

Fiscal Legibility and State Development: Theory and Evidence from Colonial Mexico^{*}

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October 13, 2022

Abstract

We examine how fiscal legibility, the ability of central authorities to observe local economic conditions for the purposes of taxation, shapes political centralization and state development. When rulers lack information about the periphery, they may cede autonomy to tax-collecting intermediaries to encourage fiscal performance. As information quality improves, rulers are better able to monitor and sanction local officials, allowing them to tighten control over taxation and establish more direct state presence. Centralization encourages additional investment in improving fiscal legibility, leading to long-term divergence in state development. We study the consequences of a technological innovation that dramatically improved the Spanish Crown's fiscal legibility in colonial Mexico: the discovery of the patio process to refine silver. We show that political centralization differentially accelerated in affected districts, that these areas saw disproportionate state investment in informational capacity, and that they were more resilient to institutional decline over a century later.

^{*}We thank Leticia Arroyo Abad, Dan Gingerich, Robin Grier, Mai Hassan, Ning He, Ruixue Jia, Alexander Kustov, Craig McIntosh, Nathan Nunn, Craig Palsson, Giuliana Pardelli, Gerard Padró i Miquel, Dan Posner, Luis Rodríguez, Oriol Sabate, Mariano Sánchez Talanquer, Hillel Soifer, as well as seminar participants at UCSD, UVA, CIDE, MPSA, REPAL, the Oz Virtual Economics Seminar at UNSW, SIOE, the HPE Working Group, the STANCE conference at Lund, King's College London, LACEA-EHN Workshop on Historical Development, APSA, Texas Tech, the PIPE seminar at USC, Penn, NEUDC, Oxford Economic History Workshop, Bocconi, NYU, UCLA, Chicago, and the Long Range Development in Latin America Conference for their thoughtful feedback.

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1. Introduction

What enables political centralization? The consolidation of power under a central authority lays the foundation for the construction of state capacity and longer-term institutional and economic development, for better (e.g. Mamdani 1996; Lange 2004; Gennaioli and Rainer 2007; Michalopoulos and Papaioannou 2013; Osafo-Kwaako and Robinson 2013) or for worse (e.g. Iyer 2010; Ahmed and Stasavage 2020; Stasavage 2020). Though state centralization can be attractive for those in power, central authorities often lack the willingness or ability to seize political control from local elites in the periphery. Indirect forms of rule, which allow provincial elites to retain considerable autonomy, may allow rulers to extend political authority and extract revenue from areas that are distant, underdeveloped, or physically impenetrable (e.g. Gerring et al. 2011; Garfias and Sellars 2021).

A crucial consideration in determining whether to centralize power is the state's level of fiscal legibility: the ability of central authorities to independently observe, measure, and assess populations, their wealth, and their activities for the purposes of taxation and control (e.g., Kain and Baigent 1992; Scott 1998; Lee and Zhang 2017). When central authorities are 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; Mayshar, Moav, and Neeman 2017; Balán et al. 2021). However, reliance on local authorities is costly in that it requires the central government to sacrifice revenue and decision-making autonomy to these elites. As rulers become better able to independently monitor and police activity across the territory, they can reduce these costs by exerting more direct control over local intermediaries and the population as a whole.

Building fiscal legibility is often difficult, costly, and constrained by geographic, social, technological, political, and other factors. In this paper, we examine how a sudden exogenous increase in fiscal legibility influences political centralization and longer-term state development. Building on work by Scott (2017), Mayshar, Moav, and Neeman (2017), and Stasavage (2020), our theory focuses on how the quality of information available to central authorities about conditions in the periphery influences their incentives to centralize political control and to invest in improving the

state's informational capacity for the future. When a ruler is unable to observe local economic conditions, it is difficult to tell whether a disappointing tax receipt is due to poor conditions or underperformance of tax-collecting intermediaries. In this situation, exerting tight control over intermediaries through the threat of dismissal is prohibitively costly because of the high likelihood of mistakes. Rather than pay the cost of improving monitoring capacity, rulers in low-information environments can rely on indirect forms of rule, which encourage intermediary performance solely through increased autonomy and high compensation.

If fiscal legibility improves, however, it becomes easier for central authorities to identify poor performance and credibly threaten to replace intermediaries who shirk on their duties. This encourages political centralization, which, in turn, has important dynamic consequences for longer-term state development. Because indirect forms of rule do not depend on direct monitoring and sanctioning of intermediaries, central authorities have less incentive to invest in improving informational capacity in peripheries under indirect rule. Under direct rule, by contrast, even a small additional improvement in fiscal legibility is beneficial because it makes it easier to monitor intermediaries and identify poor performance. Because of this, central authorities are more willing to invest in improving fiscal legibility through concerted efforts to obtain, organize, and transmit information about the periphery back to the center in areas under direct rule. Because of the dynamic relationship between political centralization and fiscal legibility, a single exogenous increase in the quality of fiscal information available to central authorities can lead to a longer-term divergence in state development.

We provide empirical support for this argument using subnational data from colonial Mexico. In the early colonial era, the Spanish Crown administered territory through 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. Over time, the Crown sought to centralize authority, replacing *encomiendas* with *corregimientos*, a more direct form of 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. While some areas moved to direct rule

within a generation of the Conquest, others remained in *encomienda* for the duration of the colonial period.

Our analysis focuses on the short- and longer-term consequences of a major technological innovation in silver mining that suddenly improved fiscal legibility in some districts. During the 1550s, a new technology to refine silver, the patio process, 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). Importantly for our argument, the 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 institute and enforce a monopoly over the sale and distribution of this key input. This gave central authorities a direct and reliable new way to observe economic fluctuations in mining districts. The mining sector’s 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 the sudden increase in fiscal legibility in mining districts led to an acceleration in political centralization. The proportion of *encomiendas* that transitioned to direct rule was around 8–13 percentage points higher in mining relative to non-mining districts and relative to the period before the patio process had been discovered. This result is robust across numerous empirical specifications and is substantively large, corresponding to about half of the within-district standard deviation in direct rule adoption over the period of analysis. We present additional evidence suggesting that the acceleration in political centralization was due to the increase in legibility provided by the patio process, as opposed to higher revenue potential, by examining demand-driven price shocks in another important commodity, cochineal dye. As we show, the cochineal boom greatly increased the profitability of economic production but did not affect fiscal legibility and thus did not influence political centralization.

We then investigate how this early shock to fiscal legibility encouraged longer-term state development. We find that affected areas had improved access to state-run post offices (*estafetas*) by the end of the colonial period, a measure of state investment in facilitating communication across the territory and thus informational capacity. We further show that political control of affected areas remained more centralized in the face of a subsequent governance crisis more than a century after the introduction of the patio process. In the early 18th century, the Crown commodified and sold bureaucratic positions as a way of generating revenue. Because both fiscal legibility and political control were higher in affected areas before office selling became commonplace, the Crown had less to gain from outsourcing administration of these districts to private actors, which insulated these areas from the negative consequences of office selling on rent extraction and official corruption (e.g., Pietschmann 1972; Guardado 2018; Garfias and Sellars 2020). Using information on the exhaustion of some 16th-century mines by the late colonial period, we can rule out that the observed long-term relationships are due to the effects of ongoing silver production.

This article makes a theoretical and empirical contribution to the literatures on political centralization, state capacity, and state development. Existing work has highlighted several determinants of state centralization, including demography (e.g., Carneiro 1970; Herbst 2000; Fenske 2013), external threats (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 2021). Building on recent work, we highlight the complementary role that fiscal legibility can play in political centralization by focusing on the agency problems inherent in colonial administration.¹ Scholars have noted how asymmetric information, conflicts of interest, and commitment problems can create agency costs for central rulers and shape institutional development (e.g., Kasara 2007; Ma 2011; Sng 2014; Gailmard 2017, 2019; Hassan 2020). A similar link between state informational capacity and political centralization has been noted, for example, in

¹Our focus is state centralization, as opposed to the emergence of the state (e.g., Boix 2015; Dal Bo, Hernández, and Mazzuca 2022; Scott 2017; Mayshar, Moav, and Pascali 2022) or the consolidation of territorial control over a new region (e.g. Spruyt 1996; Pierskalla, De Juan, and Montgomery 2017; Acharya and Lee 2018).

work that compares ancient Egypt and Mesopotamia (Scott 2017; Mayshar, Moav, and Neeman 2017), in ancient and contemporary China (Stasavage 2020; Martinez-Bravo et al. 2021), in early modern Europe (Johnson and Koyama 2014), and in U.S. bureaucratic politics (e.g., Gailmard and Patty 2012; Patty and Turner 2021).

Our work extends this line of research, building specifically on the classic work of Scott (1998; 2017) and recent work by 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 exogenous observability or “transparency” of local economic production. We extend these arguments to consider the dynamic relationship between political centralization and state investment in improving informational capacity. Others have emphasized how 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 2021), and the design of government programs (e.g., Hunter and Brill 2016; Harbers 2020), among other factors, encourage or discourage investment in improving fiscal legibility. In highlighting the dynamic interdependence between political centralization and fiscal legibility, our argument connects this work on the endogenous determinants of state capacity with a complementary literature on its *exogenous* determinants, such as geography (e.g., Dal Bo, Hernández, and Mazzuca 2022; Fernández-Villaverde et al. 2020). There is little incentive to invest in improving the capacity of low-legibility areas, but a shock that suddenly increases legibility can shift incentives toward long-term investment in political centralization and state development. This divergence may explain why informational capacity acquired centuries ago can have a persistent effect on present-day fiscal outcomes (D’Arcy and Nistotskaya 2018).

Finally, this work makes an empirical contribution by providing quasi-experimental evidence on the link between fiscal legibility and state development. Much of the existing evidence comes from analytic narratives or case studies (e.g., Ma 2011; Johnson and Koyama 2014; Mayshar, Moav, and Neeman 2017; Ma and Rubin 2019; Slantchev and Kravitz 2019; Stasavage 2020) or from primarily

cross-sectional research designs (e.g., Sng 2014; Ahmed and Stasavage 2020; Huning and Wahl 2020). The features of our context allow us to study how a single exogenous shock to fiscal legibility within an existing state shapes the trajectory of political centralization and then state development at a subnational level over several centuries. Our specific focus on the connection between political centralization and the acquisition of state informational capacity provides an important complement to work examining “legibility” and the state from other perspectives, such as Mayshar, Moav, and Pascali (2022), who document a relationship between the cultivation of cereals (which are easier to monitor and tax than other crops) and the rise of complex hierarchies across countries and societies, and Sánchez de la Sierra (2020), who examines how different commodity price shocks affect state-like functions among militias in the DRC.

2. Theory

We examine the short and long-term consequences of a sudden increase in fiscal legibility on state development. Building on seminal works in this literature, notably the writing of James Scott (e.g., 1998; 2017), we conceive of fiscal legibility as a central authority’s ability to independently observe local economic production for the purposes of taxation and political control. This 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). A ruler’s ability to do this depends both on the exogenous features of a district or territory—such as the characteristics of economic production, the ruggedness of the terrain, or the structure of human settlement—as well as on past and ongoing political decisions to improve informational capacity through, for example, administering censuses, creating cadastral records, improving the communications network, or establishing tax offices to collect information about the local economy.

Our interest is in the interdependent relationship between fiscal legibility and political centralization. Political authorities in nearly every context must rely on local intermediaries to collect taxes and administer territory. As many scholars have recognized (e.g., Levi 1988; Mayshar, Moav, and Neeman 2017; Gailmard 2017; 2019; Balán et al. 2021), this presents a challenging agency problem. Without a

physical presence in the district, a central ruler generally lacks the ability to directly observe how much effort intermediaries put into completing the tasks that they have been delegated. To encourage performance, the ruler has to design a contract that encourages intermediaries to complete assigned tasks in the absence of direct observation.

The institutional solutions to this agency problem have differed considerably across time and space. We compare two idealized contract types, which we call “indirect rule” and “direct rule.” These terms have been used to capture a variety of specific institutions (e.g., Gerring et al. 2011; Naseemullah and Staniland 2016). Our focus is on the characteristics of the contract between rulers and tax-collecting intermediaries. Under indirect rule, local powerholders are granted wide-ranging military, political, and fiscal autonomy in exchange for administering territory and collecting taxes. Intermediaries in these arrangements are generally given longer-term or indefinite contracts and frequently retain independent coercive authority. Examples of these arrangements include the contract between the monarch and lords under feudalism or the model of British indirect rule in much of Africa and South Asia, through which local authorities maintained considerable power and autonomy under the colonial state. Because it is costly and difficult to replace an intermediary under indirect rule, central authorities must encourage performance in tax collection primarily through ceding a greater share of revenues and autonomy to intermediaries.

Under direct rule, by contrast, a central ruler exerts stronger control over tax-collecting intermediaries through an institutionalized bureaucracy, making it easier to fire and replace those who underperform. By leaning more strongly on negative sanctions, a central ruler can lower the amount of compensation offered to intermediaries, retaining a greater share of tax revenue. However, establishing and sustaining direct rule is costly. To transition to this more centralized arrangement, a ruler must not only seize power from the local potentates already in charge of tax collection, but also to invest in and maintain a bureaucracy to administer territory.

In deciding whether to transition to more direct forms of rule, rulers face a trade-off. Direct rule offers the promise of greater political control and revenue retention, but it is also costlier to establish

and potentially costlier to maintain than indirect forms of rule, which do not require them to bear the cost of monitoring and sanctioning intermediaries. Drawing on the insights of recent work (Johnson and Koyama 2014; Mayshar, Moav, and Neeman 2017; Stasavage 2020; Martinez-Bravo et al. 2021), we argue that this trade-off depends critically on the quality of independent information available to a central ruler: the “observability” of production or fiscal legibility. When fiscal legibility is low, it is difficult for the ruler to discern whether disappointing outcomes (such as lower-than-expected tax revenue) are due to poor intermediary effort or bad conditions. When a ruler is unable to identify when intermediaries are underperforming, the costs of direct rule outweigh the benefits as the costs of monitoring and sanctioning would be very high. As fiscal legibility rises, however, the ruler can better tell when the intermediary’s performance is poor. This both reduces the cost and increases the benefits of political centralization. Though the immediate political cost of seizing power from local potentates can be high (e.g., Gerring et al. 2011; Garfias and Sellars 2021), once legibility rises beyond a certain point, it may be worthwhile for the ruler to pay this cost to centralize control. A sudden rise in fiscal legibility can thus encourage political centralization.

We argue that this link between fiscal legibility and political centralization has implications for the longer-term trajectory of state development. As noted above, fiscal legibility is a function not just of geographic or external factors, but also state efforts to collect and disseminate information about the periphery through, for example, the creation of cadastral records, the construction of tax offices, or the expansion of state-run communications networks like postal systems. These “endogenous legibility” investments are costly. We argue that their benefits depend on the form of contract between central authorities and intermediaries.

Because intermediaries under indirect rule are granted broad autonomy to carry out their tasks on a permanent or semi-permanent basis, a ruler gains little from marginally improving his monitoring capacity. Indirect rule contracts do not rely on the threat of firing or other punishment for underperformance, so a ruler has no need to invest in his ability to identify underperformance. By contrast, once the ruler transitions to more direct forms of rule, even a small increase in fiscal legibility is

beneficial. Better information about conditions in the periphery improves a ruler's ability to monitor intermediaries under his supervision, allowing him to exert more control and increasing the share of revenue that he can retain. Political centralization and fiscal legibility thus go hand-in-hand. Direct rule is only beneficial when fiscal legibility is sufficiently high, and it is only when a ruler operates under direct rule, or anticipates an imminent transition to direct rule, that investing in improving fiscal legibility is worthwhile.

The dynamic interdependence between fiscal legibility and political centralization can lead to a longer-term divergence in state institutions between districts with high or low initial levels of legibility. In places where legibility is very low, improving informational capacity to the point where it would be advantageous to centralize political control would require a substantial investment over a long period. This may not be worthwhile for even a moderately patient ruler. Low-legibility areas can thus become locked in a long-term path of indirect rule and low state informational capacity, where the ruler has little incentive to invest in either centralizing power or improving fiscal legibility. However, if fiscal legibility were to suddenly improve to the point where centralization became attractive, the ruler would then have an incentive to further invest in legibility to reap the benefits of greater monitoring under direct rule. This argument implies that a single exogenous increase in fiscal legibility can have marked long-term consequences on the trajectory of political centralization and state development.

2.1 Observable Implications

In the remainder of this paper, we provide empirical evidence in support of this argument, focusing on the following observable implications:

1. An exogenous shock that increases fiscal legibility should encourage political centralization by improving the ruler's ability to accurately monitor intermediaries and thus the benefits of direct rule.
2. An exogenous shock that increases fiscal legibility should increase long-term state investment in informational capacity by encouraging political centralization, which in turn increases the

benefits of improving state monitoring capacity going forward.

3. Because of the interdependence between fiscal legibility and political centralization, a single exogenous shock to fiscal legibility can lead to longer-term divergence in state institutions. Affected areas should see greater long-term investment in state informational capacity, allowing the ruler to sustain centralized political control over these areas during subsequent governance crises.

3. Context

We examine the transition from indirect to direct rule in colonial Mexico around the time of a technological innovation that greatly enhanced the Spanish Crown's ability to monitor local economic production in some areas.

3.1 Indirect Rule in Early Colonial Mexico

The Conquest and early political organization of New Spain relied heavily on the cooperation of conquistadors and other elite intermediaries to extend political control over the distant territory. The *encomienda*, an important 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. Like British indirect rule in Africa or South Asia, the *encomienda* was built on top of pre-existing institutions, most notably the tribute network of the Triple Alliance/Aztec Empire. This enabled the Crown to quickly extend its control over territory without having to invest in developing a centralized bureaucracy to monitor, tax, and police populations in the periphery (Zavala 1973; Knight 2002; García Martínez 2011; Garfias and Sellars 2021).

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*.² However, this was a costly arrangement for the Crown. By ceding revenue and autonomy to *encomenderos*, the Crown created a class of powerful elites with independent coercive authority who

²Some areas, notably Tlaxcala and areas of low pre-colonial settlement, never received *encomiendas*. These areas are excluded from our analysis.

could not be easily supplanted. Within a generation of the Conquest, the Crown had begun to centralize 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*³, differed substantially from that of the *encomenderos*. Most relevant to our argument, 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.⁴ The amount of compensation also differed substantially from what was received by *encomenderos*, who were typically ceded a sizable share of local tax revenue.⁵ As Gibson (1964) writes, for intermediaries “the smallest *encomiendas* yielded incomes larger than the best-paid *corregimientos*” (p. 83), leaving more surplus for the Crown.

For royal authorities, the move to *corregimiento* was attractive because it enabled the central government to exert greater control over intermediaries and retain more revenue. However, the transition to more centralized control was also costly and difficult. *Encomenderos* controlled local coercive power, and they resisted attempts to centralize authority, at times by force (Gibson 1964; Yeager 1995; Knight 2002; Garfias and Sellars 2021). Moreover, the move to direct rule meant that

³Other 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 little substantive distinction (Gibson 1964, p. 82; Gerhard 1993a, p. 14).

⁴The compensation scheme evolved over time. There were more fundamental changes in this institution during the late 17th and early 18th centuries, which we discuss in Section 6.2.

⁵It was initially proposed that *encomendero* tribute revenues be subject to the royal fifth, a 20% tax (Zavala 1973, p. 48, 69). Though the early implementation of this proposal is unclear, by 1537 *encomenderos* were indeed being taxed, according to Antonio de Mendoza, New Spain’s first viceroy (Zavala 1973, p. 70).

royal officials would have to bear the cost of policing and monitoring the local population, costly tasks that had previously been delegated to intermediaries with better local knowledge.⁶

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 were continuously reassigned to private holders, surviving for centuries until 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 2021). 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 thus in observing local conditions. In some districts, such as areas close to Mexico City, it would have been relatively easy for royal officials to observe shifts in local economic production and the local political environment. In others, such as frontier zones or places of ongoing insurgency, the cost of monitoring the population and local economy would have been much higher. This had implications for where the Crown chose to centralize power. As we argue in Section 2, the relative benefits of direct or indirect rule depend critically on the ease of observing local conditions to identify when intermediaries are underperforming.

In places where fiscal legibility was low, the Crown would have been unable to tell whether a disappointing tax receipt should be attributed to poor conditions or intermediary underperformance. Summarily replacing an intermediary after a bad outcome—firing a *corregidor* from the bureaucracy and then having to find and deploy an adequate replacement—would have been costly given the high potential for error. This meant that the Crown had to rely exclusively on positive incentives to

⁶Tribute was extracted in broadly similar ways under these institutions. While there were subtle differences in the regulation of labor under *encomienda* and *corregimiento* in the early colonial period, these differences were modest in practice, and there is no clear evidence that centralization entailed a major shift in local labor relations. Reliance on uncompensated labor through either institution became increasingly rare by the 1540s, and the allocation of labor in tribute schedules was formally abolished in 1549 (e.g., Gibson 1964, p. 83, 223–6).

encourage 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, this increased the benefits of moving to a *corregimiento* contract to increase royal control over district administration and reduce the share of revenue that had to be ceded to local elites.

3.2 The Patio Process: An Exogenous Shock to Fiscal Legibility

To 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 economic production in mining areas: the introduction of the patio (mercury amalgamation) process. Silver was the most important commodity 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 transformed Mexican silver production. This process relied on mercury amalgamation. 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 no more efficient or profitable than smelting for ores with high silver concentrations, this process encouraged the extraction of lower-grade silver sulfide ores common in the Americas, providing the basis for dramatically scaling up silver production in New Spain (see Appendix Figure C.1) (Brading and Cross 1972; Guerrero 2017).

Crucially, 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.⁷ Starting in 1559, the Crown maintained a monopoly over the production, sale, and distribution of mercury. 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 used mercury in a known ratio—approximately one mark of silver per pound of mercury—royal officials could infer how much silver was being produced in different areas (Lang 1977; Brading and Cross 1972).⁸

This 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 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). 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). An increase in mining production should therefore increase local wage payments and the demand for local agricultural products, making it easier for nearby communities to pay their tribute dues.

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, making it

⁷During this period, there were only three areas where mercury could be mined at scale, all within the Spanish Empire: Almaden and Idria in Europe, and Huancavelica in Peru. Peruvian mines used locally sourced mercury, but virtually all mercury in colonial Mexico originated in Europe (Brading 1971; Brading and Cross 1972, p. 562).

⁸The 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. See Guerrero (2017).

easier for central authorities to ascertain whether a fall in locally collected tax revenue could be blamed on poor conditions or intermediary underperformance. Especially in distant areas where authorities had been unable to directly observe economic conditions, access to this independent source of information dramatically reduced the cost of monitoring and disciplining intermediaries, encouraging the adoption of direct rule. While intermediaries could, and often did, resist efforts to centralize power, the decision to adopt the patio process was made by other actors—mining elites who profited handsomely from the new technology—and this surreptitiously opened the door to political centralization.

We now turn to systematically assessing how the introduction of the patio process altered the trajectory of political centralization 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 and the long-term resilience of local political institutions.

4. Data

We digitize subnational data on institutions of indirect and direct rule (*encomiendas*) and *corregimientos*) from 1521 (ca. the Conquest) until 1650. Our data come from Gerhard (1993a;b), who compiles a list of *encomiendas* in the early colonial period in central and north-central Mexico (New Spain and Nueva Galicia) 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 was centralized under 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 end 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 end of the decade. When 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 come 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. Because

Mexico's main silver and gold deposits are geologically 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.⁹

We also digitize several covariates. Time-invariant controls include latitude and longitude, 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 include 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 Appendix Section D). We code the approximate year of European contact from Gerhard (1993a;b) to account for differences in initial political control. We also include the log area of the district to address potential differences in the density of *encomiendas*, the average of maize potential productivity from the Food and Agriculture Organization's Global AgroEcological Zones database (potential yield of rain-fed, low-input maize based on climate and soil conditions).

As time-varying controls, we include a vector of decadal climate variables, 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 disproportionately affected mining districts after the introduction of the patio process, we include an indicator for climatic conditions associated with epidemics (severe drought followed by rainfall). This variable is used by Garfias and Sellars (2021) as an instrument for population decline, which they show encouraged the adoption of direct rule in this period.

⁹We code two indicators: whether a district includes a mine and whether the district includes a mine that reported production prior to the introduction of the patio process around 1550. Production often started prior to the dates reported in the Hillerkuss data, but we show results using the restrictive definition in Appendix Section B.2.

Finally, we digitize and geocode several measures of endogenous fiscal legibility and of the quality of later-colonial political institutions. We describe these data in Section 6.

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

Our argument suggests that an exogenous increase in fiscal legibility should encourage political centralization. To assess this hypothesis, we use a difference-in-differences design to compare changes in the adoption of direct rule in districts with and without silver mines before and after the introduction of the patio process in the 1550s, which increased the Crown’s ability to monitor economic conditions in mining areas.¹⁰ We estimate:

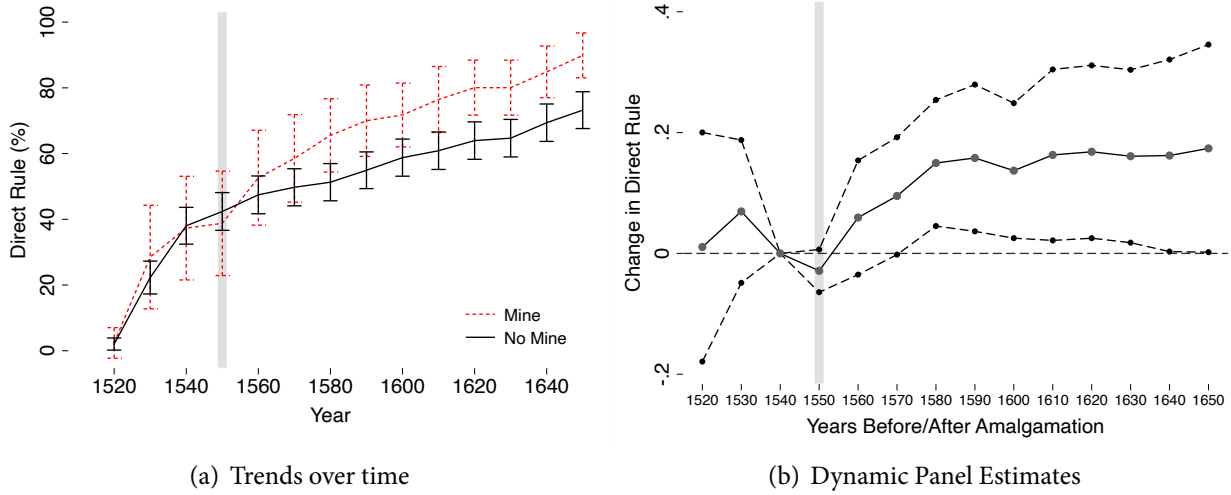
$$Direct\ Rule_{it} = \beta_1 Mine_i \times PostPatio\ Process_t + \Theta_i X_i + \Pi U_{i,t} + \lambda_t + \gamma_i + \varepsilon_{it}, \quad (5.1)$$

where $Direct\ Rule_{it}$ is the proportion of *corregimientos* (direct rule) in district i by decade $t \in [1520, 1650]$; $Mine_i \times PostPatio\ Process_t$ is an indicator for having at least one silver mine in the district after the discovery of the patio process; λ_t and γ_i are decadal and district indicators respectively; X_i are district-specific controls (i.e., malarial zone, maize suitability, elevation, log surface area, log walking hours to Mexico City, year of Spanish contact, latitude, and longitude) 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 and also compute Conley standard errors that allow for serial correlation within districts and spatial correlation between districts.

In Figure 1, we present descriptive trends in the adoption of direct rule during this time period. 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 political centralization in the decades after the Conquest in both groups. This rapid initial centralization occurred primarily in areas that were previously controlled by the

¹⁰In Appendix Table A.2, we report baseline covariate differences between mining and non-mining districts. Mining districts are more likely to be in malarial zones and be located in the west (see Appendix Figure A.1), but are otherwise similar on average to non-mining districts.

Figure 1: Silver Mining, Patio Process, and Direct Rule



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 (see Appendix Table B.3).

Triple Alliance, where fiscal legibility was plausibly higher as the new colonial administration took control of Mexica fiscal institutions and existing records. Following 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 mines.

The right panel of Figure 1 presents a similar pattern, plotting the coefficients of linear interactions between the mining district indicator and indicators for each decade from a panel regression with direct rule as the outcome, which 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.

We present our difference-in-differences estimates in Table 1. The results indicate that the adoption of the patio process had a substantial effect on the transition to direct rule in affected areas. The relative increase in direct rule adoption in mining relative to non-mining areas after the sudden increase in fiscal legibility in the 1550s is between 8–12 percentage points in New Spain (columns

Table 1: Patio Process and Direct Rule: Difference-in-Differences

	Direct Rule (% of District)			
	New Spain		New Spain & Nueva Galicia	
	(1)	(2)	(3)	(4)
Any Mine \times Post-Patio Process	0.080** (0.032) {0.035}	0.12*** (0.045) {0.045}	0.13*** (0.040) {0.038}	0.13*** (0.042) {0.038}
Climate Controls	No	Yes	No	Yes
Controls \times Year FE	No	Yes	No	Yes
Year of European Contact \times 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	0.51	0.51	0.52
Within-District SD of DV	0.23	0.22	0.24	0.24
R sq.	0.80	0.84	0.78	0.82
Observations	1680	1624	2016	1960
Number of districts	120	116	144	140

OLS estimations. Unit of analysis is the district-decade. Standard errors clustered at the district level are in parentheses. Standard errors that allow for serial correlation within districts and spatial correlation between districts within 500 km of each other are in curly brackets. Time-varying climate data are not available for four districts, which are omitted in the estimations with covariates.

1 and 2) and 13 percentage points across New Spain and Nueva Galicia (in columns 3 and 4). This amounts to between a third and a half of the within-district standard deviation in direct rule adoption. These estimates are statistically significant across specifications, including when using the full vector of time-varying and time-interacted controls. Results are also unchanged if we narrow the scope to mines that had documented production before the introduction of the patio process in 1554 (Appendix Section B.2).

Our theory generates additional observable implications that can be examined with these data as well. In Appendix Section B.1, we focus on two heterogeneous effects implied by our argument: the effect of the legibility shock should be higher where pre-shock legibility was lower (because the informational benefits of the shock should be greater) and lower where the cost of transition to direct rule was higher (because this should increase the barriers to political centralization). Consistent

with our argument, we show that the increase in direct rule adoption was larger outside of the pre-colonial Triple Alliance tribute network and farther away from Mexico City, where the colonial state particularly lacked information, and in districts with a lower potential for rebellion, where the cost of transition was plausibly lower.

5.1 Evidence on the Fiscal Legibility Mechanism

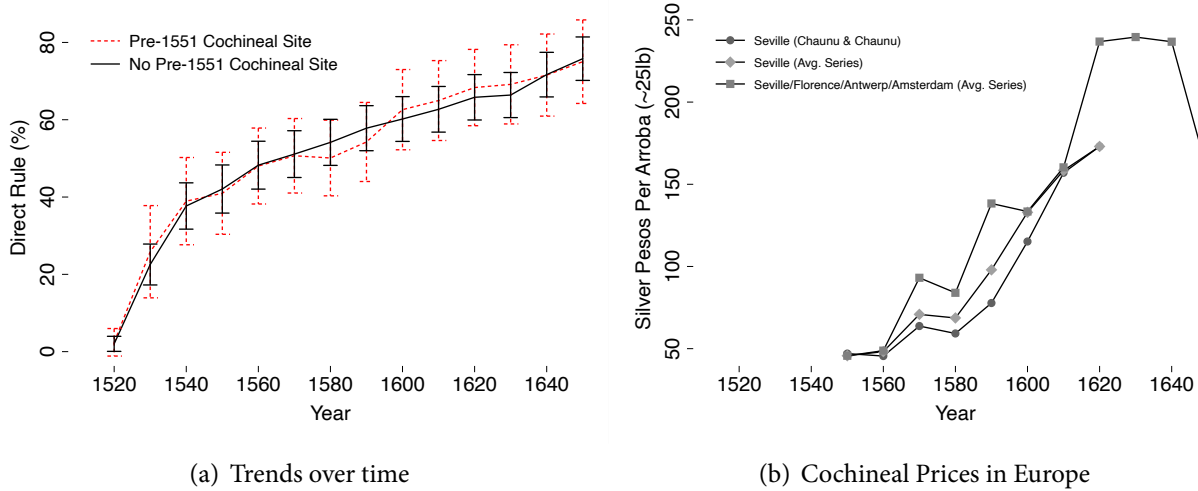
The marked differential increase in direct rule adoption in mining districts following the discovery of silver amalgamation is consistent with our argument. However, in addition to enabling the Crown to closely monitor silver production, the patio process also increased the profitability of mining ores 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, might explain the above 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, so we adopt two indirect strategies. In Appendix Section B.1, we show that the effect of the legibility shock on centralization was higher in areas farther from Mexico City and outside the tribute network of the Triple Alliance. This is consistent with our legibility-focused argument but difficult to reconcile with a profitability-focused story, as the value of the increase in silver production should be lower (not higher) in areas farther from trade networks and Mexico City. We provide additional evidence casting doubt on the profitability channel by examining the effects of a sudden increase in the value of another colonial commodity, cochineal dye, on the adoption of direct rule.

Cochineal was an important commodity extracted from the colony, arguably second only to silver in its importance. 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—a much higher increase, in fact, than the estimated effect of the patio process on silver-extraction profitability (see Appendix Section C 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 dramatic rise in profitability led to a disproportionate increase in political centralization from *encomienda* to corregimiento in these areas.

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



The **left** figure plots the average proportion of holdings under direct rule with 95% confidence intervals for cochineal-producing and non-producing districts in each decade. The **right** figure displays a cochineal price series from various sources. See Appendix Section C 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 C using a similar empirical strategy as in the previous section, 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 distinguishable from zero in any specification and are very small in magnitude.

The cochineal boom greatly increased the revenue potential of cochineal-producing areas, but there was no corresponding increase in fiscal legibility as had occurred with the discovery of the

patio process. Direct monitoring and taxation remained difficult in cochineal-producing areas, so this substantial economic boom did not increase political centralization. Alongside the evidence above and in the appendix (see Appendix Section B.1), these null findings results provide support for the mechanism described in our theory.

6. Long-Term State Development

The prior sections illustrate how the introduction of the patio process to refine silver helped to facilitate political centralization in early colonial Mexico. Through its royal monopoly over the distribution and sale of mercury, the Crown gained insight into fluctuations in local conditions in mining districts that would have been otherwise difficult to observe. The rise in fiscal legibility provided an opportunity to centralize power at the expense of local intermediaries. In this section, we explore a second set of empirical implications of our argument related to the dynamic interaction between fiscal legibility and political centralization and its implications for longer-term state development.

Key to our argument is the recognition that fiscal legibility is a function of both exogenous factors, like the technological innovation described in this paper, and purposeful efforts by authorities to improve informational capacity through investment (for example, by conducting censuses, constructing tax offices, or creating tax registers). Our theory highlights an important interdependence between these two sources of fiscal legibility and the trajectory of political centralization. Because there is little need to directly monitor and sanction intermediaries under indirect rule, central authorities have little incentive to divert funds toward improving their monitoring capacity in these areas unless they anticipate an eventual transition to direct rule. By contrast, in areas under direct rule, investment in improving fiscal legibility pays immediate dividends. A marginal improvement in a ruler's independent informational capacity makes it easier for him to identify poor performance by intermediaries and sanction them as necessary.

This discussion highlights two contrasting trajectories of state development. In districts with sufficiently high baseline fiscal legibility, political centralization is attractive, which in turn makes additional investment in informational capacity worthwhile for the ruler. In these areas, we expect

to see early political centralization alongside a gradual improvement in fiscal legibility over time. In districts where initial fiscal legibility is too low, by contrast, there is little incentive to transition away from indirect rule and thus little incentive to invest in marginally improving local fiscal legibility. We would therefore expect to see long-term reliance on indirect rule and little to no investment in purposefully improving informational capacity in these areas. A shock that increases fiscal legibility like the introduction of the patio process should therefore lead to longer-term divergence in state development by placing affected districts on a path toward both rapid political centralization and longer-term investment in informational capacity.

We assess this divergence argument in two steps. We first examine a key investment made by the colonial state to increase fiscal legibility in the periphery: the establishment and placement of state-run post offices (*estafetas*), comparing long-term investments in areas that were and were not affected by the introduction of the patio process in the early colonial period.¹¹ We then explore the longer-term implications for state development, focusing on the institutional resilience during a period of colonial disinvestment when many areas reverted to more indirect forms of rule.

6.1 Divergence in Fiscal Legibility

We begin by examining the placement of state-run post offices by the end of the colonial period. In addition to being a common measure of state capacity and public investment (e.g., Acemoglu, Moscona, and Robinson 2016; Rogowski et al. n.d.), post offices represented an important investment in local fiscal legibility by facilitating communication between the periphery and the center. For the first two centuries of colonial rule, postal operations were delegated to private agents or *Correos Mayores*. This service was integrated into the fiscal administration in 1766, when several new offices were added to increase coverage. As the Marquis of Sonora wrote following his official inspection of the postal system in the early 1770s, there were benefits in expanding postal access in under-served areas, “even if they [yielded] little revenue” (quoted in Velarde, San Juan, and Obregón M. 1908, p.

¹¹In Appendix Section B.4, we also examine a separate measure of state investment in local fiscal legibility: the construction of *Cajas Reales* or royal treasuries across space and time.

338) because they could expedite information transmission between private actors and the central government.

Our data come from Stangl (2019), who identifies the location of post offices at the end of the colonial period using information from the *Archivo General de Indias*. We record whether each district in our dataset contained a post office by the early 19th century. Using the location of colonial post offices, we also compute the least-cost walking time from each district to the nearest post office using data on colonial-era land cover, elevation, and terrain slope.¹² To further probe long-term state investment in fiscal legibility, we also examine the present-day coverage of the Mexican postal service. While postal administration has experienced substantial changes since the colonial era, our divergence argument suggests that baseline differences in fiscal legibility and state presence should persist to the present.

We present conditional correlations between exposure to the shock to fiscal legibility in the 1550s (i.e., districts with mines in the early colonial period) and these longer-term outcomes in Table 2. We include the same set of time-invariant covariates as described in equation (5.1) and add an indicator for early cochineal production, which might have independently affected state development. We report standard errors that are robust to heteroskedasticity and to spatial correlation between districts within 500 km of each other.

A potential concern with this analysis is that mining districts may vary substantially from non-mining areas along a number of unobserved dimensions. To address this concern, we also present an alternative comparison that seeks to more closely isolate the role of legibility (as opposed to ongoing profitability or other factors) in explaining these long-term outcomes. We identify districts that had an active silver or gold mine in the 16th century, and were therefore affected by the introduction the patio process, but where mining activities had ceased prior to the mid-18th century due to resource depletion or other factors. We then compare these defunct mining districts to districts that did not

¹²See Appendix Section D for a detailed description of the construction of this and our alternate walking-time measures. All four methods that we employ yield cost-distance measures that are highly correlated ($\rho > 0.9$).

have mines in either period to rule out ongoing mining as a factor to explain long-term institutional divergence. To construct this alternative comparison group, we use information from the *Theatro Americano*, a 1746 document that was transcribed and organized by Commons and Coll-Hurtado (2002), to measure the status of a district's mining production as of roughly 1740. The *Theatro* was an exhaustive and confidential official report that provided geographic, sociodemographic, and economic information of districts across the territory during the 1740s. It was an important source of information for the colonial administration and was later used in the design of a major administrative reform (the *intendencia* reforms).

The first four columns of Table 2 indicate that areas with 16th-century mines were substantially more likely to have access to a post office by the end of the colonial period than those without. Districts with early colonial mines are between 70 and 90 percent closer to a post office relative to non-mining districts, and they are between 14 and 17 percentage points more likely to have a post office in the district (Panel A). The magnitude of coefficient estimates is very similar when excluding districts with ongoing silver mining by the 1740s (Panel B), though estimates for this sample including the full set of covariates are not statistically significant at conventional levels. This evidence is consistent with the argument that the initial boost in fiscal legibility led to longer-term divergence in state development in affected areas, even in areas where mining had been abandoned.

Turning attention to present-day outcomes (columns 5 and 6), contemporary municipalities that overlap colonial districts with early mines are more likely to have a post office today than those that do not.¹³ This is true even when focusing only on districts where large-scale mining no longer took place by the 1740s. This difference is substantial. The probability of a municipality having a contemporary post office is between 6 and 30 percentage points higher in areas exposed to the 16th-century legibility shock, which is consistent with a divergence in state development beyond the colonial period.

¹³ Because contemporary administrative boundaries do not nest in colonial political units, we code a municipality as being exposed to the patio-process shock if it overlaps a district in which silver mining was taking place in the 16th century.

Table 2: Divergence in Long-Term Fiscal Legibility and Institutional Resilience

Panel A:	Districts in Regions with Indirect/Direct Rule Institutions							
	Walking Hours to Colonial Post Office (log)		Any Colonial Post Office (1766–1810)		Any Present-Day Post Office		Number of Office Sales (1702–1750)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
16th Century Mine	-0.90** (0.37) {0.47}	-0.73* (0.37) {0.38}	0.17*** (0.063) {0.082}	0.14** (0.064) {0.068}	0.28*** (0.027) {0.061}	0.060** (0.029) {0.043}	-1.15** (0.56) {0.76}	-0.59 (0.51) {0.49}
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Mean of DV	1.30	1.30	0.77	0.77	0.45	0.45	2.93	2.93
SD of DV	2.42	2.42	0.42	0.42	0.50	0.50	3.31	3.31
R sq.	0.019	0.17	0.022	0.17	0.047	0.30	0.016	0.29
Observations	196	196	196	196	1993	1993	196	196

Panel B:	Exhausted Mines vs Non-Mining Districts (Excluding Districts with Ongoing Mining by 1740)							
	Walking Hours to Colonial Post Office (log)		Any Colonial Post Office (1766–1810)		Any Present-Day Post Office		Number of Office Sales (1702–1750)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
16th Century Mine	-0.94* (0.57) {0.55}	-0.65 (0.64) {0.57}	0.19** (0.087) {0.084}	0.12 (0.10) {0.090}	0.30*** (0.037) {0.082}	0.13*** (0.039) {0.069}	-2.12*** (0.74) {0.72}	-2.10*** (0.71) {0.66}
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Mean of DV	1.38	1.38	0.75	0.75	0.42	0.42	2.96	2.96
SD of DV	2.47	2.47	0.43	0.43	0.49	0.49	3.37	3.37
R sq.	0.0098	0.17	0.013	0.16	0.033	0.31	0.027	0.30
Observations	177	177	177	177	1792	1792	177	177

OLS estimations. Unit of analysis is the colonial district in columns 1–4 and 7–8 and contemporary municipality in columns 5–6. Robust standard errors in parentheses. Standard errors that allow for spatial correlation between districts within 500 km of each other in curly brackets. Covariates include an indicator for cochineal production in the 16th century and malarial zone, maize suitability, elevation, log surface area, log walking hours to Mexico City (log distance for present-day outcomes), year of Spanish contact, latitude, and longitude.

6.2 Divergence in Institutional Resilience

We finally examine the long-term institutional consequences of the shock to fiscal legibility in the 1550s. The initial increase in legibility should shift the trajectory of political centralization and endogenous state investment in legibility over the longer term, enabling central authorities to gain tighter control over intermediaries through an improved ability to monitor and sanction bureaucratic underperformance. The accumulation of information and consolidation of authority should also make it easier retain centralized control over intermediaries in affected areas, even when the state is

revenue-constrained and may be tempted to outsource authority to private agents through more decentralized contracts.

We assess this prediction using a similar cross-sectional research design as above and data on an institutional shift in colonial administration during the second half of the 17th century. Mired in conflict in Europe, the Crown became increasingly unable and unwilling to invest in improving political control of the Empire as it was forced to divert spending to more immediate needs (e.g., Knight 2002). Short of revenue, the Crown began to commodify and sell colonial offices for short-term gain, including the office of *corregidor* in many districts. Private individuals could bid for open positions through the *Cámara de Indias*, implicitly buying out the right to extract economic resources from the district for a specified period of time.

Though maintaining the same name, the *corregimiento* of this period operated as a different contract, essentially a new form of indirect rule. The Crown exerted little direct control over those who had purchased offices and ceased to pay direct salaries to *corregidores* by the early 1700s (e.g., Pietschmann 1972). This implicit privatization had negative consequences for the quality of governance as economic elites bidding on positions sought to recoup their investment through various means, including the manipulation of local markets, the extraction of rents from those needing government services, and other forms of corruption (e.g., Pietschmann 1972; Guardado 2018; Garfias and Sellars 2020). Not all offices were sold, however, and some districts remained under Crown control even during this period of imperial disinvestment.

We digitize data on office sales in central Mexico from 1702 to 1750 using a comprehensive report commissioned to the Marquis of Ensenada by the Council of Indies (transcribed by Pietschmann 1972). We record the number of sales in each district, reflecting the willingness of the Crown to outsource a district's administration (which in turn determined its exposure to official rent-seeking). Because earlier improvements in fiscal legibility and political control should lower the relative benefits of outsourcing governance to private individuals, we expect to see fewer office sales in areas that were exposed to the legibility shock in the early colonial period.

We present our estimates on colonial office selling in Columns 7 and 8 of Table 2. These results suggest that districts exposed to the patio process shock were more resilient to the institutional decline of the 17th and early 18th centuries. During a period in which the administration of most districts was sold to the highest bidder, areas with 16th-century mines were less likely to be sold at auction—up to half as often—between 1702 and 1750. This relationship does not appear to be driven by the Crown’s desire to maintain centralized control of areas of ongoing silver production. If anything, the relationship appears to be amplified when restricting attention to areas without ongoing silver mining by the 18th century.¹⁴ Given the well-documented connection between the practice of office selling and official corruption (e.g., Pietschmann 1972; Guardado 2018; Garfias and Sellars 2020), this result illustrates a connection between the legibility shock of the early colonial period and the quality of local governance over a century later.

7. Conclusion

How does a shift in fiscal legibility—the ability of central authorities to observe economic conditions for the purposes of taxation and control—alter a ruler’s incentive to centralize power and further invest in informational capacity? We argue that a ruler can be better off ceding greater autonomy and revenue to local elites in low-information environments as a way to encourage 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 and retain a greater proportion of tax revenues. Political centralization in turn encourages additional endogenous investments in improving fiscal legibility to make it easier for central authorities to monitor and sanction tax-collecting intermediaries in the periphery.

This relationship generates path dependence in fiscal legibility and the form of rule over time. Low initial legibility can set a region on a long-term path of persistently low state informational capacity, where the central authority relies on indirect rule and thus does not benefit from investing

¹⁴We note that the effect of ongoing silver mining on office sales is potentially ambiguous as the higher revenue potential of these areas might have attracted higher private bids for these positions, no doubt an important consideration for a ruler in need of short-term revenue.

to improve local monitoring. A sudden increase in fiscal 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 on institutional development.

We provide empirical support for the theory using subnational data from colonial Mexico. In the aftermath of the Conquest, the Spanish Crown yielded considerable authority to local elites as a way of maintaining political control over newly conquered territory. Efforts to centralize power differed considerably across space. 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 conditions in mining districts. 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 provide evidence that the observed increase in political centralization was due to the informational consequences of the patio process (as opposed to the increase in potential revenue) by examining a major revenue shock in another important commodity, cochineal dye, which did not shift the trajectory of political centralization.

We then document some of the longer-term consequences of this shock to fiscal legibility. We show that affected districts saw disproportionate state investment in improving informational capacity through the establishment of state-run post offices, contributing to additional divergence in fiscal legibility. This divergence had important consequences for long-term institutional development, shielding affected districts from being outsourced to private rent-seekers during a key period of state disinvestment from colonial governance in the early 18th century. These long-term results persist even when restricting attention to areas without ongoing silver production by the 1740s. These results illustrate a connection between fiscal legibility, political centralization, and institutional development.

The features of our context allow us to provide quasi-experimental evidence on the link between fiscal legibility and political centralization, a link that others have examined theoretically, qualitatively,

and cross-sectionally (e.g., Ma 2011; Scott 2017; Mayshar, Moav, and Neeman 2017; Huning and Wahl 2020; Ahmed and Stasavage 2020). The relationships that we document are not unique to colonial Mexico. Others have established that differences in the observability of local agricultural production in Egypt and Mesopotamia led to very different paths of state development, including via differing incentives for political centralization (Scott 2017; Mayshar, Moav, and Neeman 2017). Similarly, Stasavage (2020) suggests that the adoption of forms of “legible” agricultural production in ancient China led to the development of an early and relatively centralized bureaucracy. In early modern European polities, including the Dutch republic and France, the presence of highly heterogeneous and fragmented local economies has been linked to the persistence of indirect tax collection, in part as a strategy to save on the high costs to monitoring agents (Johnson and Koyama 2014). Recent work on the rise and decline of local elections in China posits a similar connection between local informational capacity and incentives to centralize authority (Martinez-Bravo et al. 2021).

More generally, many scholars have examined how and why rulers might choose to enhance fiscal legibility over time to improve revenue collection and tighten political control. Stasavage (2020), for instance, highlights the role of endogenous technological innovations in legibility, such as writing, geometry, and land surveying techniques, which facilitated the development of early state bureaucracies. Building on these insights, our theoretical framework highlights when investments in fiscal legibility—such conducting censuses, creating property registers, or constructing tax offices and post offices—are likely to be worthwhile depending on the trajectory of political centralization and on the initial level of legibility.

The dynamics that we highlight have important implications for long-term state development. In peripheral areas where initial fiscal legibility is very low, there may be little incentive for central authorities to move toward more direct forms of rule and thus little incentive to invest in state informational capacity. Indirect forms of rule may thus persist for long periods of time. In other areas, the dynamics can work in the opposite direction. A move toward political centralization can

encourage investment in fiscal legibility, helping in turn to consolidate direct control over territory. A single shock that raises fiscal legibility can thus have far-reaching consequences, enabling central authorities to tighten control, retain more revenue, and build a more centralized state for the future.

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Online Appendix

Fiscal Legibility and State Development: Theory and Evidence from Colonial Mexico

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A. Descriptives

Table A.1: Descriptive Statistics

Panel A: Direct Rule Sample (New Spain & Nueva Galicia): 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	0.15	0.35	0.00	0.00	1.00
Any Early Mine	2016	0.12	0.32	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
Mean maize potential yield	2016	3644.82	1695.23	0.00	3422.03	8114.00
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 (log)	2016	8.73	0.94	5.16	8.93	9.97
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 (New Spain & Nueva Galicia): 1520–1750

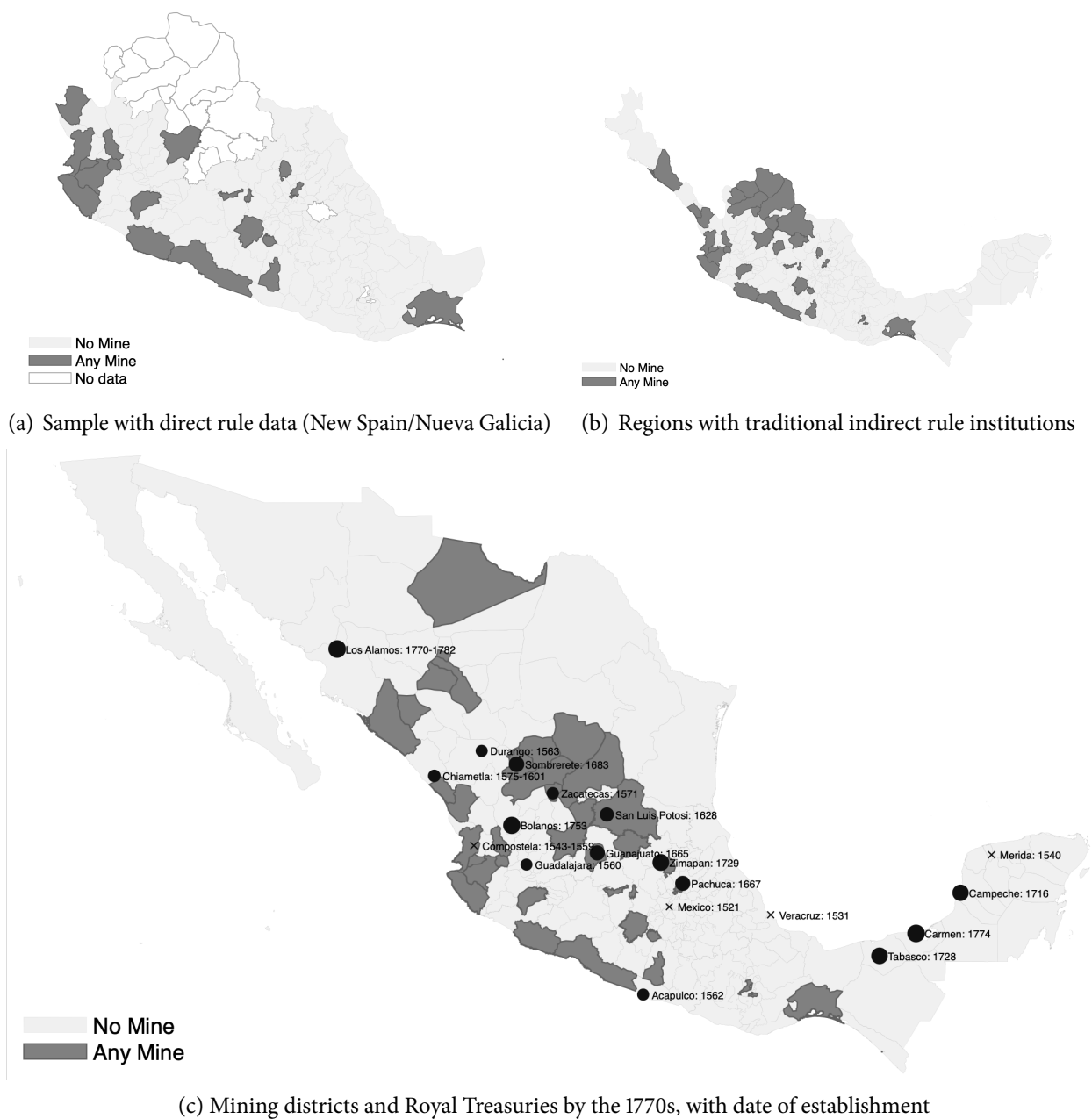
	N	Mean	Std. Dev.	Min.	Median	Max.
Least-Cost Walking Time to Nearest Treasury (log)	3588	7.40	1.79	0.00	7.84	9.88
Any Mine	3588	0.16	0.37	0.00	0.00	1.00
Any Early Mine	3588	0.13	0.33	0.00	0.00	1.00
Year of European Contact	3588	1522.98	7.13	1518.00	1521.00	1580.00
Malarial Zone	3588	0.63	0.48	0.00	1.00	1.00
Mean maize potential yield	3588	3642.40	1674.47	0.00	3432.09	8114.00
Avg. Altitude	3588	1573.96	726.56	25.79	1676.23	2904.21
Surface Area (log)	3588	7.68	1.19	4.68	7.83	10.08
Least-Cost Walking Time to Mexico City (log)	3588	8.75	0.93	5.16	8.95	9.97
Std. Dev. PDSI	3492	1.78	0.43	0.65	1.75	3.96
Avg. PDSI	3492	0.48	0.89	-3.10	0.36	3.38
Min. PDSI	3492	-2.32	1.38	-6.62	-2.14	1.28
Drought-Rain Around Known Outbreaks	3492	0.02	0.14	0.00	0.00	1.00

Table A.2: Baseline Differences Between Mining and Non-Mining Districts

	New Spain		New Spain & Nueva Galicia	
	Any Mine	Early Mine	Any Mine	Early Mine
	(1)	(2)	(3)	(4)
Year of European Contact	0.021 (0.022) {0.0081}	0.00070 (0.012) {0.0050}	-0.0045 (0.0084) {0.0044}	-0.0046 (0.0036) {0.0016}
Mean maize potential yield	0.000027 (0.000019) {0.000012}	0.000029 (0.000019) {0.000013}	0.0000056 (0.000018) {0.000017}	0.000022 (0.000017) {0.0000090}
Cochineal Production Site	-0.056 (0.079) {0.065}	-0.050 (0.079) {0.065}	0.0066 (0.080) {0.058}	-0.0066 (0.082) {0.057}
Malarial Zone	0.23** (0.11) {0.086}	0.19* (0.11) {0.075}	0.17 (0.10) {0.082}	0.12 (0.095) {0.063}
Avg. Altitude	0.000060 (0.000061) {0.000057}	0.000052 (0.000061) {0.000052}	0.0000052 (0.000062) {0.000066}	0.000018 (0.000055) {0.000046}
Least-Cost Walking Time to Mexico City (log)	-0.0011 (0.059) {0.033}	0.017 (0.056) {0.031}	-0.027 (0.047) {0.041}	-0.024 (0.043) {0.036}
Surface Area (log)	-0.015 (0.032) {0.021}	-0.0021 (0.029) {0.016}	0.017 (0.029) {0.023}	0.035 (0.026) {0.024}
Latitude	-0.020 (0.026) {0.018}	-0.028 (0.025) {0.016}	-0.019 (0.028) {0.014}	-0.041 (0.025) {0.017}
Longitude	-0.028 (0.025) {0.015}	-0.037 (0.024) {0.015}	-0.054** (0.021) {0.017}	-0.043** (0.020) {0.012}
Mean of DV	0.12	0.12	0.15	0.15
SD of DV	0.32	0.32	0.35	0.35
R sq.	0.14	0.12	0.14	0.11
Observations	120	120	144	144

OLS estimations. Unit-of-analysis is the district. Robust standard errors in parentheses. Standard errors that allow for spatial correlation between districts within 500 km of each other are in curly brackets.

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



B. Additional Evidence

B.1 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 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 2021). 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 B.1. 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

Table B.1: Heterogeneous Effect of the Patio Process on Direct Rule: Difference-in-Differences

	Direct Rule (% of District)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Any Mine \times Post-Patio Process	0.17** (0.067)	0.17*** (0.061)	-0.016 (0.062)	0.052 (0.071)	0.19*** (0.046)	0.14** (0.055)	-0.86*** (0.32)	-0.017 (0.37)
Any Mine \times Post-Patio \times Resistance during Conquest	-0.060 (0.075)	-0.070 (0.059)						
Any Mine \times Post-Patio \times Number of Towns			0.017** (0.0068)	0.0084 (0.0068)				
Any Mine \times Post-Patio \times Former Triple Alliance					-0.17*** (0.049)	-0.027 (0.055)		
Any Mine \times Post-Patio \times (log) Hours to Mexico City							0.11*** (0.036)	0.015 (0.043)
Any Mine \times Post-Patio + Resistance	0.11*** (0.04)	0.10*** (0.04)						
Any Mine \times Post-Patio + Former Triple Alliance					0.017 (0.03)	0.11*** (0.04)		
Climate Controls	No	Yes	No	Yes	No	Yes	No	Yes
Controls \times Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Year of European Contact \times 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	0.82	0.78	0.82	0.78	0.82	0.78	0.81
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.

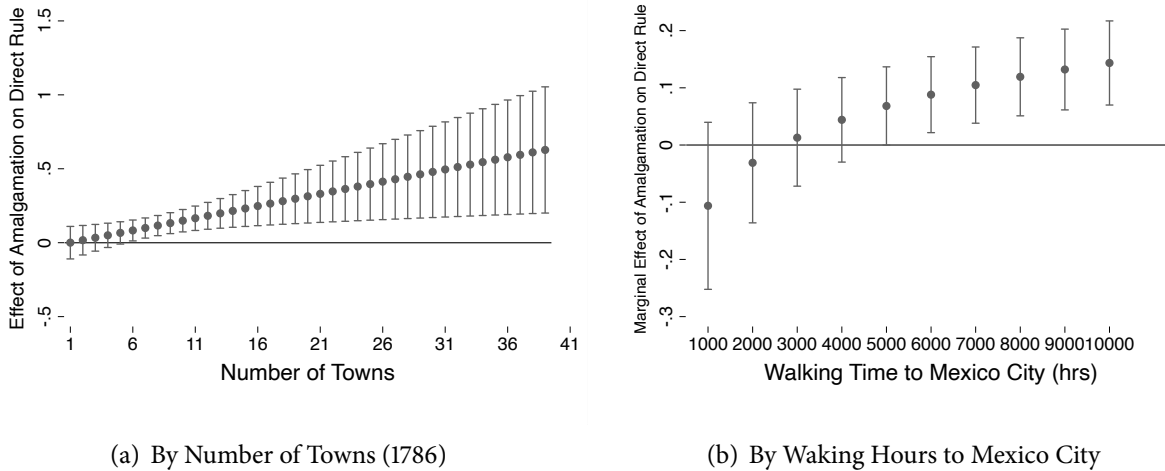
was only around two-thirds as large in districts with organized resistance during the Conquest, though this difference not statistically significant. Columns 3 and 4 present estimates of the heterogeneous effects of the legibility shock by the number of towns in a district. As the number of towns in 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 B.1, which plots the effect of legibility on direct rule at different number of towns per district. Taking the estimates from column 3, 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 7 percentage points. At the 75th percentile (11 towns), the discovery of amalgamation increases direct rule adoption by 17 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. 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 B.1: Silver Mining, Amalgamation, and Direct Rule
Heterogeneous Effects



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 B.1. Consistent with the theory, we find that the patio process increased direct rule by only a fraction in districts that were part of the tribute network of the Triple Alliance. However, this estimate is only significant in the specification without covariates (column 5), and its magnitude varies substantially. 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 B.1 shows the heterogeneous effect of the legibility shock by distance to the capital. The discovery of the patio process 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.

B.2 Main Results with Pre-1554 Mines

Figure B.2: Silver Mining, Patio Process, and Direct Rule; Early Mines

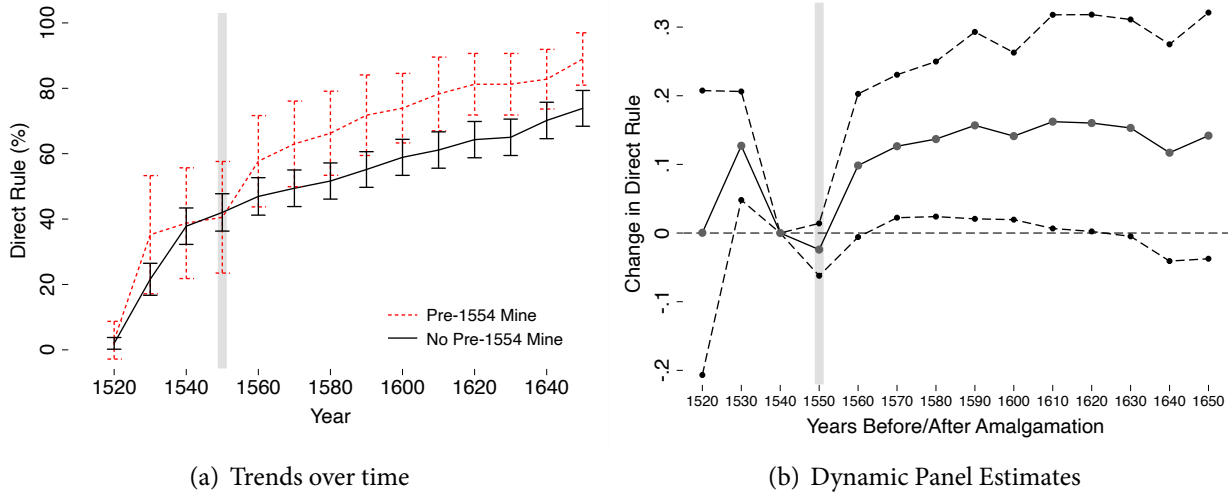


Table B.2: Patio Process and Direct Rule: Difference-in-Differences; Early Mines

	Direct Rule (% of District)			
	New Spain		New Spain & Nueva Galicia	
	(1)	(2)	(3)	(4)
Any Early Mine \times Post-Patio Process	0.076** (0.033) {0.039}	0.13*** (0.040) {0.042}	0.11** (0.046) {0.046}	0.13*** (0.042) {0.042}
Climate Controls	No	Yes	No	Yes
Controls \times Year FE	No	Yes	No	Yes
Year of European Contact \times 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	0.51	0.51	0.52
Within-District SD of DV	0.23	0.22	0.24	0.24
R sq.	0.80	0.84	0.78	0.82
Observations	1680	1624	2016	1960
Number of districts	120	116	144	140

OLS estimations. Unit-of-analysis is the district-decade. Std. errors clustered at the district level in parentheses; errors that allow for serial correlation within districts and spatial correlation between districts within 500 km of each other in curly brackets.

B.3 Dynamic Panel Estimates

Table B.3: Patio Process and Direct Rule: Dynamic Panel

	Direct Rule (% of District)			
	All Mines		Early Mines	
	(1)	(2)	(3)	(4)
Mine \times 1520	0.011 (0.096)	-0.061 (0.088)	0.00038 (0.10)	-0.083 (0.090)
Mine \times 1530	0.069 (0.060)	0.10 (0.065)	0.13*** (0.040)	0.14** (0.053)
Mine \times 1550	-0.029 (0.018)	-0.037 (0.034)	-0.024 (0.019)	-0.021 (0.029)
Mine \times 1560	0.059 (0.048)	0.087 (0.058)	0.098* (0.053)	0.13** (0.055)
Mine \times 1570	0.095* (0.049)	0.10* (0.056)	0.13** (0.053)	0.14** (0.054)
Mine \times 1580	0.15*** (0.053)	0.12* (0.063)	0.14** (0.057)	0.13** (0.059)
Mine \times 1590	0.16** (0.061)	0.11* (0.061)	0.16** (0.069)	0.12** (0.057)
Mine \times 1600	0.14** (0.057)	0.13* (0.064)	0.14** (0.062)	0.14** (0.059)
Mine \times 1610	0.16** (0.072)	0.15** (0.075)	0.16** (0.079)	0.17** (0.075)
Mine \times 1620	0.17** (0.072)	0.16** (0.078)	0.16** (0.080)	0.17** (0.077)
Mine \times 1630	0.16** (0.072)	0.14* (0.074)	0.15* (0.080)	0.15** (0.071)
Mine \times 1640	0.16** (0.080)	0.14* (0.079)	0.12 (0.080)	0.11 (0.074)
Mine \times 1650	0.17** (0.087)	0.11 (0.088)	0.14 (0.091)	0.093 (0.087)
Climate Controls	No	Yes	No	Yes
Controls \times 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	0.82	0.78	0.82
Observations	2016	1960	2016	1960
Number of districts	144	140	144	140

OLS estimations. Unit of analysis is the district-decade. Samples include Nueva España and Nueva Galicia. Omitted year is 1540. Standard errors clustered at the district level are in parentheses. Time-varying climate data are not available for four districts, which are omitted in the estimations with covariates.

B.4 Spatial and Temporal Investment in Fiscal Legibility Using Royal Treasuries

In addition to examining the long-term divergence in fiscal legibility between areas affected and unaffected by the patio process, we also analyze a separate measure of state investment in local fiscal legibility: the construction of *Cajas Reales* or royal treasuries.¹⁵ The royal treasuries were a network of 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 coordinated tax collection and provided funds for local expenditures, including officials' salaries as well as other administrative and military expenses. Each treasury was led by an accountant, who registered and certified transactions, and a royal treasurer, who collected taxes both directly from taxpaying individuals or institutions and indirectly from other specialized officials like *corregidores* (Sánchez Bella 1968; Yuste 2002).¹⁶

The establishment of a new treasury brought the fiscal bureaucracy closer to the surrounding districts. This increased 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 tribute. The creation of a treasury in a remote area, even a relatively unproductive one, was thus sometimes warranted to enable the Crown to obtain more information and control over outlying regions (Sánchez Bella 1968). Given the economic and political costs of establishing royal treasuries, the Crown had to prioritize when and where to make this investment. The placement of the treasuries followed a clear territorial logic early on, with the establishment of treasuries in Mexico City, the capital; Veracruz, Mexico's main port in the Atlantic; and Merida, a main trading center in the Yucatan. Given the importance of silver to the royal economy, it is perhaps not surprising that treasuries were sometimes established near

¹⁵Chiovelli (2016) also uses the presence of treasuries as a measure of state capacity and link their location to existing levels of state development.

¹⁶Other positions included the *factor*, who conducted the treasury's business with other branches of the bureaucracy, the *veedor*, who assayed gold and silver and monitored its production, and a variable number of deputies. The Crown used a number of strategies to minimize agency problems with treasury bureaucrats, including regular inspections and on-site audits, reliance on independent auditing bodies to check accounts, and internal safeguards on fraud (Sánchez Bella 1968; TePaske and Klein 1986; Jáuregui 1999).

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).¹⁷ Treasuries were eventually created to facilitate tax collection in the interior, but this investment was not made in all regions (Sánchez Bella 1968; Jáuregui 1999; Bertrand 2013).

We investigate how the early shock to fiscal legibility shaped Crown investment in treasury construction across space and time by examining how the least-cost walking hours from each district to the nearest treasury evolved from the 16th century until the end of the colonial period. Specifically, we construct a decadal panel of minimum walking times (in hours) from each district to the nearest royal treasury using the same least-cost analysis methodology as described in the previous section and information on the successive construction of new treasuries. We geolocate each treasury constructed over the colonial period and code its date of construction (Table B.4). 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.

Our interest is in whether districts affected by the legibility shock in the 1550s saw a differential increase in investment toward improving the Crown's ability to observe and monitor local production through the construction of nearby treasuries. In Table B.5 we present difference-in-differences estimates from an equation similar to (5.1), now using minimum distance to royal treasury as the outcome. We extend the analysis from the Conquest period until the 1750s, when a major set of fiscal reforms shifted the pattern of treasury placement (see below). We present estimates with and without time-varying and time-interacted controls for the same two sub-samples as in Table 1: the core region of New Spain (columns 1 and 2) and the full sample of districts in New Spain and Nueva Galicia where institutions of indirect or direct rule were employed in a consistent way (columns 3 and 4).¹⁸

¹⁷ Relatedly, the Crown also established treasuries along the coast to monitor contraband; the Carmen treasury is one example (TePaske and Klein 1986).

¹⁸ We use the same vector of covariates as the estimations in Section 5: the time-varying climate measures and the time-invariant district characteristics (malarial zone, maize suitability, elevation, log surface area, log walking hours to Mexico City, year of Spanish contact, latitude, and longitude) interacted with each year indicator. In Appendix Section ??, we restrict attention to mines recorded as operational prior to 1550 and find similar results.

Table B.4: *Cajas Reales*/Royal Treasuries in Colonial Mexico, 1520–1810

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)
Rosario	Sinaloa & Sonora	1783–1806	TePaske and Klein (1986)
Chihuahua	Nueva Vizcaya	1785	TePaske and Klein (1986)
Michoacan/Valladolid	New Spain	1788	TePaske and Klein (1986)
Puebla	New Spain	1789	TePaske and Klein (1986)
Oaxaca/Antequera	New Spain	1790	TePaske and Klein (1986)
Arizpe	Sinaloa & Sonora	1791	TePaske and Klein (1986)
Saltillo	Coahuila	1794	TePaske and Klein (1986)
Cosala	Sinaloa & Sonora	1807	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.

The results in Table B.5 provide mixed evidence that the introduction of the patio process encouraged endogenous investment in fiscal legibility. In New Spain, the introduction of the patio process led to a differential decrease in the minimum walking time to the nearest treasury in mining relative to non-mining districts of around 60 and 70 percent up to 1750, though this difference is not

Table B.5: Patio Process and Walking Time to Nearest Royal Treasury (log):
Difference-in-Differences

	Walking Hours to Treasury (log)			
	New Spain		New Spain & Nueva Galicia	
	(1)	(2)	(3)	(4)
Any Mine \times Post-Patio Process	-0.73** (0.36) {0.34}	-0.63 (0.43) {0.40}	-0.12 (0.34) {0.39}	0.076 (0.41) {0.40}
Climate Controls	No	Yes	No	Yes
Controls \times Year FE	No	Yes	No	Yes
Year of European Contact \times Year FE	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Within-District Mean of DV	7.47	7.42	7.40	7.36
Within-District SD of DV	0.37	0.38	0.49	0.50
R sq.	0.83	0.86	0.80	0.83
Observations	3012	2916	3588	3492
Number of districts	126	122	150	146

OLS estimations. The unit of analysis is the district-decade. Districts with direct/indirect rule. Standard errors clustered at the district level are in parentheses. Standard errors that allow for serial correlation within districts and spatial correlation between districts within 500 km of each other are in curly brackets. Time-varying climate data is not available in four districts, which are not included in the estimations with covariates.

significant in the specification with covariates. When including Nueva Galicia, the decrease is smaller, not statistically different from zero, and flips signs when including covariates. While imprecisely estimated, the coefficient estimates are substantively large for the New Spain sample, equivalent to almost two within-district standard deviations of walking time. However, we cannot reject a null effect across all samples and specifications.

Because our theory focuses on the Crown's dual 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 standard institutions of indirect rule had existed in the early colonial period.¹⁹ There is a tradeoff, however, in focusing solely on within-unit variation

¹⁹The Crown relied on a more heterogeneous set of institutions in places where settlement patterns at European contact were not compatible with the establishment of classic *encomiendas*, such as areas inhabited by nomadic or semi-nomadic

across the central governorships for regionally-defined outcomes like this one. The construction of a treasury targeted to a mining area would mechanically affect walking times to neighboring non-mining districts as well. In addition, because treasuries are an expensive investment, areas close enough to treasuries constructed in the early colonial period may see little or no change in walking time after the 1550s. To explore additional implications of our conceptual framework, we therefore broaden our focus to consider temporal and regional trends in treasury construction elsewhere in Mexico.

We consider two predictions. First, because improved access to information only benefits a ruler under direct forms of rule, we expect little investment in treasury construction in areas under indirect rule, especially those that have low initial levels of fiscal legibility (putting a future transition to direct rule out of reach). Second, only a sufficiently patient central authority should be willing to give up resources in the short term to invest in either improving the quality of monitoring under direct rule or investing in informational capacity to put districts on the path towards centralization.

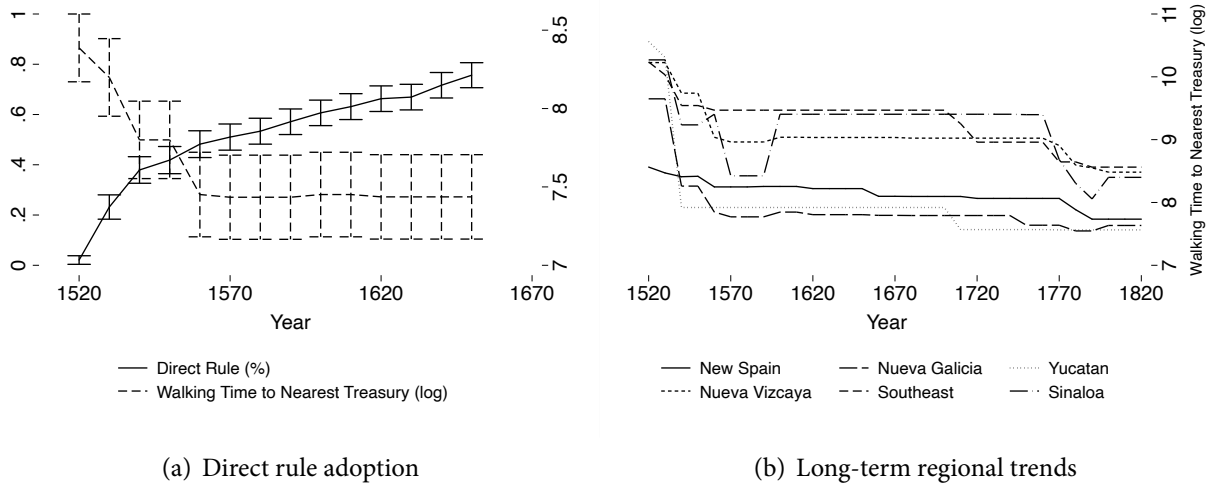
We assess these predictions in Figure B.3. On the left panel, we plot the temporal trajectory of endogenous fiscal legibility (log hours to nearest treasury) alongside political centralization (percent of holdings under direct rule) for the colonial governments of New Spain and Nueva Galicia, the areas where we have disaggregated data on the transition to direct rule. Consistent with our argument, centralization and investment in fiscal legibility followed similar trends in the early colonial period. The concurrent steep decline in walking time to treasury and steep incline in direct rule adoption is especially notable in the middle of the 16th century around the time when the patio process had been discovered.

In the right panel of Figure B.3, we plot the average least-cost walking time (in log hours) to the nearest royal treasury by region and decade for the colonial period (1520s–1810s) using a larger sample including New Spain, Nueva Galicia, Nueva Vizcaya, Sinaloa, the Yucatán, and the southeast frontier (parts of what are now the states of Chiapas, Tabasco, and eastern Oaxaca)²⁰ As the figure illustrates, regions saw very different patterns in investment in fiscal legibility, particularly after the early wave

populations (Gerhard 1993*b*).

²⁰See Gerhard (1993*a;b;c*) and Figure A.1).

Figure B.3: Trends in Walking Time to Nearest Treasury



The **left** figure plots average log least-cost walking time to nearest treasury over direct rule adoption from 1520 until 1700 for New Spain and Nueva Galicia. The **right** figure plots log least-cost walking time by region from 1520 until 1810 for areas with direct/indirect rule institutions. The full list of treasuries with date of construction can be found in Appendix Section B.4. See the text and Section D for information on construction of this measure.

of treasury construction in the 16th century. The core areas of New Spain and Nueva Galicia, which were already under solid control of the Empire, saw periodic improvements in fiscal legibility, while areas that were then frontier regions—Sinaloa and Nueva Vizcaya in the north and the southeast region—saw little decrease in walking time between the early wave of treasury construction and the late 18th century despite being considerably farther from existing treasuries.²¹

The theoretical framework provides insight into why the Crown would have prioritized enhancing fiscal legibility in core areas under centralized control over attempting to penetrate low-legibility areas through treasury construction. In very low legibility zones, the payoff to gaining a small amount of informational capacity is minimal. The central ruler is better off simply ceding revenue and autonomy to local intermediaries to facilitate tax collection. In higher legibility areas under direct forms of rule, by contrast, even a marginal improvement in fiscal legibility can yield benefits by improving the ruler's ability to monitor and sanction intermediaries in the short term. These frontier areas were not entirely economic backwaters; commodity-producing activities, such as cochineal in Oaxaca and silver mining in the northern regions, provided significant potential revenue. However,

²¹Sinaloa saw a short-term decline in walking time due to the temporary placement of a treasury in the northwest district of Chiametla between 1575 and 1601.

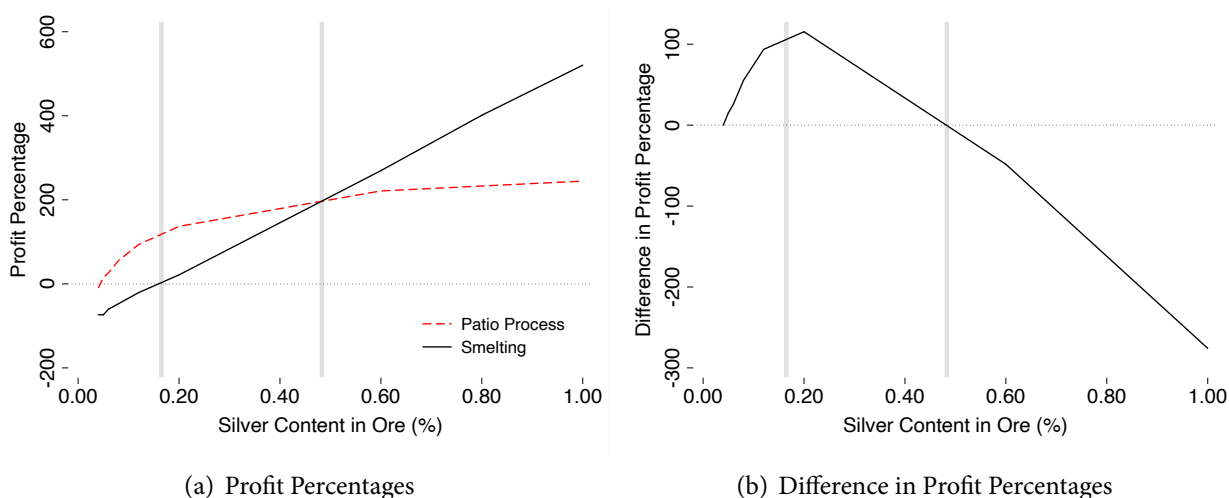
these distant areas had much lower ex ante informational capacity, which reduced the benefit of legibility investment until the very end of the colonial period. The temporal trends in the right side of Figure B.3 are also consistent with our theoretical predictions. The first 50 years of colonial rule saw a rapid decline in walking time in Nueva Galicia, New Spain, and the Yucatan through the construction of nine treasuries by the 1570s. After this, treasury construction slows down. Only four new treasuries were established over the next century, all in the core regions of New Spain and Nueva Galicia. Mired in conflict in Europe, the Crown was forced to divert spending to more immediate needs over most of the 17th and early 18th centuries (see Section 6.2). This decline in the Crown's patience for investment reduced its willingness to improve informational capacity in the Americas for longer-term gain. As we discuss in the paper, this corresponded with a general period of disinvestment in colonial institutions when trends toward political centralization arguably reversed as well (e.g., Knight 2002).

The Bourbon period saw a reversal in both trends. During the second half of the 18th century, as external conflict waned and Britain's threat in the Americas grew, the Crown embarked on a series of ambitious reforms to centralize authority and improve revenue collection. In moving toward more direct forms of rule, the value of obtaining better information about the local economy increased, and the Crown became more willing to invest in state informational capacity via the construction of treasuries. Political centralization and investment in fiscal legibility worked in tandem in the last decades of Spanish rule, as was true in the early colonial period and as would be suggested by our framework.

C. 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 C.1: Profitability Percentages for the Patio Process and Smelting



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 C.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.²²

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 B.1 and Figure B.1. 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.

C.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 and 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.

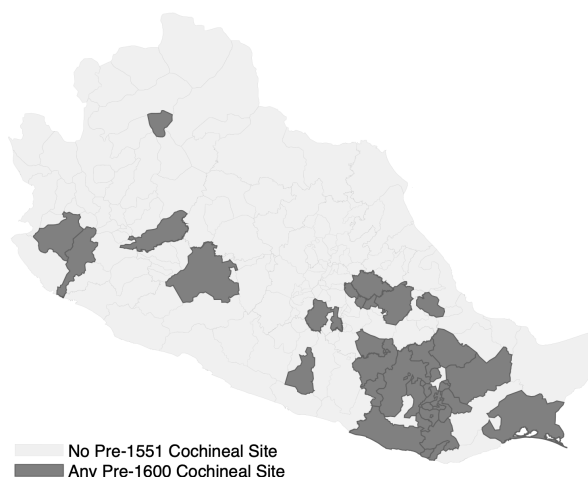
To quantify this shock to cochineal external demand, we rely on a number of price series collected in different European markets, compiled and normalized to silver pesos per *arroba* ($\sim 25\text{lb}$) by

²²Moreover, 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.

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



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 prehispanic times, cochineal production was concentrated in certain regions, due in large part to the specific environmental conditions that allow for its cultivation (see Figure C.2). To identify these cochineal-producing areas, we georeference a list of production sites compiled by Donkin (1977), based on primary sources that include 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.

Table C.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 × Seville Price (Chaunu & Chaunu)	0.00038 (0.00034) {0.00031}	0.00039 (0.00042) {0.00035}				
Cochineal Site × Seville Price (Avg. Spain)			0.00035 (0.00035) {0.00032}	0.00036 (0.00043) {0.00036}		
Cochineal Site × Price (Avg. Seville/Florence/Antwerp/Amsterdam)					0.00017 (0.00024) {0.00023}	0.00022 (0.00028) {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	0.88	0.86	0.88	0.84	0.86
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. Std. errors clustered at the district level in parentheses; errors that allow for serial correlation within districts and spatial correlation between districts within 500 km of each other in curly brackets. 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).

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

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

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 C.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 sharp increase in its revenue potential led to differential changes in 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 districts did not experience the same transition from non-dismissal to dismissal contracts.²³

D. Distance Measure Construction

We calculate distance to Mexico City, the nearest post office, and the nearest royal treasury in several ways. The simplest measure is the (minimum and space-weighted average) Euclidean distance (by decade for the treasuries). This measure ignores any barriers to travel, such as mountains or ocean, which is a potential concern given Mexico's terrain. We therefore construct an alternative measure that incorporates terrain ruggedness, drawing on Least-Cost Analysis (LCA) methods from archaeology and using a 90-m digital elevation model (DEM) from INEGI and the procedure described in (White 2015). From this friction surface, we calculate the cumulative cost distance to the nearest treasury and extract the minimum and space-weighted average cumulative travel cost

²³The 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.

to the nearest treasury (in hours) 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.)

We also construct a cost distance measure that incorporates land cover and elevation as well as slope using 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). The elevation and slope measures are calculated from the same 90-meter DEM. 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 as a base, we convert the ISLSCP II land cover measures to IGBP equivalents to use the walking speed multipliers in Weiss et al. (2018) (Table D.1). We verified these conversions using contemporary remote sensing data from NASA's MODIS.²⁴

Table D.1: 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).

²⁴Because of the coarse resolution of the ISLSCP II data, some coastal/lakefront land is coded as ocean/open water, including a couple of coastal treasuries. We handle these overlapping areas by using 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, we note that there is little difference between these measures in practice.

E. Supporting Information References

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