous increase in the quality of independent information available to the central government also increases the ruler's incentive to endogenously invest in future fiscal legibility to improve the quality of monitoring. As the Crown gained control of new territory in colonial Mexico, it established a network of *Cajas Reales*—royal treasuries—to monitor tax collection and administer regional royal funds. We show that, after the introduction of the patio process, the strategic establishment of new treasuries led to a differential and sizable reduction in the least-cost walking time to the nearest treasury in mining relative to non-mining districts over the next 200 years. This early shock to fiscal legibility thus had an important and sustained impact on state development in colonial Mexico.

This article contributes to several literatures related to political centralization and state development. Existing work on the politics of state centralization has primarily focused on other determinants of state development, including demography (e.g., Carneiro 1970; Herbst 2000; Fenske 2013), external threat (e.g., Tilly 1990; Gennaioli and Voth 2015; Koyama, Moriguchi, and Sng 2018), the preexisting social structure or political institutions (e.g., Boone 2003; Gerring et al. 2011),

and domestic conflict (e.g., Slater 2010; Garfias and Sellars n.d.).[1] We highlight the complementary role that fiscal legibility can play in the transition to direct rule by focusing on the agency problems inherent in colonial administrations.[2]

Scholars have noted how asymmetric information, the high cost of monitoring, conflicts of interest, and commitment problems can create agency costs for central rulers and shape institutional development (Ma 2011; Johnson and Koyama 2014; Sng 2014; Gailmard 2017; 2019). Our theory specifically builds on the work of Mayshar, Moav, and Neeman (2017), who examine how the optimal contract between a ruler and local intermediaries in charge of tax collection depends on the observability or "transparency" of local economic production. We extend their model to consider how the ruler's choice of contract — better incentives or tighter monitoring — in turn influences his incentive to invest in improving future fiscal legility. Scholars of bureaucratic politics have noted that increasing oversight and control over agents does not always lead to an improvement in their performance (e.g., Gailmard and Patty 2012; Patty and Turner 2021). Where fiscal legibility is low, a ruler is often better off encouraging effort through positive incentives given the high cost of monitoring officials, but reliance on this type of contract reduces his willingness to incur costs to improve his informational capacity going forward. This illustrates why some areas of the periphery may end up trapped under indirect forms of rule over the long term and also why a single shock that increases fiscal legibility can set a district on the path to centralization and encourage the development of informational capacity over the long term.

Our work also makes an empirical contribution to this literature. Much of the existing evidence on the consequences of fiscal legibility for state development comes from detailed analytic narratives and case studies (e.g., Ma 2011; Johnson and Koyama 2014; Mayshar, Moav, and Neeman 2017;

[1] There is a related extensive empirical literature that associates indirect rule with negative long-term economic and political outcomes (e.g. Lange 2004; Banerjee and Iyer 2005; Hariri 2012; Acemoglu et al. 2014; Lee 2019).

[2] We distinguish between our focus on the process of state centralization and the prior emergence of state institutions (e.g., Olson 1993; Boix 2015; Dal Bo, Hernández, and Mazzuca 2015; Scott 2017; Mayshar, Moav, and Pascali 2020) or the initial process of territorial control over a region (e.g. Spruyt 1996; Pierskalla, De Juan, and Montgomery 2017; Acharya and Lee 2018).

Ma and Rubin 2019; Slantchev and Kravitz 2019; Stasavage 2020) or is based primarily on cross-sectional data (e.g., Sng 2014; Ahmed and Stasavage 2020; Huning and Wahl 2020). The features of our setting allow us to study how a shock to fiscal legibility shapes the trajectory of state development on the sub-national level over the short and long term (see also Sánchez de la Sierra n.d.).[3]

Our findings on the self-reinforcing nature of fiscal legibility — how an initial shock that increases the ruler's ability to observe economic production can engender additional investments in future fiscal legibility — offer a novel explanation of the emergence and development of informational capacity. Others have shown how the choice to build state informational capacity may be related to inequality and redistributive considerations (e.g., Hollenbach and Silva 2019; Sánchez-Talanquer 2020; Suryanarayan and White 2021), political institutions (e.g., Ma and Rubin 2019; Brambor et al. 2020), electoral incentives (e.g., Christensen and Garfias n.d.), or the specific design of government programs (e.g., Hunter and Brill 2016; Harbers 2020). Our argument connects the work on strategic incentives to invest or underinvest in legibility to the complementary literature on the exogenous determinants of state development, such as geography (e.g., Dal Bo, Hernández, and Mazzuca 2015; Fernández-Villaverde et al. 2020). Initial informational conditions determine whether a self-interested ruler will want to build greater fiscal legibility over the longer term. A shock that suddenly increases in legibility can shift incentives toward long-term investment in political centralization and state development. This helps to explain why informational capacity acquired centuries ago, such as the creation of detailed cadastral records, might have a persistent effect on present-day fiscal outcomes (D'Arcy and Nistotskaya 2018).

2. Theory

Our theory focuses on the conditions under which a central ruler would prefer to have more direct control over local intermediaries in charge of tax collection. In a context where tax revenue depends

[3]Other empirical work has documented the effects of specific types of legibility on other outcomes, such as the effects of biometric smartcards on the efficiency of social program disbursements (Muralidharan, Niehaus, and Sukhtankar 2016), civil registration on access to higher education (Bowles 2021), and cadastral updates on property tax revenue (Martínez 2017; Christensen and Garfias n.d.).

jointly on local economic conditions and an intermediary's level of effort, neither of which are directly observable to the ruler, he has to design a contract to encourage the intermediary to exert effort in tax collection. As we show in this section, the ruler faces a trade-off in deciding whether to encourage intermediary effort strictly through rewards (wages and/or bonuses) or whether to make a costly transition to a contract that allows for more direct control over the intermediary via the threat of dismissal following disappointing performance. While incorporating the possibility of dismissal into the contract enables the ruler to lower the rewards needed to encourage the intermediary to exert effort, this also requires the ruler to invest in monitoring the local economy so that he can tell when poor performance is due to lack of effort or poor conditions.

As we show below, this trade-off depends crucially on the ruler's ex ante ability to observe conditions within a district. When fiscal legibility is low (when it is difficult for the ruler to differentiate whether poor outcomes are due to poor effort or bad conditions), the cost of exerting direct control over the agent exceeds the benefits, and the ruler is better off allowing the intermediary more autonomy. However, when legibility is high enough, the ruler can use high-quality information on the local economy to discern when an intermediary's performance is poor. This allows the ruler to credibly threaten to dismiss intermediaries who underperform, allowing him to exert more direct control and retain more revenue through lowering compensation.

Importantly, this has implications for where the ruler will want to invest in improving legibility over the longer term. In contexts where the capacity to observe local conditions is very low, improving legibility to the point where it would be advantageous for the ruler to centralize control over the intermediary would require a substantial investment over an extended period of time, which may not be worthwhile for even a moderately patient central ruler. By contrast, once the ruler has committed to more direct control, even a marginal improvement in the ability to monitor intermediaries allows him to retain a greater expected share of tax revenue through the threat of dismissal, which encourages further investment in legibility. This dynamic creates a long-term divergence in fiscal legibility and in the ruler's degree of control over agents between districts with

ex ante low and high levels of informational capacity. We develop this argument in more detail below.

2.1 Setting

We model the strategic interaction between a central ruler and a local intermediary in charge of tax collection. We build on the model of Mayshar, Moav, and Neeman (2017), who explore the role of the observability of economic activity by central rulers on their ability to extract tax revenue and the degree of state centralization. Local tax revenue in each period is jointly determined by local economic conditions, $\theta_t \in \{G, B\}$, where $\theta_t = G$ implies a good year (and $\theta_r = B$ a bad year) for economic production, and by the intermediary's effort level in tax collection, $e_t \in \{h, l\}$, where $e_t = h$ indicates high effort in that year and $e_t = l$ indicates low effort. In our setting, this effort could capture both the collection and processing of tribute payments as well as investment in keeping the peace locally so that taxes can be collected (e.g., Garfias and Sellars n.d.). We assume that tax revenue R_t is high H when $\theta_t = G$ and $e_t = h$ and low L otherwise.

The ex ante probability of a good year for economic production is given by $\Pr(\theta_t = G) = p \in (0,1)$. Local conditions are drawn independently in each year. Both the ruler and the intermediary receive a public signal about the state of the world after the intermediary's effort level has been realized, $\sigma_t \in [g, b]$. The accuracy of the signal is given by q_t, where $q_t = Pr(G|g) = Pr(B|b)$ and $1 - q_t = Pr(B|g) = Pr(G|b)$. We call this parameter q_t *legibility* or informational capacity: the degree to which the ruler can correctly infer the state of the world from its signal in that year. We assume baseline legibility $q_0 \in [0.5, 1]$. As we develop below, the ruler can choose whether to invest in increasing legibility over time.

We assume that exerting effort in revenue collection is costly. The intermediary's utility each period, when under contract with the principal, is given by $I_t - \gamma \mathbb{1}\{e_t = h\}$, where I_t represents the income from the principal, γ represents effort cost, and $\mathbb{1}\{e_t = h\}$ is an indicator for whether the agent exerts high effort $e_t = h$. We assume that the intermediary cannot save or borrow across

periods. We standardize the value of the intermediary's outside option to 0. The intermediary also has discount factor, $\delta \in (0,1)$.

The ruler seeks to maximize the present discounted value of his expected net revenue stream, with discount factor $\beta \in (0,1)$. Because effort is costly for the intermediary, the ruler has to create an incentive for him to exert effort each period. Following Mayshar, Moav, and Neeman (2017), we assume that the ruler's baseline incentive scheme to the intermediary takes the following form. Intermediaries are paid a basic wage or payment $w_t \geq 0$ regardless of outcome and a bonus $a_t \geq 0$ paid if tax revenue is H that period. We call this contract "Indirect Rule" (IR), and make it the status quo contract for the intermediary (i.e., $C_0 = IR$ where C_t represents the contract in each period).[4]

At the beginning of each period — before local conditions are realized and before the agent has made any effort choice — the ruler may choose to transition to a contract that allows for dismissal of the intermediary for underperformance. We call this contract with dismissal a Direct Rule (DR) contract). Adding dismissal to a contract is costly, however, as this requires renegotiating terms with the intermediary, who stands to lose from the reform, and may create a short-term governance crisis. We assume that switching from Indirect Rule to a contract with dismissal ($C_t = DR$ when $C_{t-1} = IR$) requires a one-time cost of $\kappa > 0$ to implement. We interpret κ as a transition cost, capturing the difficulty of seizing control from semi-autonomous intermediaries under Indirect Rule who may wield independent coercive power (Garfias and Sellars n.d.). This κ parameter could also encompass any additional present or future-discounted benefits or costs of direct relative to indirect rule for central authorities that do not determine intermediary effort or depend on legibility (e.g., cost of setting up an administrative state, benefits of consolidating political power). [5]

[4] As we discuss in the next section, the terms "direct" and "indirect rule" have been used to capture a variety of institutional forms (e.g., Naseemullah and Staniland 2016). We focus here on one critical distinction between institutions of direct and indirect rule: the ease with which a central ruler can monitor and replace underperforming intermediaries. Our Direct and Indirect Rule arrangements correspond, respectively, to the "carrot only" and "carrot and stick" contracts in Mayshar, Moav, and Neeman (2017).

[5] We assume that it is costless to revert back to Indirect Rule after Direct Rule has been established, though, as we discuss below, a reversion to Indirect Rule will not occur in equilibrium in this model.

If the ruler has established a contract with dismissal (i.e, if $C_t = DR$), he may choose whether or not ($d = 0$, $d = 1$) to replace the intermediary at the end of the period based on performance at cost $x > 0$.[6]This cost encompasses the difficulty of removing an intermediary or the cost of hiring a new intermediary. Note that because dismissal is costly and the ruler wishes to encourage effort, the intermediary will only be dismissed if revenue is L, so there is a possibility that the intermediary has shirked. We further assume that the cost of dismissal is high enough ($x > \hat{x}$) that the ruler would dismiss the intermediary only if the evidence of shirking is sufficiently high (as opposed to simply removing all intermediaries when observing low output). Let $\mu_t = (1-p)(1-q_t)$ represent the probability that the intermediary is removed after exerting high effort. This expression comes from the probability that there is a bad year for output $(1-p)$ but the signal erroneously suggests a good year $(1-q_t)$. Note that this probability of mistaken dismissal μ_t is decreasing in both current legibility (q_t) and the probability of good economic conditions (p).

The ruler also faces a choice of whether and how much revenue to invest in increasing local legibility. Let the amount invested be $I_t \in [0, \bar{I}]$, where $\bar{I} < L$ represents the maximum amount of revenue that local institutions can absorb in a given year.[7] Specifically, we assume that $q_{t+1} = q_t + g(q_t, I_t)$, where I_t represents the amount of revenue invested in increasing legibility; q_t is current legibility of the district; and $g(\cdot)$ is a differentiable function that is non-negative ($g(\cdot) \geq 0$), increasing in investment $\left(\dfrac{\partial g}{\partial I_t} > 0\right)$, and decreasing in current legibility q_t $\left(\dfrac{\partial g}{\partial q_t} < 0\right)$. We further assume that no investment yields no change in legibility ($g(q_t, 0) = q_t$) and that q_{t+1} is bounded from above by 1 ($g(q_t, I_t) < 1 - q_t,$ so that as $q_t \to 1, g(q_t) \to 0$).[8]

[6]While we model the probability that an intermediary can be dismissed as 1 under the Direct Rule contract and 0 under the Indirect Rule contract, our results require only that the probability that an intermediary can be dismissed is higher under the Direct Rule contract. The relative costs of dismissal are strictly declining and the benefits rising in q. See Appendix A.

[7]The assumption that I_t is capped at something less than than lower bound on revenue for the period is not necessary, but avoids potential complications with the ruler's budget constraint. Substantively, this can be motivated by a natural limit to how much legibility can realistically improve in any given period.

[8]Among other things, these conditions ensure that legibility is bounded between 0.5 and 1. An example of a function that meets these criteria would be: $g(q_t, I_t) = \left(\dfrac{I_t}{\bar{I}}\right) \dfrac{(1-q_t)^a}{b}$, for some $a, b > 1$.

2.2 Analysis

We construct a stationary (i.e., restricting attention to state-dependent strategies), Markov Perfect Equilibrium in which the ruler offers the intermediary the minimal value contract needed to ensure that the he exerts high effort in each period, and the intermediary exerts high effort. We analyze the model and prove the results in Appendix A. In this section, we summarize and provide intuition for these results to set up our empirical analysis in the remainder of the paper.

Proposition 1. *The ruler will choose to transition to Direct Rule only if the dismissal contract will yield the ruler greater expected net revenue this period. Further, the ruler will only choose to transition to Direct Rule if the gain in expected retained revenue today is at least* $(1-\beta)\kappa$ *larger than would be expected under Indirect Rule.*

This result obtains for a couple of reasons. First, the ruler can transition to Direct Rule at a cost of κ in any period. This means that the benefit of transitioning to Direct Rule today as opposed to tomorrow can be decomposed into the direct benefits of having Direct Rule in place for this period (i.e., the amount of retained revenue for the ruler today) and not having to pay the one-time transition cost next period at discounted cost $\beta\kappa$. Second, the choice to invest in future legibility, q_{t+1}, does not directly depend on this period's contract once these transition costs are accounted for because this decision is only forward-looking: it yields some benefit from next period forward at a direct, linear cost today. As we discuss below, the benefit does depend on the future contract between the intermediary and the ruler, but this contract can be changed at cost κ at any date. Because we assume that the ruler discounts future payoffs at rate $\beta \in (0,1)$, it is less costly to postpone the cost of transition if there is no immediate benefit of exerting more direct control over the agent. In order for the transition to be worthwhile in the current period, it must be true that the immediate benefits of the dismissal contract outweigh the higher transition cost of moving to Direct Rule today as opposed to tomorrow.

Because it is costly to transition to Direct Rule, it is not enough to show that the Crown could retain more revenue this period under the dismissal contract. The benefit also has to outweigh the

cost of transitioning. The $(1-\beta)\kappa$ term comes from the ruler's discount factor (a more patient ruler will be more willing to pay a one-time cost to transition to Direct Rule) and the cost of transition (the expected benefits of Direct Rule must be higher where it would be costlier to implement the dismissal contract).

Proposition 2. *Given the intermediary's incentives, the ruler's desire to maximize revenue, and the above parameter assumptions, the ruler's optimal contract under Direct Rule and Indirect Rule takes the following form:*

- *The optimal wage w^* is set to 0 (the intermediary's participation constraint) regardless of the type of contract.*
- *The optimal bonus $a^*(q_t)$ depends on the type of contract, where the optimal bonus under Direct Rule $a_d^*(q_t)$ is strictly less than that under Indirect Rule $a_{nd}^*(q_t)$, for all levels of legibility.*
- *Bonuses under both contracts are increasing in the cost of intermediary effort γ and decreasing in the probability of a good year for production p.*
- *The optimal bonus under Direct Rule $a_d^*(q_t)$ is decreasing in transparency q_t. The optimal bonus under Indirect Rule a_{nd}^* does not depend on q_t.*

This is a similar result as in the Mayshar, Moav, and Neeman (2017) base model. First, because the wage is paid regardless of outcome, a high wage will not enter into the intermediary's effort decision. The intermediary will receive a wage this period whether or not he exerts effort. The ruler will therefore pay a wage that is just high enough for the intermediary to remain under under contract (i.e., his participation constraint will be binding). We standardize the value of these outside options to 0 in this discussion.

The intermediary's decision to exert effort depends only on the size of the bonus that he will receive when revenue is high ($R_t = H$) and — in the case of Direct Rule — the possibility that underperformance will lead to dismissal. Because there is no possibility of dismissal under an

Indirect Rule contract, the promise of a bonus today has to be high enough to encourage the intermediary to exert effort in this case. The intermediary will begin next period with the same contract regardless of his performance today. As we show in the appendix, the optimal bonus under Indirect Rule depends only on the probability of good conditions p (a higher probability implies a higher likelihood that high effort will be rewarded in any given period, lowering the necessary size of the bonus) and on the cost of effort γ (when effort costs are higher, the bonus must be higher to compensate).

Under Direct Rule, by contrast, the ruler has two tools to induce effort: the bonus and the threat of dismissal. Because the Crown can dismiss an intermediary following a disappointing performance, he does not need to pay as high a bonus as under Indirect Rule. An intermediary who shirks not only loses out on any bonus this period but also runs the risk of losing the value of the contract going forward. As we show in the Appendix, the size of the bonus in this case is also decreasing in p and increasing in γ. It is also decreasing in q_t, the ruler's ability to observe local conditions in the district. The reason for this is that as the ruler acquires the ability to differentiate between poor effort and poor economic conditions, it becomes easier to identify and punish shirking. This enters into the incentive constraint for the intermediary, reducing the bonus that must be offered by the ruler to induce effort.

Proposition 3. *For cost of replacement x sufficiently large and cost of transition cost κ sufficiently small, there exists a threshold transparency level $q^* \in (0.5, 1)$ such that the ruler prefers Indirect Rule when $q_t < q^*$, prefers Direct Rule when $q + t > q^*$, and is indifferent when $q_t = q^*$. This threshold q^* is increasing in the cost of replacing an agent x and in the cost of transition κ and declining the ruler's level of patience β.*

This follows from the above discussion. The ruler will transition to Direct Rule only if the expected retained revenue this period would be higher than would be expected under Indirect Rule. Under the Indirect Rule contract, the expected retained revenue for the ruler in every period does not depend on transparency q_t. By contrast, under the Direct Rule contract, the ruler's expected

revenue is increasing in q_t because this enables the ruler to provide a lower bonus to an intermediary who is under the threat of dismissal. The benefit of Direct Rule therefore increases as it becomes easier to observe local conditions.

If the ruler's cost of dismissing and rehiring an intermediary (x) is high enough, Direct Rule is too costly to implement at low levels of legibility, There is a high likelihood that the ruler will erroneously dismiss an intermediary who exerts high effort ($\mu_t = (1-p)(1-q_t)$), forcing him to pay the cost of replacement needlessly. However, this risk declines as legibility increases. Once q_t reaches the level q^*, the benefit of a Direct Rule contract (lower bonuses paid to intermediary) begins to outweigh the cost. This threshold is higher when the costs of dismissing an agent and of transitioning to Direct Rule (x and κ) are higher as this lowers the benefit of implementing Direct Rule. The threshold is lower as the ruler becomes more patient (β rises) because this increases his willingness to pay a transition cost today for a higher payoff from next period forward.

Proposition 4. *The ruler will only have an incentive to invest a positive amount in increasing future legibility if Direct Rule is in place or if the ruler can profitably transition to Direct Rule within N periods, where this number N depends on the ruler's discount factor* β.

We now turn attention to the conditions under which the ruler will have an incentive to invest in increasing future legibility. Note first that, by Propositions 2 and 3, increasing the observability of production in a district does not benefit the ruler under Indirect Rule. Under this contract, the ruler does not need to differentiate between lack of effort and poor conditions when tax collection is disappointing. The intermediary's incentive to exert effort comes only from the promise of bonuses if economic conditions are good, and he is guaranteed to remain under contract during the next period regardless of the outcome.

Under Direct Rule, the ruler's expected retained revenue each period is increasing in legibility because this reduces the potential for an erroneous dismissal and lowers the bonus that must be paid to the intermediary. It may therefore be worthwhile for the ruler to invest in greater legibility today if the Direct Rule contract is in place or if he anticipates an eventual transition to Direct Rule in

order to yield higher future expected net revenue. The ruler's choice will depend on discount factor β. A more impatient ruler will be less likely to invest to increase legibility tomorrow, especially if any anticipated transition to Direct Rule lies in the distant future. By contrast, a more patient ruler may be more willing to invest over several periods, even when he is under the Indirect Rule contract, to accrue enough legibility to make a future transition to Direct Rule more profitable.

Proposition 5. *Let q_0 represent the baseline level of legibility. If dismissal cost x is sufficiently high, the ruler will only invest a positive amount I_t to improve legibility if q_0 is larger than some threshold value $\hat{q}$. This threshold is increasing in the cost of replacing an agent x and in the cost of transition κ, and decreasing in the ruler's level of patience β and the technology of legibility development $(g(q_t, I_t))$.*

When the baseline level of legibility in a district is very low (i.e., much lower than q^*), a high level of investment, perhaps spread over several periods, would be required to raise legibility to the point where Direct Rule would be advantageous for the ruler. Any future benefit would have to be balanced against paying the cost of investment today. For even a moderately patient ruler, this trade-off may not be worthwhile unless he anticipates a transition to Direct Rule in the near term. As the ruler's impatience increases, any investment today for a future payoff becomes less attractive. However, if the ruler is sufficiently patient and the level of legibility in the district is greater than or close to q^*, it might be worthwhile to endogenously invest to increase future legibility. As we show in the appendix, this threshold also depends on the technology of endogenously improving legibility. A more effective technology will yield a faster payoff to investment at any q_t, whereas a worse technology restricts the range of q_t where investment will be worthwhile.

Note further that if that the ruler's discount factor is high enough and the technology is sufficiently efficient, the threshold level necessary for investment to be worthwhile, $\hat{q}$, is lower than the threshold needed for Direct Rule to be beneficial (q^*). This is because a patient ruler may choose to invest in a district in order for Direct Rule to be profitable at some point in the future. There are therefore

conditions under which a district under Indirect Rule will receive investment in legibility though this is not immediately useful for the ruler.[9]

The last two propositions highlight an important implication of our theory. For investment in legibility to be worthwhile, baseline legibility has to be high enough so that the ruler benefits from Direct Rule immediately or will be able to benefit from transitioning to Direct Rule in a relatively short period of time. This dynamic can lead to divergence in long-term trends in legibility in districts that may begin from a nearby baseline level. Districts where $q_0 < \hat{q}$ will not see any additional investment by the ruler to obtain more information over conditions or exert more control over the intermediary, while those with q_0 just above this threshold level will be set on a path of gradual investment in capacity and eventual centralization. This dynamic also implies that an exogenous shock that raises the legibility of district from below to above this threshold $\hat{q}$ can have large long-term consequences for local institutional development.

2.3 Observable Implications

In the remainder of this paper, we provide empirical evidence on the following implications of this theory:

1. An exogenous shock that increases the baseline legibility of economic production should encourage the transition to Direct Rule, both in the near term and in the longer term. In the near term, this shock can push districts over the threshold q^* necessary for Direct Rule to be profitable (Proposition 3). In the longer term, the shock can also encourage legibility-enhancing investment in districts that remain under Indirect Rule to set them on a path for a future transition to Direct Rule (i.e., the shock makes q_t to rise above $\hat{q}$) (Proposition 5).
2. The consequence of an exogenous increase in legibility should be lower where the cost of transition (κ) is higher and lower where ex ante legibility would have been lower ($q_0 < \hat{q} < q^*$) (Propositions 3 and 5).

[9] As we discuss in the appendix, if the ruler is very impatient (β close to 0), he will never want to invest in legibility regardless of payoff as there is little incentive to increase his discounted future revenue stream.

3. Endogenous investment in increasing legibility should be higher over the long term in areas affected by the exogenous increase in legibility. This is because the ruler only benefits from legibility investments in districts under Direct Rule ($q_t > q^*$) (Proposition 5).

3. Context

3.1 Indirect Rule in Early Colonial Mexico

The model illustrates that as the ruler's ability to observe local conditions improves, the relative benefits of exerting higher control over political intermediaries increases. To assess these ideas, we examine the transition from indirect to direct rule in early colonial Mexico around the time of a technological innovation that greatly increased the Spanish Crown's ability to monitor mining production and thus learn about local economic conditions.

The Conquest and early political organization of New Spain relied heavily on the cooperation of the conquistadors and other elite intermediaries both militarily and administratively. The *encomienda*, a central economic and political institution under Spanish colonial rule, facilitated this interaction. Under the *encomienda*, a local elite (*encomendero*) was given the right to extract tribute and labor from the local population in exchange for bearing the cost of local tax collection, pacification, and Christian conversion. It functioned as a critical institution of indirect rule, enabling the Crown to quickly extend its control over territory without having to invest in developing a centralized bureaucracy to monitor, tax, and police the periphery (Zavala 1973; Knight 2002; García Martínez 2011; Garfias and Sellars n.d.).

During the early years of colonial rule, when the Crown had limited information about its holdings and limited control over the territory, much of the colony was administered via the *encomienda*.[10] However, this was an costly arrangement for the Crown. By ceding revenues and autonomy to *encomenderos*, the Crown created a class of empowered elites with independent military authority that could not be easily supplanted. Within a generation of the Conquest, the Crown had started the

[10]Some areas, notably Tlaxcala and areas of low pre-colonial settlement, never received *encomiendas*. These areas are excluded from our analysis of indirect and direct rule.

process of centralizing power, gradually replacing *encomiendas* with *corregimientos*, public offices with salaried officials who could be hired and fired by the central government (Zavala 1973; Hassig 1985; Knight 2002).

The contract for the holders of these public offices, the *corregidores*[11] , differed substantially from that of the *encomenderos*. Most relevant to the theory in Section 2, these officeholders were under more direct control of the Crown. Unlike *encomenderos*, who typically held their position for the duration of their lives and could even initially pass on the office to their heirs, *corregidores* were typically appointed for a single year by viceregal authorities (Gibson 1964, p. 84). They could be, and often were, replaced at the end of each term and sent to other districts (Gibson 1964). Also unlike *encomenderos*, the *corregidores* received a salary from the government. In the early years of this office, this salary was drawn from locally collected tribute in a specified formula, though this compensation scheme evolved over time. Importantly, the size of these payments differed substantially from what was received by *encomenderos*, who were able to retain a sizable share of tax revenue. As Gibson (1964) writes, "the smallest encomiendas yielded incomes larger than the best-paid corregimientos" (p. 83), which left more surplus for the Crown.

For royal authorities, the move to *corregimiento* was attractive on several dimensions. It enabled the government to exert greater control over intermediaries and retain more revenue. However, the transition to more centralized control was also costly. *Encomenderos* controlled local coercive authority, and they resisted attempts to centralize power, at times by force (Gibson 1964; Yeager 1995; Knight 2002). Moreover, the move to direct rule meant that royal officials would have to bear the cost of policing and monitoring the local population, costly tasks that had previously been delegated to *encomenderos* who could depend on better local knowledge.

In practice, the transition to direct rule in colonial Mexico was uneven across space and time. Some *encomiendas* were dissolved by the early 1530s, while others survived for centuries until

[11] Other terms used for these local civil authorities included *alcaldes mayores*, *justicias*, and *subdelegados*. There were a few minor differences between these offices in the early colonial period, but this position was generally the same (Gibson 1964, p. 82; Gerhard 1993*a*, p. 14).

the end of the colonial period. Scholars have proposed several explanations for when, where, and why royal officials chose to centralize power, including differences in the value of holdings (Yeager 1995), in a district's strategic military importance (Pastore 1998), or in the threat of domestic conflict (Garfias and Sellars n.d.), among others. Drawing on our theory, we examine the complementary role of fiscal legibility: the Crown's ability to observe local economic production.

The move to direct rule required the Crown to take on a stronger role in monitoring local officials and observing local conditions. In some districts, such as areas close to Mexico City, it would have been relatively easy for the Crown to observe shifts in local economic production and the political environment. In others, such as frontier zones or places of ongoing insurgency, the cost of monitoring the economy or population would have been much higher. The model in Section 2 illustrates that the relative benefits of direct or indirect rule for the Crown depend critically on the ease of observing local conditions and the Crown's ability to identify when intermediaries are underperforming.

In places where it was difficult to observe local conditions, the Crown would have been unable to tell whether a disappointing tax receipt should be attributed to poor conditions or low effort on the part of the intermediary. Dismissing the intermediary — firing a *corregidor* from the bureaucracy and finding an adequate replacement — would have been costly given the high potential for error. This meant that the Crown had to rely exclusively on bonuses to incentivize effort in these areas, in this case allowing *encomenderos* to keep their position indefinitely and retain the lion's share of tax receipts. As the Crown's ability to observe local conditions improved, it became easier to identify when intermediaries were shirking, raising the value of centralization. Moving to a *corregimiento* contract both increased the Crown's control over local administration and reduced the share of revenue that had to be ceded to local elites.

3.2 The Patio Process: An Exogenous Shock to Fiscal Legibility

To empirically examine the relationship between fiscal legibility and the transition to direct rule, we focus on a technological innovation in the mid-16th century that dramatically increased the

Crown's ability to observe silver production: the introduction of the patio (mercury amalgamation) process. Silver was a major, arguably the most important, resource extracted from colonial Mexico. The discovery of extensive silver deposits during the Conquest of northern Mexico reshaped the economic structure of the colony toward extracting bullion for a newly empowered class of mining elites and for the Crown (e.g., Brading and Cross 1972; Knight 2002, p. 62–64). After an early wave of extraction depleted rich surface ores in places like Zacatecas and Guanajuato, attention turned to mining the deeper deposits of silver sulfides, which were considerably more difficult to process (Brading and Cross 1972; Guerrero 2017). The primary processing technology available in the early 16th century, smelting and cupellation, relied on heating ores to a high temperature and treating them with lead. This process required a large amount of fuel and imported lead from England, limiting the profitability of processing ores of marginal quality (Brading and Cross 1972; Guerrero 2017).

The introduction of the patio process in the 1550s radically changed Mexican silver production. This process relied on mercury amalgamation to extract silver from ore. Ores would be crushed using a stamp mill or other device and treated with salt and mercury, leaving the silver to form an amalgam with mercury that could be subsequently reheated to extract pure silver (e.g., Brading and Cross 1972, p. 552–6; Guerrero 2017, Ch. 4). Though not necessarily more efficient or profitable than smelting for ores with high silver concentrations, this process enabled the profitable extraction of lower grade silver sulfide ores common in the Americas, providing the basis for dramatically scaling up silver production in New Spain (Brading and Cross 1972; Guerrero 2017).

Importantly, the shift toward refining silver through the patio process improved the Crown's ability to monitor economic production in mining areas. Processing ores required large amounts of mercury, which had to be imported from Spain.[12] The Crown maintained a monopoly over the production, sale, and distribution of this vital resource starting in 1559 and throughout the rest of

[12]During this period, there were only three known areas where mercury could be mined at scale: Amaden in Spain, Idria in Central Europe, and Huancavelica in Peru. Peruvian mines used locally sourced mercury, but virtually all mercury in colonial Mexico originated in Spain (Brading 1971; Brading and Cross 1972, p. 562).

the colonial period. In addition to providing a sizable source of revenue, the monopoly enabled the Crown to directly observe the demand for mercury across space and time. As TePaske (2010, p. 105) writes, "royal authorities checked sales of mercury against the silver declared at royal treasuries by miners or refiners in order to detect fraud." Because silver production required mercury in a known and predictable ratio — approximately one mark of silver per pound of mercury — royal officials gained considerable insight over how much silver was being produced in different areas (Lang 1977; Brading and Cross 1972).[13]

This in turn provided insight on local economic conditions tied to taxation. Control over the provision of mercury provided an simple and reliable way to cross-reference production figures in silver taxation (e.g., Brading and Cross 1972, p. 570–1), but it also improved knowledge about economic fluctuations in other sectors. An increase in silver mining stimulated local economies, most directly by increasing demand for mining inputs. These included salt, fuel, and mining equipment, but especially labor, which accounts for a significant portion of the variable cost of smelting and amalgamation (Guerrero 2017, p. 315). A thriving mine would indicate steady wage payments to laborers and a higher demand for local agricultural products. Unlike in Peru, for example, laborers in the Mexican mining sector were generally compensated, even when labor was provided through the forced labor draft or *repartimiento* (Brading and Cross 1972, p. 557–8; Bakewell 1984, p. 123–5; Knight 2002, p. 65). This meant that a local mining boom could lead to an increase in wages or other income into nearby communities, increasing their ability to pay tribute.

By observing the demand for mercury across space and time, the Crown could therefore glean more general information about economic conditions in the areas surrounding mines. As is highlighted in Section 2, this altered the costs and benefits of adopting direct rule. Given access to an

[13]The accuracy of this ratio, or *correspondencia*, depended in practice on the quality of the mercury and ore and on the skill of refiners. Miners could opt to refine silver through smelting and smuggle their production to avoid taxation, but this was generally unprofitable. This would have been most likely in areas with abundant woodland nearby (lowering the price of fuel/charcoal for heating) and where there were rich ores with high silver content (reducing the benefit of the patio process).

independent source of information about local economic booms and busts, it became easier for central authorities to ascertain whether a fall in locally collected tax revenue could be blamed on poor conditions or by poor effort by intermediaries. Especially in distant areas where authorities had been unable to directly observe economic conditions, this dramatically reduced the cost of monitoring and disciplining intermediaries, encouraging the adoption of direct rule.

In the next sections, we describe the data and systematically assess how the adoption of the patio process altered the trajectory of state centralization in Mexico using subnational panel data and a difference-in-differences empirical strategy. We then examine how this technological innovation shaped the Crown's endogenous investment in fiscal legibility through the strategic placement of royal treasuries over the longer term.

4. Data

To examine how the introduction of silver amalgamation influenced the trajectory of state centralization, we digitize subnational data on indirect and direct rule institutions (encomiendas and *corregimientos*) from 1521 (ca. the Conquest) until 1650. Our data come from Gerhard (1993*a*;*b*), who compiles a list of *encomiendas* in the early colonial period across central and north-central Mexico at the level of the 1786 administrative region. These data include the approximate dates at which each holding remained privately assigned to an *encomendero* or switched to Crown control. We aggregate these data to the district level and calculate the proportion of holdings in each district that had transitioned to direct rule (i.e., *corregimiento*) by the start of each decade. For the small number of *encomiendas* that alternate between private and Crown control, we code the status of that holding as of the start of the decade. In cases where we are unable to verify the status of a particular holding at a given time point, we code its status as missing.

Data on early colonial mines comes primarily from Hillerkuss (2013), drawing on the work of Gerhard and others. Hillerkuss lists known silver and gold mines in colonial Mexico during the 16th century, noting the starting decade of production and the primary ores produced in each case. Because Mexico's main silver and gold deposits are found in the same locations (Guerrero

2017), we include all mines as the decision to extract silver or gold at any given location may be endogenous. We digitize these data and geographically assign each mine to a 1786 administrative region.[14]

We also digitize several control variables for use in our analysis. Time-invariant controls include whether a district is in a malarial zone (< 1000 meters) and the average elevation of the district, which were calculated using a digital elevation model from Mexico's National Institute for Statistics and Geography (INEGI). We also include a measure of the average least-cost walking time (in hours) from each district to Mexico City, which we extracted using GIS software and data on elevation and colonial land cover (see Section 6 and Appendix Section E.1). We code the approximate year of European contact from Gerhard (1993*a*;*b*) to account for potential differences in the ease of bringing different districts under direct rule. We also include the log area of the district to address potential differences in the density of *encomiendas*.

As time-varying controls, we include a vector of decadal climate variables, which were calculated using data from Cook and Krusic (2004). This source contains year-by-year estimates of soil moisture or drought conditions across space calculated using tree-ring chronologies. These data are reported at the level of 2.5 degree grid cells in terms of the Palmer Drought Severity Index (PDSI), a measure of soil moisture that is standardized to local conditions. We rasterize these data and extract the space-weighted average, minimum, and standard deviation of PDSI by district and by decade. To account for the possibility that disease-related demographic shocks disproportionally affected mining districts after the introduction of amalgamation, we also include an indicator for a sequence of severe drought followed immediately by a period of rainfall. This variable is used by Garfias and Sellars (n.d.) to instrument for population decline, which is shown to lead to the adoption of direct rule during this period.

[14]We code two indicators: whether a district includes a mine, and whether a mine in the district is reported to have started production prior to the introduction of the patio process around 1550. We note that production in a mine often started prior to the dates reported in the Hillerkuss data. However, we show results using the most restrictive definition in Appendix Section C.1.

Finally, to estimate heterogeneous effects of the discovery of the patio process, we digitize the number of towns in each district as of approximately 1786 and whether a district mounted an organized resistance to the Spanish Conquest using information from Gerhard.

5. Exogenous Shock to Fiscal Legibility and the Transition to Direct Rule

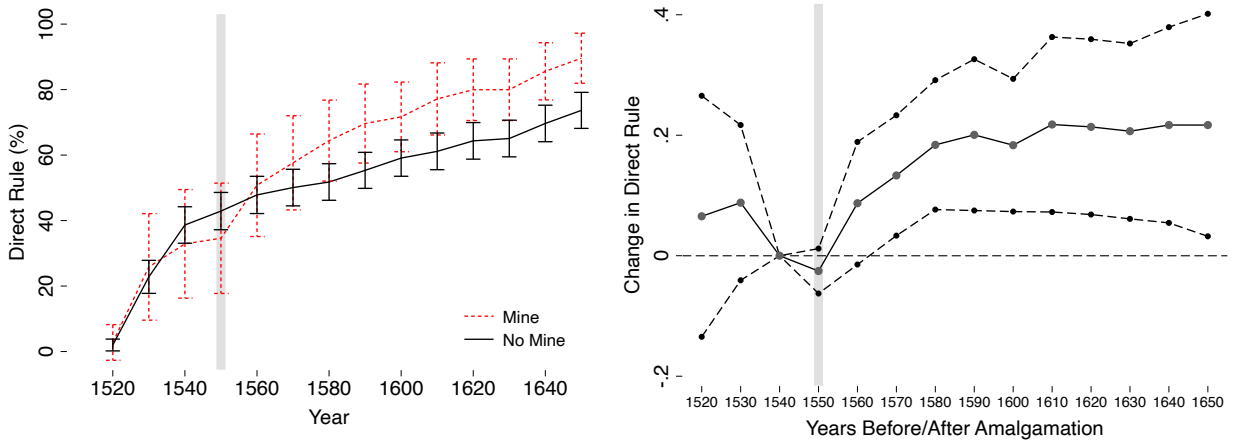
Our model suggests that an exogenous increase in the legibility of production should lead to a move toward political centralization. To assess this hypothesis, we adopt a difference-in-differences approach that compares changes in the adoption of direct rule between districts with and without silver mines before and after the introduction of silver amalgamation. As discussed in Section 3, the introduction of the patio process provided a sharp increase in the Crown's ability to estimate economic production in areas surrounding mines. We estimate:

$$Direct\ Rule_{it} = \beta_1 Mine_{it} \times PostPatio\ Process_t + \Theta_t X_i + \Pi U_{i,t} + \lambda_t + \gamma_i + \varepsilon_{it}, \tag{5.1}$$

where $Direct\ Rule_{it}$ is the proportion of *corregimientos* (direct rule) in district i by decade $t \in [1520, 1650]$; $Mine_{it} \times PostPatio\ Process_t$ is the product of an indicator at least one silver mine in the district; γ_i are district indicators; X_i are district-specific controls (i.e., malarial zone, elevation, log surface area, walking distance to Mexico City, year of Spanish contact) interacted with each year indicator to allow the trajectory and the level of direct rule adoption to vary by these observables; $U_{i,t}$ are time-varying climate covariates; and ε_{it} is an error term. We cluster standard errors at the district level.

In Figure 1, we present descriptive trends in the adoption of direct rule: the transition from the indirect rule contract of the *encomienda* to the direct rule contract of *corregimiento*. In the left panel, we plot the proportion of *encomiendas* converted into *corregimientos* over the period of analysis for districts with (red) and without (black) mines. As noted in the historical literature, there is a steep increase in direct rule during the decades after the Conquest in both groups. Around the time of the discovery of the patio process in 1554, however, mining and non-mining areas begin to diverge as centralization continues at an accelerated rate in districts with mines and slows in districts without

Figure 1: Silver Mining, Amalgamation, and Direct Rule



(a) Trends over time

(b) Dynamic Panel Estimates

The figure on the **left** plots the average proportion of holdings under direct rule with 95% confidence intervals for mining and non-mining districts in each decade. The figure on the **right** displays the point estimates and 95% confidence intervals of decade-by-mining district interactions from a panel regression that includes district and decade fixed effects.

mines.

The right panel of Figure 1 presents a similar pattern. It plots the coefficients of linear interactions between an indicator for mining districts each decade indicator from a panel regression with direct rule as the outcome that includes district and decade fixed effects. Relative to 1540 (the omitted category), there is no clear difference in direct rule adoption in districts with and without mines before the discovery of amalgamation. After the introduction of this process, however, districts with mines experience a relative increase in the transition to direct rule.

To quantify the magnitude of the differential increase in direct rule in mining areas following the introduction of the patio process, we estimate equation 5.1. The estimates, presented in Table 1, suggest the adoption of the patio process, and the resulting increase in fiscal legibility, had a substantial effect on the transition to direct rule. Direct rule adoption increases by between 13 and 15 percentage points in districts with mines relative to non-mines after fiscal legibility increases in the 1550s, which amounts to around half of the within-district standard deviation in direct rule adoption. These estimates are significant across specifications with and without additional

Table 1: Silver Amalgamation and Direct Rule: Difference-in-Differences

	Direct Rule (% of District)			
	(1)	(2)	(3)	(4)
Any Mine × Post-Patio Process	0.15***	0.13***		
	(0.041)	(0.038)		
Any Early Mine × Post-Patio Process			0.14***	0.13***
			(0.046)	(0.042)
Climate Controls	No	Yes	No	Yes
Controls × Year FE	No	Yes	No	Yes
Year of European Contact × Year FE	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Within-District Mean of DV	0.51	0.52	0.51	0.52
Within-District SD of DV	0.24	0.24	0.24	0.24
R sq.	0.78	0.81	0.78	0.81
Observations	2016	1960	2016	1960
Number of districts	144	140	144	140

OLS estimations. Unit-of-analysis is the district-decade. Standard errors (clustered at district level) in parentheses.

covariates, both in models using all documented mines in the period (columns 1 and 2) and when narrowing the scope to mines that had started production before the introduction of the patio process in 1554 (columns 3 and 4).

5.1 Revenue Potential as an Alternative Mechanism

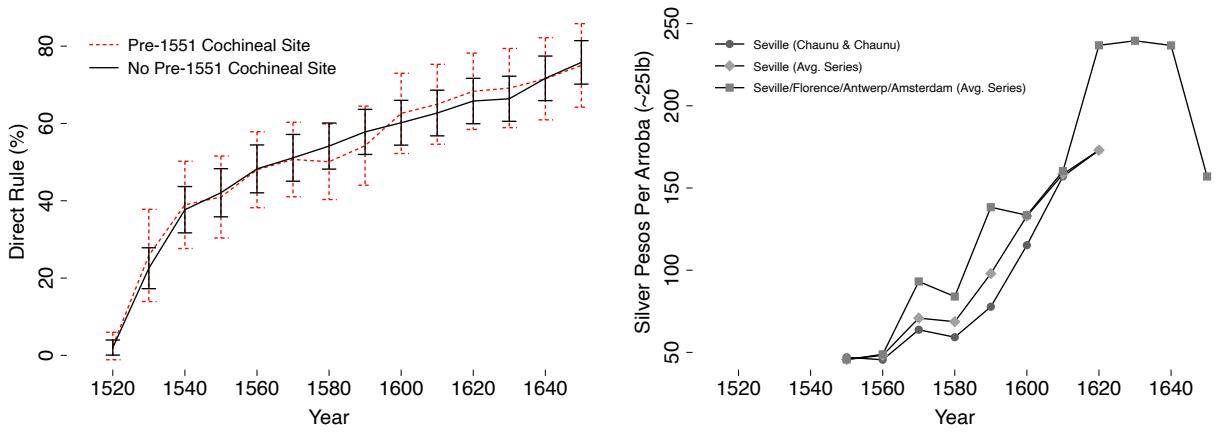
This differential increase in direct rule in mining districts following the discovery of amalgamation is consistent with the theory. However, in addition to enabling the Crown to closely monitor silver production, the patio process also increased the profitability of mining of ores with lower silver concentrations, which are prevalent in the Americas (Guerrero 2017). We consider here whether increased profitability or revenue potential, and not fiscal legibility, could explain our results.

Without detailed information on the amount of silver extracted or mining profits across districts and over time, it is difficult to directly assess this alternative mechanism. We adopt two indirect

strategies instead. We assess additional observable implications of our legibility-focused theory that would not be expected if centralization were driven by increased profitability alone (below). We also provide evidence casting doubt on this profitability channel by examining the effects of a large price shock in cochineal dye — a commodity whose importance in colonial Mexico was second only to mining at this time — on the adoption of direct rule.

Between 1580 and 1620, the international market price for cochineal increased threefold, driven by a sharp increase in European demand. This led to a dramatic increase in the profitability of cochineal production — one that was much higher than the estimated effect of the patio process on silver-extraction profitability (see Appendix Section D for a detailed comparison). We combine information on districts that were producing cochineal prior to this shock and European price trends to assess whether this price shock also led to a disproportionate increase in political centralization.

Figure 2: Cochineal-Producing Sites, Cochineal Price Shock, and Direct Rule



(a) Trends over time

(b) Cochineal Prices in Europe

The figure on the **left** plots the average proportion of holdings under direct rule with 95% confidence intervals for cochineal-producing and non-producing districts in each decade. The figure on the **right** displays a cochineal price series from various sources. See Appendix Section D for sources and a detailed description of the construction of the data.

Figure 2 compares the average proportion of holdings under direct rule in cochineal-producing and non-producing districts around the time of the price shock (left) alongside a graph of European cochineal prices over time. As the figure shows, despite the dramatic climb in cochineal prices

and demand in Europe beginning in the late 16th century, there was no corresponding acceleration in direct rule adoption in cochineal-producing districts. We present a more detailed analysis in Appendix Section D using a similar empirical strategy as above, now interacting an indicator for cochineal production in a district with the price of cochineal over time. We find that the remarkable increase in cochineal's profitability did not lead to a differential adoption of direct rule in cochineal-producing districts. Our estimates are not statistically significantly different from zero in any specification and are very small in magnitude (between 0.5 and 2 percentage points as a result of a one standard deviation increase in price or between 1 and 4 percentage points as a result of the full price shock).

The cochineal boom increased revenue potential. However, without a corresponding increase in fiscal legibility as had occurred with the patio process for silver mining, it did not encourage political centralization as direct monitoring and taxation remained difficult in cochineal-producing areas.

5.2 Heterogeneity by Transition Costs to Direct Rule and Lower Prior Legibility

The theory generates additional observable implications that can be examined with these data. We focus on two heterogeneous effects that the theory would imply: the shock to fiscal legibility that came with of the introduction of the patio process should have been lower where the cost of transition to direct rule (κ) was higher and where pre-shock legibility was lower.

First, we assess whether the increased fiscal legibility provided by the discovery of the patio process had a higher impact on direct rule adoption in areas where the cost of centralizing power would have been lower (i.e., where κ is smaller). From the perspective of the Crown, an important advantage of the *encomienda* was that local intermediaries had a vested interest in maintaining local political order (because they expected to remain in their position over their lifetime) and extensive local knowledge that could enable them to keep the peace more effectively. In areas prone to rebellion, the transition to more direct forms of rule was therefore costly, forcing the Crown to lose the benefits of the *encomienda* for political order (Garfias and Sellars n.d.). As our theory

illustrates, increasing the cost of transition should direct rule adoption less likely following the increase in legibility.

We rely on two measures to examine this prediction. First, we construct an indicator for whether the district mounted a violent resistance to the conquest at first contact, which captures both the extent to which areas may have been able to overcome collective action problems in the past and the possibility of greater opposition to Spanish rule. Second, we use the number of towns in a district as of approximately 1786 as a measure of the difficulty of coordinating a large-scale rebellion against royal authority. We would expect collective action to be more difficult when populations are spread out among many small settlements rather than concentrated in larger towns. Using these measures, we estimate models similar to equation (5.1), now interacting $Mine_{it} \times PostPatio\ Process_t$ with each measure of the cost of transition κ.

We present results on these heterogeneous effects in Table 2. Columns 1 and 2 show that fiscal legibility leads to an increase in direct rule across districts, but the effect is muted in places that mounted a resistance to the Conquest. Coefficient estimates imply that the effect of the patio process was between 25 and 50% lower in districts with organized resistance during the Conquest, though this difference not statistically significant. Columns 3 and 4 present estimates of the heterogeneous effects of the legibility shock by the number of towns in a district. As the number of towns in a district increases — and coordination between towns to organize large-scale resistance becomes more difficult — so does the effect of fiscal legibility. This effect is illustrated in the left panel of Figure 3, which plots the effect of legibility on direct rule at different number of towns per district. At the 25th percentile of this variable, when the district is split into 5 towns, the legibility shock is estimated to increase direct rule adoption by 8 percentage points. At the 75th percentile (11 towns), the discovery of amalgamation increases direct rule adoption by 18 percentage points.

These results suggest that in districts where the cost of transition from indirect to direct rule would have been higher, the increase in fiscal legibility had a more limited impact on centralization.

Table 2: Heterogeneous Effect of Silver Amalgamation on Direct Rule: Difference-in-Differences

	Direct Rule (% of District)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Any Mine	0.19**	0.17**	0.00093	0.031	0.19***	0.12**	0.032	0.083*
× Post-Patio Process	(0.077)	(0.074)	(0.067)	(0.085)	(0.048)	(0.054)	(0.048)	(0.048)
Any Mine	-0.049	-0.065						
× Resistance at Conquest	(0.084)	(0.077)						
Any Mine			0.016**	0.010				
× Number of Towns			(0.0073)	(0.0086)				
Any Mine					-0.14***	0.019		
× Post-Patio					(0.049)	(0.065)		
× Former Triple Alliance								
Any Mine							0.000010***	0.0000059
× Post-Patio							(0.0000036)	(0.0000046)
× Hours to Mexico City								
Any Mine	0.14***	0.11***						
× Post-Patio + Resistance	(0.04)	(0.04)						
Any Mine					0.051	0.14***		
× Post-Patio					(0.03)	(0.04)		
+ Former Triple Alliance								
Climate Controls	No	Yes	No	Yes	No	Yes	No	Yes
Controls × Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Year of European Contact × Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Within-District Mean of DV	0.51	0.52	0.51	0.52	0.51	0.52	0.51	0.52
Within-District SD of DV	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
R sq.	0.78	0.81	0.78	0.81	0.78	0.81	0.78	0.80
Observations	2016	1960	2016	1960	2016	1960	2016	1960
Number of districts	144	140	144	140	144	140	144	140

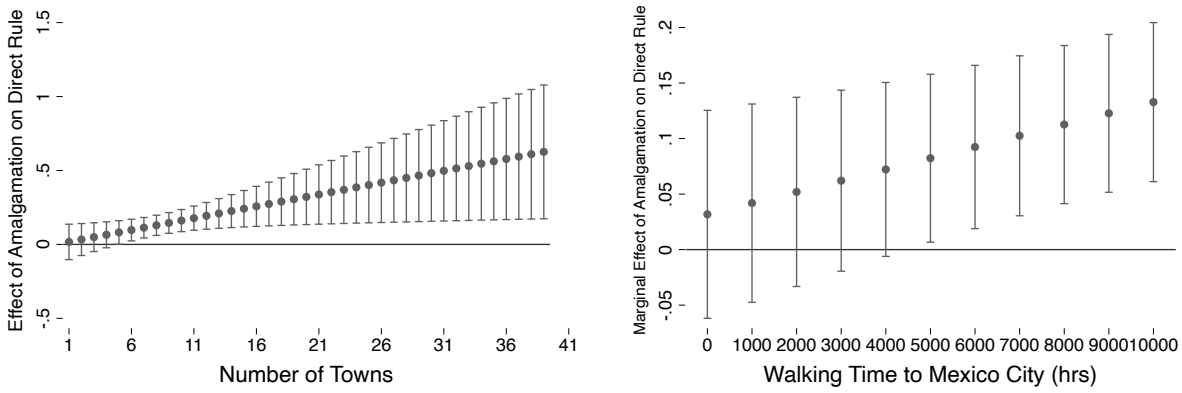
OLS estimations. Unit-of-analysis is the district-decade. Standard errors (clustered at district level) in parentheses.

While these measures are not perfect (e.g., the number of towns in a district is captured at a later date and could induce post-treatment bias), the results provide additional suggestive evidence in support of the theory.

We also assess a second observable implication suggested by the theory: the discovery of the patio process should have an especially large effect in regions with a low initial level of legibility. We use two measures to capture this. First, we record whether a district paid tribute to the Triple Alliance (Aztec Empire) prior to the Conquest. Upon the fall of the Aztec capital of Mexico-Tenochtitlan,

the Spanish adapted the pre-existing tribute system of the Triple Alliance and expanded it to newly conquered territories. Through usurping Mexica institutions and records, the Crown gained access to information that would have been costly to acquire anew, such as earlier tribute records. The Crown therefore had a better sense of local conditions in mining areas that paid tribute to the Triple Alliance, even before the introduction of silver amalgamation.

Figure 3: Silver Mining, Amalgamation, and Direct Rule
Heterogeneous Effects



(a) By Number of Towns (1786)

(b) By Waking Hours to Mexico City

The figure on the **left** plots estimates and 95% confidence intervals of the differential change in direct rule following the introduction of the patio process for different number of towns (by 1786) per district. The figure on the **right** plots similar estimates for different least-cost walking hours to Mexico City.

We also examine walking distance to Mexico City as an alternative measure of pre-amalgamation legibility. Mexico City was the center of colonial administration in the Americas, and the Crown's ability to directly observe and monitor nearby districts would have been high even before the discovery of the patio process. An additional increase in the observability of economic conditions should therefore not have had the same impact on the transition to direct rule as it did in more remote and less legible areas.

We estimate the heterogeneous effect of the introduction of the patio process by walking hours to Mexico City and by a district's pre-colonial tributary status in columns 5-8 of Table 2. Consistent with the theory, we find that the patio process increased direct rule by only 5 percentage points in

districts that were part of the tribute network of the Triple Alliance, about a quarter of the effect seen in non-Triple Alliance districts. However, this estimate is only significant and in the expected direction in the specification without covariates (column 5). We also find supportive evidence in the heterogeneous effect of the shock to legibility by walking distance to Mexico City (columns 7 and 8). Figure 3 shows the heterogeneous effect of the legibility shock by distance to the capital. The discovery of amalgamation has a small effect in districts in close proximity to Mexico City relative to more distant regions where there would have been less prior information on local economic and political conditions.

Taken together, the results provide additional empirical support for the theory. The discovery of the patio process led to a marked increase in the transition to direct rule, replacing the institution of the *encomienda* with the more direct monitoring and control of the *corregimiento*. Consistent with the theory, the increase in direct rule was larger in districts where the cost of transition was lower, those with a lower potential for rebellion, and in districts where initial legibility was very low, those outside of the pre-colonial centralized tribute network and farther away from Mexico City.

6. Endogenous Investment in Legibility

The introduction of the patio process led to a large and exogenous increase in the Crown's ability to monitor local production. This innovation increased fiscal legibility in the context of an expanding fiscal bureaucracy, and, as we show, facilitated the transition to direct rule.

What were the longer-term consequences of this shock for institutional development? The theory developed in Section 2 highlights how a shock that increases legibility can have lingering effects on the trajectory of political centralization. A central ruler has little incentive to invest in improving the legibility of areas administered through indirect rule, as monitoring and punishment do not play an important role in this type of contract with elites. By contrast, once a district is on the path toward centralization, obtaining better information about a district benefits a ruler directly: it makes it easier to identify poor effort by intermediaries, which reduces the expected costs of mistaken dismissal and lowers the amount of revenue he needs to cede to elites. A shock that suddenly

raises fiscal legibility can therefore lead to longer-term divergence in state building in affected areas by encouraging further efforts to improve the quality of information and monitoring. Unaffected areas, by contrast, remain under indirect forms of rule and receive no further investments in future legibility.

To empirically evaluate this prediction, we examine the establishment and strategic placement of *Cajas Reales*, royal treasuries, a network of formal fiscal institutions designed to oversee and administer the collection of taxes across the territory. These institutions had broad fiscal authority over their jurisdictions and remarkable autonomy from each other (TePaske and Klein 1986). Within their catchment areas, royal treasuries concentrated collected taxes and provided funds for local expenditures, including salaries as well as administrative and military expenses. Each treasury was led by an accountant, who registered and certified transactions, and a royal treasurer, who collected taxes directly from taxpaying individuals or institutions, or indirectly from other specialized officials like *corregidores* (Sánchez Bella 1968; Yuste 2002).[15]

The establishment of a new treasury brought the fiscal bureaucracy closer to the surrounding districts, increasing the ability of the Crown to monitor local conditions. In addition to facilitating tax compliance, the establishment of a treasury allowed the Crown to assess nearby economic production more reliably and thus to better evaluate the effort of local agents — *corregidores* and *encomenderos* — tasked with the collection of the tribute. We focus on this deliberate investment by the Crown as an important measure of endogenous fiscal legibility.

We specifically examine how the least-cost walking hours from each district to the nearest treasury evolved over time in mining and non-mining areas from the 16th century until the 1770s, just before

[15] Other positions included the *factor*, who conducted the treasury's business with other branches of the bureaucracy, and the *veedor*, who assayed gold and silver and monitored its production, and a variable number of deputies. The Crown relied on a number of strategies to minimize separate agency problems with treasury bureaucrats. The two main officials, the accountant and treasurer, and the main authority in the region, often the viceroy or governor, each had one of three keys necessary to open the actual treasury chest, making it difficult to defraud the Crown without high-level coordination. All of the accounts of each treasury, the *cartas cuentas*, were scrutinized by two independent auditing bodies — the *Contaduría Mayor del Consejo de Indias* in Seville and, starting in 1605, the *Tribunal de de Cuentas* in Mexico City (Sánchez Bella 1968; Jáuregui 1999). On-site audits were also conducted periodically and unexpectedly (TePaske and Klein 1986). Finally, the Crown sporadically empowered specially appointed *visitadores* with broad authority to inspect treasuries and discipline officials (Sánchez Bella 1968).

a series of important reforms in the Bourbon period that changed long-running trends in state capacity investments. The placement of the treasuries followed a clear territorial logic early on, with the establishment of treasuries in Mexico City, the capital, and Veracruz, Mexico's main port in the Atlantic (see Table E.1 for a complete list of treasuries with dates of creation). Treasuries were also eventually created to facilitate tax collection in the interior (Sánchez Bella 1968; Jáuregui 1999; Bertrand 2013).

Given the importance of silver to the royal economy, it is perhaps not surprising that treasuries were sometimes established near mines following the discovery of productive deposits. This seems to have motivated the creation of early treasuries in Compostela, Durango, and Zacatecas, for example (Parry 1968; Bakewell 1971; Lacueva 2011).[16] However, profitability was not the sole consideration. The creation of a treasury in a remote area, even a relatively unproductive one, was sometimes warranted to enable the Crown to obtain more information and control over outlying regions (Sánchez Bella 1968). Our interest is in whether districts affected by the amalgamation shock saw a sustained increase in investment toward improving the Crown's ability to observe and monitor local production through the construction of nearby royal treasuries.

To examine this question, we construct a decadal panel of space-weighted average walking times (in hours) from each district to the nearest royal treasury using information on the successive construction of new treasuries. This measure draws from a least-cost analysis that incorporates land cover, elevation, and terrain slope.[17]

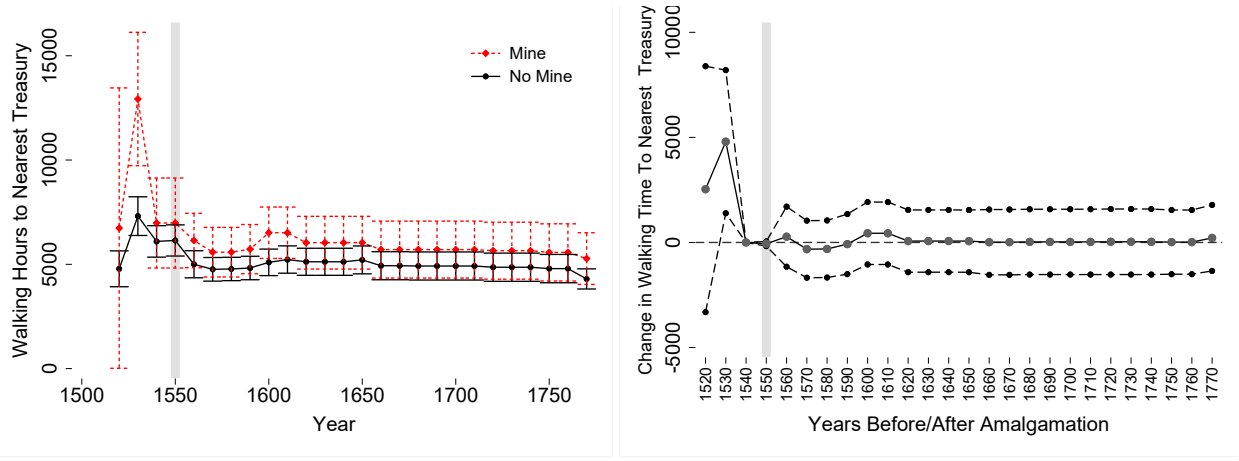
The left panel of Figure 4 presents the trajectory of the average time to the nearest treasury. The most striking, if unsurprising, pattern that emerges is the rapid drop in average walking times during the first decades following the Conquest. This emerges almost mechanically; the first few treasuries, as long as they spaced apart, necessarily dramatically lowered walking distance to outlying zones.

[16] Relatedly, the Crown also established treasuries along the coast to monitor contraband; the Carmen treasury is one example (TePaske and Klein 1986).

[17] See Appendix Section E.1 for a complete list of the treasuries and their dates of establishment, and Appendix Section E for a detailed description of the construction of the walking-time measure.

The figure presents the trajectories in the average walking time for districts with and without mines. We are interested in the differential trends between these areas. Both groups exhibit an initial large drop in average times to the nearest treasury in the earliest years of colonial rule. Following the introduction of the patio process, and most notably following the creation of the San Luis Potosi treasury in 1629, mining districts subsequently experience a significantly steeper reduction in walking time relative to non-mining districts (right panel).

Figure 4: Amalgamation and Walking Time to Nearest Royal Treasury



(a) Trends over time

(b) Dynamic Panel Estimates

The figure on the **left** plots average walking hours to the closest treasury with 95% confidence intervals for mining and non-mining districts in each decade. The figure on the **right** displays the point estimates and 95% confidence intervals of decade-by-mining district interactions from a panel regression that includes municipality and decade fixed effects.

As the Figure shows, however, estimation of the differential trajectory following the introduction of amalgamation is noisy. To further explore this relationship, in Table 3 we present difference-in-differences estimates from an equation similar to (5.1), now using our measure of endogenous investment in legibility as an outcome. We present estimates with and without time-varying and time-interacted controls for two separate samples: all districts in colonial Mexico where institutions of indirect or direct rule were employed in a consistent way (columns 1 and 2) and districts where we have data on indirect rule (columns 3 and 4).[18] Because our theory focuses on the Crown's dual

[18]The larger sample includes New Spain, Nueva Galicia, all of the southern districts, and Sinaloa in the north west

decisions of selecting a type of contract with intermediaries — indirect or direct rule — and the choice to invest in future legibility, we are most confident of its applicability in districts where these contracts existed.[19]

Table 3: Amalgamation and Walking Time to Nearest Royal Treasury (log): Difference-in-Differences

	Walking Hours to Treasury			
	Regions with Direct/Indirect Rule		Sample with Direct/Indirect Rule	
	(1)	(2)	(3)	(4)
Any Mine × Post-Patio Process	-1408.2**	86.4	-1501.9***	-834.1
	(620.6)	(569.0)	(514.2)	(561.2)
Climate Controls	No	Yes	No	Yes
Controls × Year FE	No	Yes	No	Yes
Year of European Contact × Year FE	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Within-District Mean of DV	4973.5	4930.5	4440.8	4284.7
Within-District SD of DV	1507.4	1502.9	1545.0	1493.0
R sq.	0.83	0.88	0.78	0.84
Observations	5077	5044	4464	4200
Number of districts	176	175	144	140

OLS estimations. Unit-of-analysis is the district-decade. Standard errors (clustered at district level) in parentheses.

Across both samples, the introduction of the patio process led to a differential decrease in the average walking time to the nearest treasury in mining relative to non-mining districts. Using all the regions where indirect rule was used, the shock led to a significant reduction of between about 750 and 1400 hours. In the sample with available information on indirect rule contracts, the decrease is

(Gerhard 1993*a*;*b*;*c*; see Figure B.1). In a few districts in New Spain and Nueva Galicia, the *encomienda* was not employed due to sparse settlement; these areas were placed under direct rule as new indigenous settlements emerged.

[19]Beyond these areas, settlement patterns at European contact were not compatible with existing institutions of indirect rule; some were inhabited by semi-nomadic populations and others were not settled at all. In these districts, the Crown relied on a more heterogeneous set of institutions (Gerhard 1993*b*).

between about 800 and 1500 hours. In both cases, the estimated reduction is not significant in the models with covariates.[20] These estimates are substantively large, equivalent to between around one half and a full within-district standard deviation of walking time to the nearest treasury, and between one sixth and one third of the sample mean.

This evidence supports of the idea that the exogenous shock to fiscal legibility of the patio process altered some regions' trajectory of endogenous investment in legibility. The Crown, previously hesitant to make an unprofitable investment in establishing a presence, changed its calculus once silver production in these low-legibility areas became more observable. However, we note that this evidence, while supportive of one of the theory's implications, is only suggestive as we cannot reject a null effect of the patio process across all the samples and specifications.

7. Conclusion

How does a shift in the observability of economic production alter a ruler's incentive to centralize power? Our model illustrates that a central ruler can be better off ceding greater autonomy and revenue to local elites in low-information environments as a way of encouraging performance when the cost of monitoring is high. As fiscal legibility improves, it becomes easier for the ruler to discern when intermediaries are underperforming. This makes it possible for the ruler to tighten control over intermediaries, threaten dismissal for underperformance, and retain a greater proportion of tax revenues for the Crown. The threshold level of legibility at which direct rule becomes advantageous depends on the cost of transition, the cost of replacing intermediaries, and the level of patience for the Crown.

Moreover, our formalization examines how an exogenous increase in legibility can encourage additional endogenous investments in future legibility. Low initial legibility can set a region on a long-term path of persistently low legibility, where the ruler relies on indirect forms of rule and thus does not benefit from the increased ability to monitor the local population. A sudden increase

[20] In Appendix Section C.2, we present additional evidence using logged walking times, and find similar results, though the estimates for the sample with indirect rule contracts are smaller in magnitude and not significant.

in legibility has the potential to alter this trajectory by lowering the barriers to centralization and making it advantageous for the ruler to start investing in future legibility for an eventual transition to direct rule. A single shock to fiscal legibility can thus have important long-term consequences.

We provide empirical support for the theory using subnational data on state centralization in 16th and 17th century Mexico. In the aftermath of the Conquest, Spain yielded considerable authority to local intermediaries as a way of maintaining political control over newly conquered territory. Efforts to centralize power differed considerably across space. We show that an important technical innovation in silver refining, the introduction of the patio process in the 1550s, greatly increased the Crown's ability to independently monitor economic fluctuations in districts with mines. Using a difference-in-differences empirical strategy, we show that mining areas saw a differential increase in centralization efforts following the introduction of the patio process. We further show that this effect was dampened where the cost of centralizing power would have been higher (i.e., where the threat of rebellion was elevated) and where authorities had better access to information prior to the 1550s (areas near Mexico City or that paid tribute to the Triple Alliance). Finally, we present suggestive evidence that, following this shock, mining areas also experienced a differential reduction in the walking time to the nearest royal treasury, a measure of an important endogenous investment in legibility by the Crown.

This paper provides insight into how fiscal legibility plays a role in state centralization. An exogenous change in the observability of economic production can lead to a permanent shift in the terms of the bargain between local elites and central authorities. When it becomes easier to monitor intermediaries, the state needs to offer fewer incentives to encourage compliance with the terms of the contract. This enables central authorities to tighten control, retain more revenue, and build more capacity for the future.

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Supporting Information

Fiscal Legibility and State Development: Evidence from Colonial Mexico

Contents

Appendix

A. Proofs of Propositions 1–5

In this appendix, we prove the main results of our model. We begin by setting up the ruler's problem. The ruler faces two set of choices each period: the contract to offer the intermediary and whether and how much to invest in improving legibility. If he chooses to keep the non-dismissal contract, he chooses a wage $w_t \geq 0$, bonus $a_t \geq 0$, and $I_t \geq 0$ to maximize:

$$V_r(q_t, C_t = IR) = p(H - a_t) + (1-p)L - w_t - I_t + \beta V_r(q_t + g(q_t, I_t), IR) \tag{A1}$$

subject to the intermediary's incentive constraint to exert high effort (where p is the probability that the state of the world is G, H represents high tax revenue, and L is low tax revenue). If the ruler chooses to switch to a contract with the option of dismissal at cost κ, their choice each period becomes to choose wage w_t, bonus a_t, and dismissal $d \in \{0,1\}$ to maximize:

$$V_r(q_t, C_t = DR) = p(H - a_t) + (1-p)L - \mu_t x - w_t - I_t - \kappa + \beta V_r(q_t + g(q_t, I_t), DR) \tag{A2}$$

where $\mu_t = (1-p)(1-q_t)$ is the probability of inadvertently dismissing the intermediary after high effort, x is the cost of dismissal, and other variables are defined as above).

Proof of Proposition 1: The ruler will choose to transition to Direct Rule if and only if this decision maximizes the net revenue that he receives this period.

To see this, compare expressions A1 and A2. These can each be decomposed into two components: the expected payoff that the ruler will receive today under either indirect rule ($p(H-a_t)+(1-p)L-w_t-I_t$, for the optimally chosen a_t, w_t, and I_t) or direct rule ($p(H-a_t)+(1-p)L-\mu_t dx-w_t-I_t-\kappa$, for the optimal a_t, w_t, and I_t) and the discounted value of the ruler's position next period under indirect rule $V_r(q_t+g(q_t,I_t),IR)$ or Direct Rule $V_r(q_t+g(q_t,I_t),DR)$. Note further that next period's legibility $q_{t+1} = q_t + g(q_t, I_t)$ depends only on today's level of legibility q_t and investment I_t, which enters linearly into the ruler's utility function. This means that the optimal investment I_t and next period's legibility q_{t+1} do not depend directly on this period's contract between the intermediary and the ruler and that the ruler's two decisions—which contract to offer the intermediary today and whether and how much to invest in future legibility—can be separated. Put another way, the optimal legibility investment is only forward-looking and does not change based on today's contract between the intermediary and the ruler.

Furthermore, because the ruler at any point can transition to Direct Rule at cost κ, there is a straightforward relationship between these value functions: $V_r(q_t + g(q_t, I_t), IR) - \beta\kappa = V_r(q_t + g(q_t, I_t), DR)$. This one-time cost of transition also appears linearly in expression A2. Let this period's expected payoff under indirect rule be represented by $U(IR)_t$ and under direct rule be given as $U(DR)_t - \kappa$ (the payoff net the cost of transition κ). Substituting the equivalence relation for the value functions into equation A1 and canceling terms, we see that the ruler will prefer to transition to direct rule when:

$$U(DR)_t - \kappa \geq U(IR)_t - \beta\kappa \tag{A3}$$

Because discount factor $\beta \in (0,1)$, $\beta\kappa < \kappa$. Rearranging terms, we see that the transition to Direct Rule is only profitable for the ruler if the expected retained revenue this period under direct rule exceeds the expected revenue under indirect rule by $(1-\beta)$ or more.

Proof of Proposition 2: Given the intermediary's incentives, the ruler's desire to maximize revenue, and the parameter assumptions, the ruler's optimal contract under dismissal and non-dismissal takes the following form:

- The optimal wage w^* is set to 0 (the intermediary's participation constraint) in both cases
- The optimal bonus a^* depends on the type of contract, where the optimal bonus under dismissal a_d^* is strictly less than that under non-dismissal a_{nd}^*
- Both a_d^* and a_{nd}^* are increasing in the cost of effort γ and decreasing in the probability of a good year for production p.
- The optimal bonus under dismissal a_d^* is decreasing in transparency q. The optimal bonus under non-dismissal a_{nd}^* does not depend on q.

This result follows directly from Mayshar, Moav, and Neeman (2017) and the first proposition. To show this, we begin by finding the conditions under which the local intermediary will exert high effort. Given the structure of the contract, the value of exerting high effort each period for the intermediary is given by:

$$V_a(q_t, C_t = IR) = w + pa - \gamma + \delta V_a(q_{t+1}, C_{t+1}) \tag{A4}$$

under the indirect rule contract and:

$$V_a(q_t, C_t = DR) = w + pa - \gamma + (1-\mu_t)\delta V_a(q_{t+1}, C_{t+1}) \tag{A5}$$

under the Direct rule contract, where parameters are defined as above and where μ_t represents the probability that the ruler will erroneously dismiss the intermediary. Note that, next period's legibility and contract depend only on the ruler's present and future actions. Holding constant the ruler's strategy, exerting high effort will be preferred to low effort in each period when:

$$w + pa - \gamma + \delta V_a(q_{t+1}, C_{t+1}) \geq w + \delta V_a(q_{t+1}, C_{t+1}) \tag{A6}$$

for the contract under indirect rule. Note that the wage w cancels as it is paid regardless of outcome. This implies that the wage will be set to make the intermediary indifferent between this contract and the outside option (standardized to 0). Given that dismissal is not an option under indirect rule, the discounted value of next period's contract also cancels. Solving, we have that the intermediary will exert high effort when $pa - \gamma > 0$ or when $a \geq \frac{\gamma}{p}$. Note that because intermediaries under Indirect Rule are guaranteed to remain on the contract next period, and because the intermediary's effort choice does not affect next periods' legibility, the minimal bonus paid each period under Direct Rule does not change based on the trajectory of investment.

Under the direct rule contract, assuming that the cost of dismissal x is sufficiently high and that the ruler thus chooses to dismiss the intermediary only upon observing $\sigma = g$ and $R_t = L$, the intermediary will exert high effort when:

$$w + pa - \gamma + (1 - (1-p)(1-q_t))\delta V_a(q_{t+1}, C_{t+1}) \geq w + (pq_t + (1-p)q_t)\delta V_a(q_{t+1}, C_{t+1}) \tag{A7}$$

or when:

$$a(q_t) \geq \frac{\gamma - pq_t \delta V_a(q_{t+1}, C_{t+1})}{p} \tag{A8}$$

The value function thus does enter into the calculus of the effort decision under direct rule as this determines the potential loss for forgoing revenue. Note that the bonus necessary to sustain high effort under Direct Rule is always strictly lower than under Indirect Rule, as the value function is positive. Looking at the numerator of this expression, we can see that it is declining in q_t. As q_t rises, it is easier for the ruler to identify shirking, and it becomes more likely that low effort will lead to the loss of the contract.

Proof of Proposition 3: For cost of replacement x sufficiently large and cost of transition cost κ sufficiently small, there exists a threshold transparency level $q^* \in (0.5, 1)$ such that the ruler prefers

the non-dismissal contract when $q_t < q^*$, prefers the dismissal contract when $q+t > q^*$, and is indifferent when $q_t = q^*$.

Proposition 1 shows that the decision to transition to Direct Rule depends only on whether this contract yields a higher revenue for the ruler this period (and in fact exceeds the revenue expected under Indirect Rule by at least $(1-\beta)\kappa$). Consider first the per period revenue expected under Indirect Rule. As we showed in the prior proposition, the optimal bonus in this case does not depend on q_t or the continuation value of the contract for the intermediary. The expected per period retained revenue for the ruler under Indirect Rule, conditional on the intermediary exerting high effort, is thus:

$$\pi_{IR} = pH + (1-p)L - \gamma \tag{A9}$$

where p is the probability of good conditions and γ represents the cost of effort (from the expression for the optimal bonus under Indirect Rule $\frac{\gamma}{p}$). Importantly, this expression does not depend on q_t.

Under Direct Rule, the ruler's expected retained revenue each period depends both on the bonus that he must pay the agent and on the probability that he dismisses the intermediary. The per-period expected cost of erroneous dismissal is $\mu_t x$. Note that by $\mu_t = (1-p)(1-q_t)$, this per period cost is decreasing in legibility q_t. The expected retained revenue in each period for the ruler, subject to meeting the agent's incentive constraint, is therefore:

$$\pi_{DR} = pH + (1-p)L - (\gamma - pq_t\delta V_{t+1}) - (1-p)(1-q_t)x \tag{A10}$$

where V_{t+1} is shorthand for the intermediary's continuation payoff, which is positive. Taking the derivative with respect to q_t, we can see that this expression is increasing in legibility q_t for two reasons. First, as q_t increases, this lowers the bonus that needs to be paid to the intermediary. Second, as q_t increases, the expected loss from incorrectly dismissing an intermediary declines.

Comparing expressions,A9 and A10, canceling terms, and incorporating Proposition 1, we have that the Direct Rule contract will be preferred when:

$$pq_t\delta V_{t+1} - (1-p)(1-q_t)x - (1-\beta)\kappa > 0 \tag{A11}$$

The first expression on the lefthand side is always positive. This implies that if x and κ are sufficiently small (and the ruler is sufficiently patient), the Direct Rule contract is always preferred,

even if when legibility is low. Conversely, if the cost of implementing the dismissal contract κ is large relative to the other parameters, given the ruler's discount factor, the ruler is always better off under Indirect Rule, even given perfect information about the state of the world.

We focus on the interior case, where x is large enough given the other parameters that replacing a high-effort intermediary is very costly, but κ is small enough so that the ruler would benefit from from Direct Rule given perfect information about the state of the world. In this case, if the ruler's signal about the state of the world is completely uninformative ($q = 0.5$), the ruler is better off under Indirect Rule given the difficulty of determining whether an intermediary has exerted high effort and thus the expected cost of erroneously dismissing a high-effort intermediary. As the signal quality q_t gets larger, the ruler becomes more able to discern shirking from declines in economic production, and the expected cost of replacing the agent shrinks. When the signal is perfectly informative, $q_t = 1$, the expected cost of dismissing the agent goes to 0, and the ruler is better off under the Direct Rule (for low enough κ).

Under these assumptions, because the lefthand side of A11 is continuous and increasing in q_t over $[0.5, 1]$, by the intermediate value theorem, there is a q^* where the ruler is indifferent between implementing Direct Rule and not. Direct Rule is preferred only when the signal is sufficiently precise, or $q_t > q^*$.

Proof of Proposition 4: The ruler will only have an incentive to invest a positive amount in increasing future legibility if Direct Rule is in place or if the ruler can profitably transition to Direct Rule within N periods, where this number N depends on the ruler's discount factor β and the technology of legibility investment $g(q_t, I_t)$.

Proposition 1 illustrates that the ruler's choice of contract this period and the decision to invest are separable in the sense that the optimal contract only depends on current-period legibility and given that investment only begins to pay off in subsequent periods. The trade-off that the ruler faces in determining whether to invest in legibility can thus be represented by:

$$\beta \left[V_R(q_t + g(q_t, I_t), C^*(q_t + g(q_t, I_t))) - V_R(q_t, C^*(q_t)) \right] > I_t \tag{A12}$$

where I_t represents the investment made this period, V_R is continuation value for the ruler, and the other variables are defined as above. In other words, the discounted future benefit of investment in legibility must outweigh the immediate costs.

The lefthand side of expression A13 can be further decomposed into two components: the discounted increased benefit of legibility investment in period t_1 and the twice-discounted continuation value from $t+2$ forward. Let $\beta\left[U^*(q_t+g(q_t,I_t))-U^*(q_t)\right]$ be the discounted difference in the increased amount of revenue retained next period with and without investment, given optimal choice of contract, and let $\beta^2\left[V_R^*(I_t)-V_R^*(0)\right]$ represent the continuation value, assuming optimal choice of contract and investment in each period going forward.

Consider the case where $q_t+g(q_t,I_t)<q^*$ for any possible I_t, where q^* represents the threshold level of eligibility needed for a transition to Direct Rule to be beneficial (Prop 3). This implies that the ruler will not choose to transition to Direct Rule next period, regardless of investment decision today. In this case, $\beta\left[U^*(q_t+g(q_t,I_t))-U^*(q_t)\right]=0$. Because the ruler's per-period payoff under Indirect Rule does not depend on legiblity, investment in legibility does not yield any payoffs next period unless there is a Direct Rule contract in place.

Extending this logic forward, consider a situation where the first period where transition to Direct Rule would be profitable is N periods in future, assuming optimal legibility investment in periods $t+1$ through $t+(N-1)$. In this case, the discounted payoffs to any investment in period $t+1$ through period $t+(N-1)$ are 0 as legibility yields no benefit under Indirect Rule. Then the ruler's investment decision in period t can be represented as:

$$\beta^N\left[V_R^*(I_t)-V_R^*(0)\right]>I_t \tag{A13}$$

As N grows large, the lefthand side of the expression goes to 0 by the assumption that $\beta\in(0,1)$. This implies that there will only be positive investment if Direct Rule transition will occur in some finite N periods of time. Rearranging, for it to be profitable to invest income today, the ratio of the cost today over the future difference in the ruler's expected revenue stream from the point of Direct Rule transition forward must be greater than β^N. This threshold N depends on β (a more patient ruler is more willing to wait longer for investment to payoff).

Proof of Proposition 5: Let q_0 represent the baseline level of legibility. If dismissal cost x is sufficiently high, the ruler will only invest a positive amount I_t to improve legibility if q_0 is larger than some threshold value $\hat{q}$. This threshold is increasing in the cost of replacing an agent x and in the cost of transition κ, and decreasing in the ruler's level of patience β and the technology of legibility development $(g(q_t,I_t))$.

This result builds on the prior one. The prior proposition established that investment in legibility can only be profitable if the ruler will transition to Direct Rule within N periods of time t, where this threshold N depends on the ruler's discount factor β. Proposition 3 establishes that this transition will only occur at some time $t+n$ if $q_{t+n} > q^*$.

Recall that $\bar{I}$ represents the maximum investment in legibility that can be made in any period. This implies that, for given baseline legibility q_0, the maximum improvement in legibilty possible for next period is $g(\bar{I}, q_0)$. Let $\tilde{g}(q_0, n)$ represent the maximal increase in legibility in a district possible over n periods, given starting legibilty q_0 (i.e., the increase in legibility n periods from now that would obtain if the ruler invests the maximum amount $\bar{I}$ each period. Note that $\tilde{g}(q_0, n) < ng(\bar{I}, q_0)$ by the assumptions that $\frac{\partial g}{\partial q_t} < 0$ and $g(\cdot) \geq 0$ (there is a decreasing marginal benefit to investment as legibilty improves and legiblity does not decline over time). This implies that:

$$\bar{q}(q_0, n) < q_0 + ng(\bar{I}, q_0) \tag{A14}$$

where $\bar{q}(q_0, n)$ is the highest level of legibility possible to obtain in a district within n periods starting from point q_0 (using the assumption that $\frac{\partial g}{\partial I_t} > 0$, so investing $\bar{I}$ yields the highest potential gain in legibility each period). Let N represent the threshold number of periods in the future that the transition to Direct Rule can occur for any investment to be worthwhile, as shown in Proposition 4. If $\bar{q}(N) < q_0 + Ng(\bar{I}, q_0) < q^*$, the maximum investment over N periods will not raise legibility enough to enable the ruler to profitably transition to Direct Rule by time N, so he will have no incentive to invest in improving legibility. Rearranging terms, we can see that the ruler has no incentive to invest if baseline legibility is sufficiently low ($q_0 < q^* - Ng(\bar{I}, q_0)$).

Define $\hat{q}$ as the baseline level of legibility starting from which the ruler would be able to just obtain enough legibility to transition to Direct Rule in N periods (i.e., $\bar{q}(\hat{q}, N) = q^*$). Then the ruler will have no incentive to invest in legibility if baseline $q_0 < \hat{q}$. Note that by the prior proposition, this threshold will depend on the level of patience as this determines the number of periods that the ruler is willing to wait to transition to Direct Rule. It also depends on the technology of enhancing legibility over time as this determines how quickly legibility can be improved, noting that $g(\cdot)$ appears implicitly in the expression for $\bar{q}(q_0, n)$. Finally , this threshold $\hat{q}$ also depends on the threshold q^* from Proposition 3. As the costs of Direct Rule x and κ rise, both q^* and $\hat{q}$ increase because this raises the necessary bar for Direct Rule to be worthwhile for the ruler.

B. Descriptives

Table B.1: Descriptive Statistics

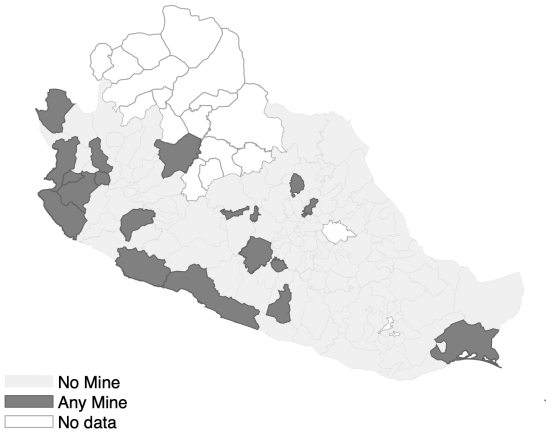
Panel A: Direct Rule Sample: 1520–1650

	N	Mean	Std. Dev.	Min.	Median	Max.
Direct Rule (%)	2016	0.51	0.36	0.00	0.50	1.00
Any Mine	2016	0.12	0.33	0.00	0.00	1.00
Any Early Mine	2016	0.10	0.31	0.00	0.00	1.00
Year of European Contact	2016	1522.40	6.27	1518.00	1521.00	1580.00
Malarial Zone	2016	0.64	0.48	0.00	1.00	1.00
Avg. Altitude	2016	1560.03	736.02	25.79	1661.97	2904.21
Surface Area (log)	2016	7.64	1.19	4.68	7.80	10.03
Least-Cost Walking Time to Mexico City	2016	8552.64	5540.80	172.41	7578.11	21339.27
Std. Dev. PDSI	1960	1.74	0.44	0.65	1.72	3.96
Avg. PDSI	1960	0.52	0.97	-3.10	0.39	3.38
Min. PDSI	1960	-2.16	1.24	-5.67	-2.12	1.28
Drought-Rain Around Known Outbreaks	1960	0.03	0.17	0.00	0.00	1.00
Cochineal Production Site	2016	0.19	0.40	0.00	0.00	1.00

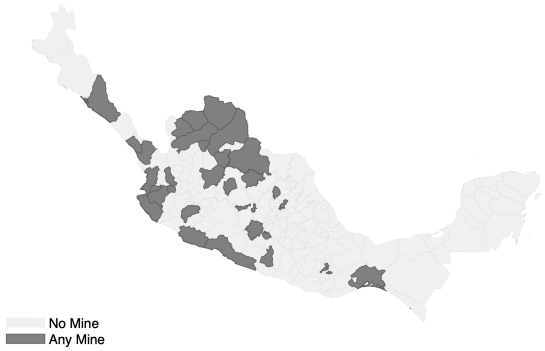
Panel B: Royal Treasuries Sample: 1520–1770
(Regions with Traditional Indirect Rule Institutions)

	N	Mean	Std. Dev.	Min.	Median	Max.
Least-Cost Walking Time to Nearest Treasury	5077	4973.46	3940.34	125.11	4172.96	29724.58
Least-Cost Walking Time to Nearest Treasury (log)	5077	8.20	0.87	4.84	8.34	10.30
Any Mine	5077	0.16	0.36	0.00	0.00	1.00
Any Early Mine	5077	0.11	0.31	0.00	0.00	1.00
Year of European Contact	5073	1527.09	15.53	1518.00	1521.00	1649.00
Malarial Zone	5073	0.62	0.48	0.00	1.00	1.00
Avg. Altitude	5073	1578.86	705.49	25.79	1676.23	2904.21
Surface Area (log)	5073	7.92	1.33	4.68	8.14	11.89
Std. Dev. PDSI	5044	1.86	0.44	0.65	1.86	3.96
Avg. PDSI	5044	0.43	0.89	-3.17	0.34	3.38
Min. PDSI	5044	-2.51	1.28	-6.62	-2.32	1.06
Drought-Rain Around Known Outbreaks	5044	0.02	0.13	0.00	0.00	1.00

Figure B.1: Maps of 16th Century Mining Districts and Sample Districts



(a) Sample with direct rule data (New Spain/Nueva Galicia)



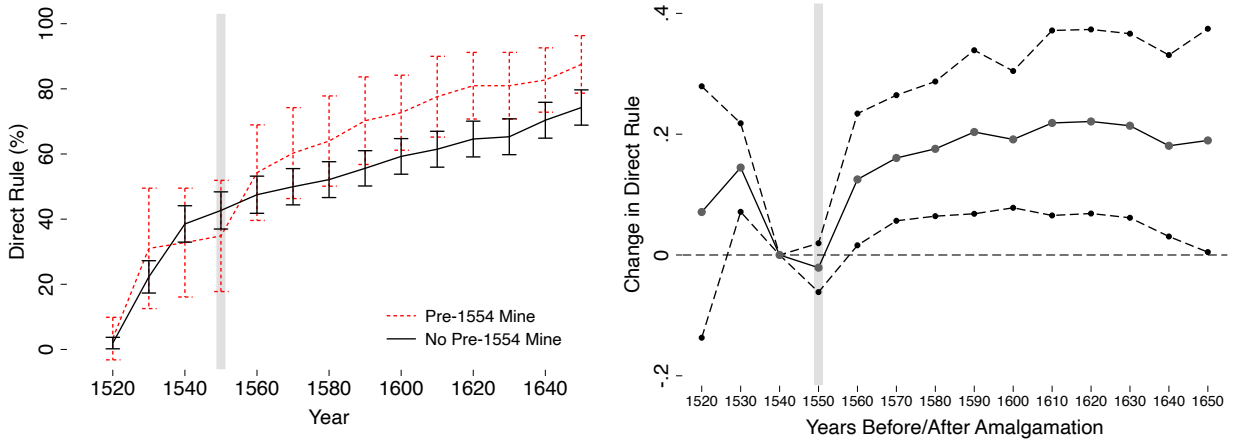
(b) Regions with traditional indirect rule institutions

(c) Mining districts and Royal Treasuries by the 1770s, with date of establishment

C. Additional Evidence

C.1 Main Results with Pre-1554 Mines

Figure C.1: Silver Mining, Amalgamation, and Direct Rule
Early Mines



(a) Trends over time

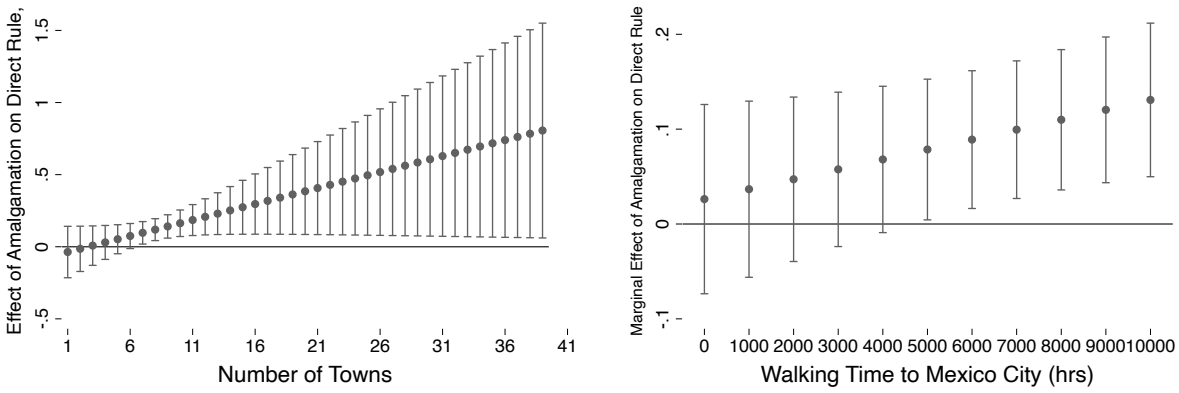
(b) Dynamic Panel Estimates

Table C.1: Heterogeneous Effect of Silver Amalgamation on Direct Rule: Difference-in-Differences
Early Mines

	Direct Rule (% of District)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Any Early Mine × Post-Patio Process	0.18**	0.17**	-0.059	-0.038	0.19***	0.13**	0.026	0.074
	(0.077)	(0.074)	(0.10)	(0.12)	(0.059)	(0.063)	(0.051)	(0.050)
Early Mine × Post-Patio × Resistance during Conquest	-0.068	-0.053						
	(0.089)	(0.083)						
Early Mine × Post-Patio × Number of Towns			0.022*	0.019*				
			(0.012)	(0.011)				
Early Mine × Post-Patio × Former Triple Alliance					-0.14**	0.012		
					(0.060)	(0.072)		
Early Mine × Post-Patio × Hours to Mexico City							0.000010*	0.0000069
							(0.0000054)	(0.0000060)
Early Mine × Post-Patio + Resistance	0.12**	0.11***						
	(0.05)	(0.05)						
Early Mine × Post-Patio + Former Triple Alliance					0.046	0.14***		
					(0.03)	(0.04)		
Climate Controls	No	Yes	No	Yes	No	Yes	No	Yes
Controls × Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Year of European Contact × Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Within-District Mean of DV	0.51	0.52	0.51	0.52	0.51	0.52	0.51	0.52
Within-District SD of DV	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
R sq.	0.78	0.81	0.78	0.81	0.78	0.81	0.78	0.80
Observations	2016	1960	2016	1960	2016	1960	2016	1960
Number of districts	144	140	144	140	144	140	144	140

OLS estimations. Unit-of-analysis is the district-decade. Standard errors (clustered at district level) in parentheses.

Figure C.2: Silver Mining, Amalgamation, and Direct Rule
Heterogeneous Effects

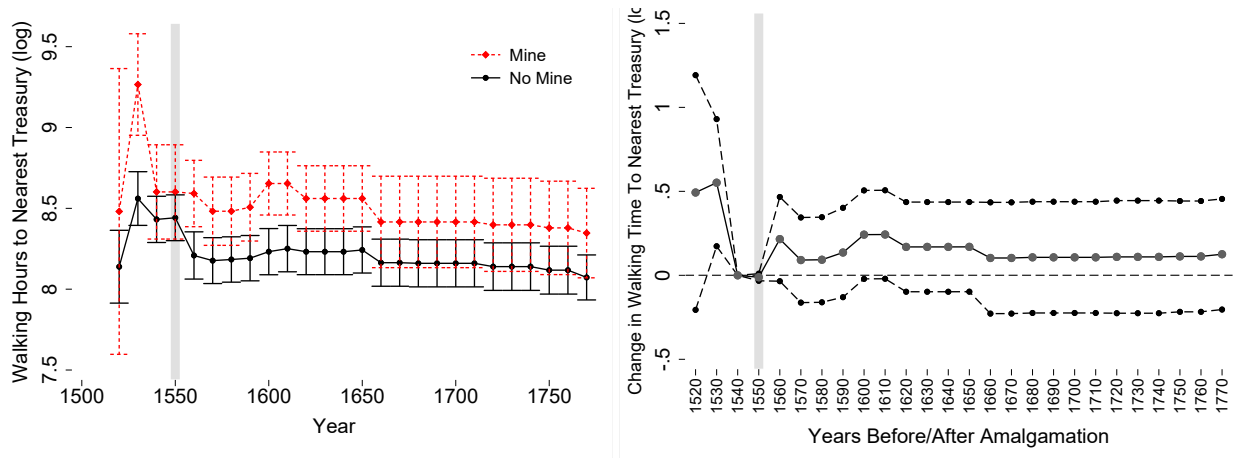


(a) By Number of Towns (1786)

(b) By Waking Hours to Mexico City

C.2 Endogenous Investment in Fiscal Legibility

Figure C.3: Amalgamation and Walking Time to Nearest Royal Treasury (log)



(a) Trends over time

(b) Dynamic Panel Estimates

Table C.2: Amalgamation and Walking Time to Nearest Royal Treasury (log): Difference-in-Differences

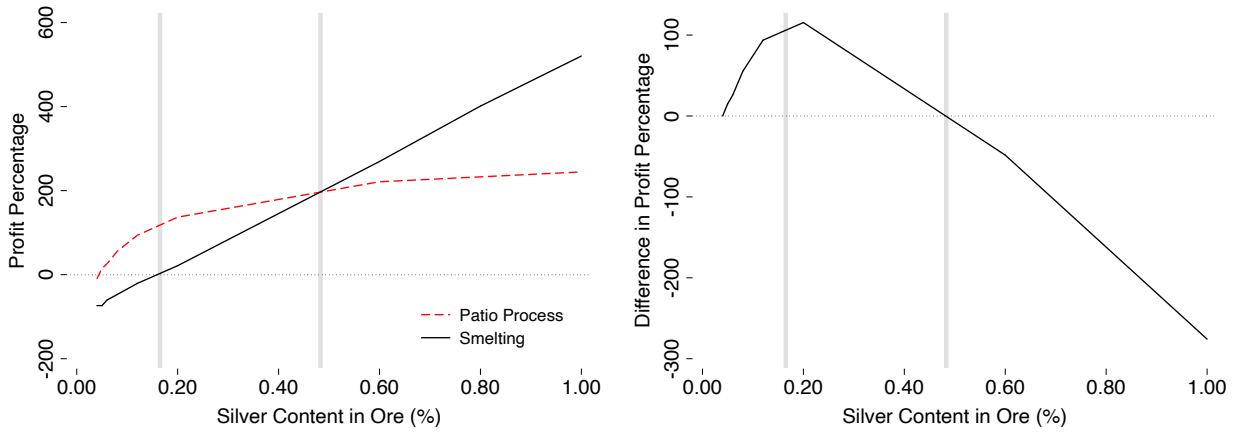
	Walking Hours to Mexico City (log)			
	Regions with Direct/Indirect Rule		Sample with Direct/Indirect Rule	
	(1)	(2)	(3)	(4)
Any Mine × Post-Patio Process	-0.041	0.13	-0.089	-0.0053
	(0.11)	(0.13)	(0.088)	(0.13)
Climate Controls	No	Yes	No	Yes
Controls × Year FE	No	Yes	No	Yes
Year of European Contact × Year FE	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Within-District Mean of DV	8.20	8.19	8.10	8.08
Within-District SD of DV	0.29	0.30	0.31	0.31
R sq.	0.87	0.90	0.86	0.88
Observations	5077	5044	4464	4200
Number of districts	176	175	144	140

OLS estimations. Unit-of-analysis is the district-decade. Standard errors (clustered at district level) in parentheses.

D. Revenue Potential as an Alternative Mechanism

The discovery of the patio process led to an exogenous shift in the Crown's legibility of silver production due to its control over the supply of mercury, an essential input in this refining technique. At the same time, however, this new process increased the profitability of extraction in certain deposits. In particular, it enabled the profitable mining of ores with lower silver concentrations. Thus, it remains possible that this increased profitability, and not fiscal legibility, explains the results presented in Table 1.

Figure D.1: Profitability Percentages for the Patio Process and Smelting



(a) Profit Percentages

(b) Difference in Profit Percentages

The figure on the **left** plots the estimated profit percentage $(net\ profit/cost)$ for processing silver using smelting (black solid line) and the patio process (red dashed line) at different levels of ore silver content. The figure on the **right** plots the difference in the profit percentages between the patio process and smelting. Cost estimates and effectiveness of silver extraction by method from Guerrero (2017).

In the left panel of Figure D.1, we present estimates of the return on investment for processing silver using the patio process and the traditional method of smelting, based on detailed production information from the Hacienda Santa María de Regla in the XIX century and input prices for the second half of the XVII century, computed by Guerrero (2017). These estimates suggest that the introduction of the patio process affected production in two main ways. First, it enabled the profitable processing of ores of very low silver content — between around 0.04% and 0.16% — which were not economically viable via smelting. Above this threshold, and up to ores of a silver concentration of around 0.48%, amalgamation also offered a higher return on investment than

smelting. For deposits with higher silver concentrations, however, amalgamation remains more profitable: this was the case because, while smelting processing costs remain fixed, the patio process requires additional mercury to effectively extract silver from even richer ores.[21]

Without detailed information about the silver-extraction processes in each district, including changes in profits following the introduction of amalgamation, we are unable to examine whether changes in profitability explain our findings, and so we cannot rule out this alternative mechanism directly. Instead, we assess additional observable implications from the legibility-based theory that are not explained by increased profitability in Table 2 and Figure 3. In this section, we pursue a second indirect approach. We focus on the role that a notable price shock to cochineal dye — one of the most important commodities produced in colonial Mexico at the time — had on the adoption of direct rule among Cochineal-producing districts. The cochineal price shock arguably induced a much larger increase in profitability than the introduction of the patio process. Depending on the time window and price series, the increase ranged from 180 to 420% (see Figure 2), and, given the type of artisanal production, it is unlikely that production costs changed drastically over the period.

D.1 Evidence from a Cochineal Price Boom

Cochineal dye, produced from the cochineal insect, became a prized luxury good in European markets following the conquest. By the end of the 16th century, it was the third most important export commodity from colonial Mexico after silver an gold, accounting for almost 9% of the value of silver exports (Lee 1951). In Europe, the dye was considered of superior quality, due to its long-lasting deep red color — associated with the nobility and higher positions in the church (Marichal 2014). Following its introduction to European markets in 1526, imports primarily served the Spanish textile industry, but eventually found their way into the rest of the continent, including important textile centers in England, France, the Low Countries, and Italy, and later even into Asian markets (Lee 1951). This expansion fueled a demand-driven cochineal boom, which accelerated in the last decade of the 16th century.

To quantify this shock to cochineal external demand, we rely on a number of price series collected in different European markets, compiled and normalized to silver pesos per *arroba* ($\sim$ 25lb) by

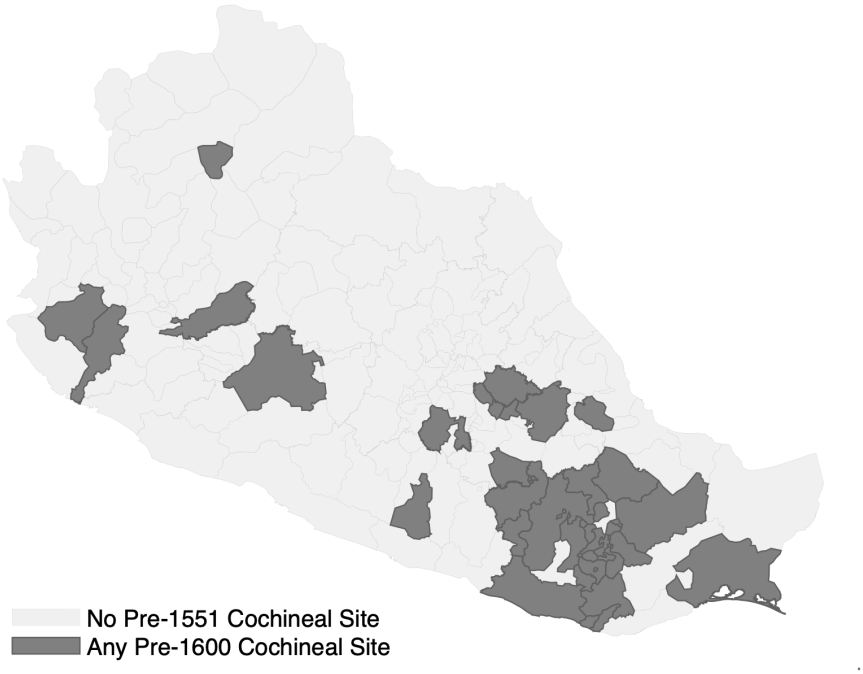
[21] Moreover, while amalgamation is effective for silver sulphide deposits, the most common in the Americas, smelting remained the only feasible method for argentiferous lead deposits.

Serrano (2016). For each price series, we average prices per decade, ignoring missing years. This allows to sidestep year-to-year price fluctuations that are likely driven by short-term supply, as well as to match this data to our decadal panel on direct rule. We focus on three series: first, data from Chaunu and Chaunu (1956), who present the most complete series around the onset of the price hike, based on official import registries in Seville; second, an average of prices in Spain, composed of the Chaunu and Chaunu series, as well as spottier data from Sanz (1979) and Morineau (1969), also mostly based on official records; and an average of all available series, including the Spanish sources, scattered transaction prices at Antwerp and Florence, collected by Sanz (1979), as well as market prices at Amsterdam, compiled by Posthumus (1946), which become more complete beginning in the second decade of the 17th century.

The resulting series are presented in the right panel of Figure 2. Across series, there is a notable increase in the price of cochineal dye at the close of the 16th century, with an especially steep hike beginning in the 1590s. This timing may be related to the rise of Amsterdam as a new market for the dye, which in time facilitated its reach beyond western European markets, as well as to scarcity associated with the ongoing Spanish-English and Spanish-Dutch wars. The boom continued after these conflicts came to a halt — in 1604 and 1609, respectively — and lasted until at least the first few decades of the 17th century.

To examine whether this steep increase in the value of cochineal — with no changes to its fiscal legibility — led to a differential transition to direct rule, we compare centralization between cochineal- and non cochineal-producing districts around the years of the price hike. Since pre-hispanic times, cochineal production was concentrated in certain regions, due in large part to the specific environmental conditions that allow for its cultivation (see Figure D.2). To identify these cochineal-producing areas, we georeference a list of production sites compiled by Donkin (1977), based on primary sources that incude the Triple Alliance's *Matrícula de Tributos* for the prehispanic period, and the *Suma de Visitas*, and the *Relaciones Geográficas* for the 16th century. We then assign these sites to the districts used in the main analysis. Because cochineal production seems to respond endogenously to prices, as noted by Diaz-Cayeros and Jha (2016), we focus on pre-1551 sites.

Figure D.2: Map of Pre-1551 Cochineal-Producing Districts



Using these data, we estimate a modified version of equation 5.1:

$$Direct\ Rule_{it} = \beta_1 Cochineal\ District_i \times Cochineal\ Price_t + \Theta_t X_i + \Pi U_{i,t} + \lambda_t + \gamma_i + \varepsilon_{it}, \quad \text{(A1)}$$

where $Cochineal\ District_i$ indicates whether a district contains pre-1551 cochineal-producing sites and $Cochineal\ Price_t$ is one of the cochineal price series described above. We present the estimates for specifications with and without climate $U_{i,t}$ and time-interacted geographic controls X_i for the three price series in Table D.1. In all cases, the estimates are very small. A one standard deviation increase in price is estimated to increase direct rule by between 0.5 and 2 percentage points. The largest point estimate, from model 1, indicates that an increase in price from the pre-hike 1580 decade to the highest value in the Chaunu and Chaunu series — from 59.2 to 173 silver pesos per arroba of cochineal — is associated with a 4 percentage point increase in direct rule. The rest of the coefficients suggest even smaller associations including in models 5 and 6, which use a price series that reaches a global high of almost 240 silver pesos per arroba of cochineal in 1630. Moreover, in no case are these estimates statistically significantly different from zero.

In short, when using a different commodity — one of great importance in the colonial economy — we find no evidence that a notable increase in its revenue potential led to differential changes in

Table D.1: Cochineal-Producing Sites, Cochineal Price Shock, and Direct Rule: Difference-in-Differences

	Direct Rule (% of District)					
	(1)	(2)	(3)	(4)	(5)	(6)
Cochineal Site × Price (Chaunu & Chaunu)	0.00038	0.00029				
	(0.00034)	(0.00036)				
Cochineal Site × Price (Avg. Spain)			0.00035	0.00023		
			(0.00035)	(0.00037)		
Cochineal Site × Price (Avg. Spain/Florence/Antwerp/Amsterdam)					0.00017	0.000078
					(0.00024)	(0.00025)
Climate Controls	No	Yes	No	Yes	No	Yes
Controls × Year FE	No	Yes	No	Yes	No	Yes
Year of European Contact × Year FE	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Within-District Mean of DV	0.55	0.55	0.55	0.55	0.60	0.60
Within-District SD of DV	0.11	0.11	0.11	0.11	0.14	0.13
R sq.	0.86	0.87	0.86	0.87	0.84	0.85
Observations	1152	1120	1152	1120	1584	1540
Number of districts	144	140	144	140	144	140

OLS estimations. Unit-of-analysis is the district-decade. Standard errors (clustered at district level) in parentheses. All prices are in silver pesos per arroba of cochineal, as converted by Serrano (2016). Models 1 and 2 use the price series from Chaunu and Chaunu (1956); models 3 and 4 use an average of available Spanish series, from Chaunu and Chaunu (1956), Sanz (1979), and Morineau (1969); models 5 and 6 average across all available series, including the Spanish series, prices from Antwerp and Florence (Sanz 1979), and from Amsterdam (Posthumus 1946). Pre-1551 cochineal-producing sites from Donkin (1977).

direct rule. Without a shift in fiscal legibility similar to the patio process for silver mining, on-site taxation of cochineal remained out of reach to the Crown, and cochineal-producing districts did not experience the same transition from non-dismissal to dismissal contracts.[22]

[22]The Crown in fact floated different plans to appropriate part of the increasing value of cochineal, including monopolizing its trade by forcing all imports into the king's account. Instead, a hefty Spanish export tax — of approximately 14 silver pesos per arroba — was enacted around 1608, on top of preexisting Mexican taxation, which included a tithe, sales taxes, export tariffs, and other levies. As Lee (1951) documents, this plan backfired: as the export tax was rolled out for all dye leaving Spain, cochineal-related revenue collapsed, and, as was recognized by the members of the council of hacienda, the black market for the dye exploded.

E. Data Appendix

E.1 Distance Measure Construction

To construct our measures of time-varying distance to the nearest royal treasury, we first geolocate each treasury constructed over the colonial period up to the Bourbon reforms in the 1570s and code its date of construction (Table E.1). We then construct a time-varying measure of the minimum and space-weighted average distance to the nearest caja at the district (1786 administrative region) level by decade.

We calculate distance in several ways. The simplest measure is the (minimum and space-weighted average) Euclidean distance to the nearest treasury by decade. This measure ignores any barriers to travel, such as mountains or ocean, which is a potential concern given Mexico's mountainous terrain. We therefore construct an alternative measure that accounts for terrain ruggedness, drawing on Least-Cost Analysis (LCA) methods from archaeology (White 2015). To do this, we use a 90-m resolution digital elevation model (DEM) from INEGI to create a slope raster. We then transform the slope into a travel friction surface using the procedure described in White (2015) based on Tobler's Hiking Function, which calculates potential walking speed across terrain as a function of slope. Tobler's Hiking Function is given by:

$$W = 6e^{-3.5*|S+0.05|} \tag{A1}$$

where W represents walking speed in kilometers per hour and S is the slope of the surface.[23] We use this to create our friction surface (i.e., the time needed to traverse each raster cell in hours) by dividing the DEM resolution (0.09 km) by estimated walking speed. Oceans are considered infinitely difficult to traverse and are omitted. We then use this friction surface to calculate a surface of the cumulative cost distance to the nearest treasury using GIS software (White 2015). Finally, we extract the minimum and space-weighted average cumulative travel cost to the nearest treasury (in hours) by 1786 administrative region and by decade. (For comparability, we divide the Euclidean distance measure in km for our analysis by the maximum Tobler walking speed of 5 km/hr.)

[23] As White (2015) describes, "slope" here carries the meaning of "change in elevation over linear distance", which is distinct from the typical GIS slope output (angle in degrees). To obtain rise-over-run slope, we convert the slope angle in degrees into radians and calculate the tangent.

Table E.1: *Cajas Reales*/Royal Treasuries in Colonial Mexico, 1520–1779

Location	Region	Years	Source
Mexico City	New Spain	1521	TePaske and Klein (1986)
Veracruz	New Spain	1531	TePaske and Klein (1986)
Merida	Yucatan/SE	1540	TePaske and Klein (1986)
Compostela	Nueva Galicia	1543–1559	Bakewell (1971); Parry (1968)
Guadalajara	Nueva Galicia	1560	Bakewell (1971); Parry (1968)
Acapulco	New Spain	1562	Maniau y Torquemada (1794)
Durango	Nueva Vizcaya	1563	Lacueva (2011)
Zacatecas	Nueva Galicia	1571	Bakewell (1971); Parry (1968)
Chiametla	Nueva Galicia	1575–1601	Lacueva (2011)
San Luis Potosi	New Spain	1628	TePaske and Klein (1986)
Guanajuato	New Spain	1665	TePaske and Klein (1986)
Pachuca	New Spain	1667	TePaske and Klein (1986)
Sombrerete	Nueva Galicia	1681	Maniau y Torquemada (1794)
Campeche	Yucatan/SE	1716	TePaske and Klein (1986)
Zimapan	New Spain	1721	Maniau y Torquemada (1794)
Tabasco	Yucatan/SE	1728	TePaske and Klein (1986)
Bolaños	Nueva Galicia	1753	TePaske and Klein (1986)
Alamos	Sinaloa & Sonora	1770–1782	TePaske and Klein (1986)
Presidio del Carmen	Yucatan/SE	1774	TePaske and Klein (1986)

Notes: Where no end date is noted, the treasury remains until the end of the colonial period. Because TePaske and Klein (1986) generally assign the dates establishment to the first year with available records — which could erroneously identify a treasury as being created years after its real establishment — we reviewed the secondary historical literature to verify the dates of treasury establishment. We keep the date from the most reliable source. We follow the formal criteria used during the period to identify a royal treasury: having an appointed treasurer and accountant. This sets main treasuries apart from smaller dependent offices that were staffed by these officials' deputies. The only exceptions to this coding rule are the treasuries of Veracruz and Acapulco, both of which were dependent on the Mexico City treasury, but which were among the most important treasuries throughout the colonial period. TePaske and Klein (1986) speculate that the Tabasco treasury may have existed for a very brief period in the early 17th century (1605–1612) and then disappeared, but it is not clear whether it was merely a dependent office during those early years. Chiametla stopped operating briefly between 1587 and 1590; we consider it to be operative in the 1580 decade when we aggregate to the decadal level.

We additionally construct a cost distance measure that incorporates land cover and elevation as well as slope. This is an important consideration given the high elevations in parts of interior Mexico and the difficulty of traversing dense jungle in much of the southeast. We use the approach of Weiss et al. (2018), who estimate the typical walking speed (km/hr) across different terrain types (as classified by IGBP land cover classifications). These walking speeds (Table E.2) are multiplied by slope adjustment factor (Tobler's Hiking Function, divided by the maximum speed of 5 km/hr)

and an elevation adjustment factor to account for the difficulty of traversing terrain at high altitudes where oxygen levels are low. Weiss et al.'s elevation adjustment factor is given by:

$$1.016e^{-0.0001072*elev} \tag{A2}$$

where *elev* is elevation in meters. By multiplying the three terms (estimated walking speed by land cover, the slope adjustment factor based on Tobler's Hiking Function, and the elevation adjustment factor), we obtain a composite measure of walking speed in km/hr across terrain. We use this composite walking speed to create travel friction and cumulative cost-distance surfaces, as described above, and to create a comparable decadal panel of minimum and space-weighted average cost distance to the nearest treasury in hours.

The elevation and slope measures are calculated from the same 90-meter DEM from INEGI. For the land cover analysis, we use the Goldewijk (2010) ISLSCP II Historical Land Cover and Land Use dataset, which provides an estimate of global land cover from 1700 to 1990 at a resolution of 0.5 degrees. Using the 1700 data (the earliest) as a base, we convert the ISLSCPII land cover measures to IGBP equivalents to use the walking speed multipliers in Weiss et al. (2018) (Table E.2). We verified these conversions using contemporary remote sensing data from NASA's MODIS project.

Because of the coarse resolution of the ISLSCP II land cover dataset, some coastal and lakefront land is coded as ocean/open water, including a couple of coastal treasuries. We handle these overlapping areas in two ways. We first use the Weiss et al. (2018) speed multiplier for open water (1.00) as a conservative estimate of the speed needed to traverse these areas. We alternatively use a multiplier of 4.86, corresponding with grassland, pasture, or savanna. Virtually all of the land areas in overlapping ocean cells border one of these three land categories, which together make up over 42% of Mexico's land area in the original dataset. We believe that the faster speed more accurately reflects the cost of traversing coastal zones, which are at sea level and generally flat. However, because so few land areas overlap with water, there is little difference between these measures in practice.

Table E.2: Land Cover Walking Speed Multipliers

ISLSCP II Land Cover Category	IGBP Equivalent	Weiss et al. (2018) Multiplier	Description
Ocean	See text	1.00/4.82	See text for description of alternate measures
Cultivated Land	Croplands	2.50	Seasonal croplands with a bare soil period
Pasture	Grasslands	4.86	Herbaceous cover; less than 10% tree and shrub cover
Warm Mixed Forest	Mixed Forest	3.24	Over 60% mixed tree cover, with height exceeding 2 meters
Grassland	Grasslands	4.86	Herbaceous cover; less than 10% tree and shrub cover
Hot Desert	Barren	3.00	Exposed soil, sand, and rocks, no more than 10% vegetated
Scrubland	Open Shrublands	4.20	Short (<2 m), woody vegetation, with 10-60% canopy cover
Savanna	Savannas	4.86	Herbaceous cover, 10-30% forest canopy cover
Tropical Woodland	Evergreen Broadleaf Forest	1.62	At least 60% broadleaf forest cover, with height exceeding 2 m. Year-round green vegetation.
Tropical Forest	Evergreen Broadleaf Forest	1.62	At least 60% broadleaf forest cover, with height exceeding 2 m. Year-round green vegetation.

Notes: See Weiss et al. (2018) for description of methodology. IGBP land cover category descriptions from the University of Oklahoma Earth Observation and Modeling Facility (EOMF).

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