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Pandemic Spikes and Broken Spears: Indigenous Resilience after the Conquest of Mexico

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ABSTRACT

It is well-established that the Conquest of the Americas by Europeans led to catastrophic declines in indigenous populations. However, less is known about the conditions under which indigenous communities were able to overcome the onslaught of disease and violence that they faced. Drawing upon a rich set of sources, including Aztec tribute rolls and early Conquest censuses (chiefly the *Suma de Visitas* (1548)), we develop a new disaggregated dataset on pre-Conquest economic, epidemiological and political conditions both in 11,888 potential settlement locations in the historic core of Mexico and in 1,093 actual Conquest-era city-settlements. Of these 1,093 settlements, we show that 36% had disappeared entirely by 1790. Yet, despite being subject to Conquest-era violence, subsequent coercion and multiple pandemics that led average populations in those settlements to fall from 2,377 to 128 by 1646, 13%

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would still end the colonial era *larger* than they started. We show that both indigenous settlement survival durations and population levels through the colonial period are robustly predicted, not just by Spanish settler choices or by their diseases, but also by the extent to which indigenous communities could themselves leverage nonreplicable and nonexpropriable resources and skills from the pre-Hispanic period that would prove complementary to global trade. Thus indigenous opportunities and agency played important roles in shaping their own resilience.

Keywords: Conquest of Mexico; indigenous; settlement survival; pandemics

JEL Codes: I15, N36, N76, N96, O10, P48

> Nothing but flowers and songs of sorrow are left in Mexico and Tlatelolco where once we saw warriors and wise men ... We wander here and there in our desolate poverty. We are mortal men. We have seen bloodshed and pain where we once saw beauty and valor.
>
> — *Cantares Mexicanos*, 1523. Translated by Miguel León Portilla, *The Broken Spears.*

> There are ... great differences between [the plagues of Mexico] and those of Egypt. First, in only one of those ... were there deaths of people; but here, in each ... there have been many deaths. Second, in each one of the houses there remained someone to mourn the dead, and here, of the plagues already described, many houses were left abandoned, because all their occupants died. Third, in Egypt, all the plagues lasted only a few days, and here, some a very long time.
>
> Those, by the commandment of God: most of these by the cruelty and depravity of men, although God permitted it.
>
> — Fray Toribio de Motolinia, *Memoriales.* Passage expunged from the 1541 *Historia.* Translated by McCaa (1995).

Introduction

In 1519, or 1-Reed according to the Aztec calendar, the indigenous peoples of what is now Mexico confronted the soldiers, arms and diseases of a new world.[1] What followed was one of the most traumatic moments in history. Over-matched militarily, unprepared epidemiologically, the indigenous peoples of Mexico had to find new means to survive. Many would fail: as we show, 36% of settlements mentioned in historical sources would disappear by the 1790s.[2] Much has been written about the 'guns, germs and steel' of the Spanish (e.g. Diamond, 1999; Thomas, 2005). And an important emerging literature documents the lives of the indigenous peoples during the Conquest from their own perspective (Magaloni Kerpel, 2014; Restall, 2021; Townsend, 2019). However, we are only beginning to forge a social-scientific understanding of the strategies and conditions specific indigenous communities deployed to survive — and even grow — after the devastating political, economic and epidemiological shocks of the Conquest.

Which indigenous communities survived the Conquest, and why? To answer this question, we draw upon a rich set of sources, including pre-Columbian tribute rolls and early Conquest censuses, to develop a new and highly disaggregated dataset of the economic, political and epidemiological conditions faced by populations in 1,093 actual settlements and 11,888 potential locations in the historic core of Mexico from early in the Conquest (1548) to the end of the colonial period (ca. 1790). Disaggregating settlement patterns — to the extent possible — to the level of individual pre-Columbian political units (*altepeme*) themselves — we are able to document demographic dynamics that have been thusfar obscured when examining extrapolations based upon the much more aggregate data which has been the basis of most analyses of this period.

The individual settlement (or *altepetl*) was the building block of pre-Columbian society and the level at which key local political institutions operated. We use a conceptual framework and empirical evidence to help understand which of these altepeme — and their accompanying indigenous cultural and political institutions — would last to form the nuclei for many of the future pueblos and towns of Mexico today. In contrast, work carried out

[1] We will refer to the Colhua Mexica within the Triple Alliance of Tenochtitlan, Tacuba and Texcoco by the general term, *Aztecs*.

[2] Cook and Simpson (1948) calculate the population of Central Mexico at the time of the Conquest to be 11 million, with a precipitous decline down to 2 million by 1607. Revised estimates by Cook and Borah (1960) place the surviving population by 1605 as no more than 1.37 million, plus perhaps some 200,000 whites, blacks and mixed *mestizo* and *mulato* inhabitants (p. 49, footnote 49). Disagreements remain regarding an accurate quantitative estimate of the overall demographic decline (Denevan, 1992; Henige, 1998), and about the relative weight that should be given to the various potential causes war, epidemics, famine and social dislocation, among others (Livi-Bacci, 2008).

at higher levels of aggregation cannot distinguish between population growth within these indigenous settlements, growth through new towns nearby, or growth in colonial communities.

We first document that there was substantial variation in the geographical patterns of settlement survival, both regionally, but also among neighboring settlements. In fact, of more than one thousand locatable settlements mentioned in the most comprehensive record of the time, the 1548 *Suma de Visitas de los Pueblos* [Compendium of Town Inspections], 36% had disappeared entirely by the end of the colonial period. Conquest-era violence, subsequent coercion and multiple pandemics led average populations in those settlements to fall from an estimated 2,377 inhabitants per settlement to only 128 by 1646. However, despite being subject to those pressures, 13% of the settlements would end the colonial era *larger* than they started. Further, we provide evidence that diseases and actions by the Spanish were only part of the story. A crucial element was the ability of indigenous communities to leverage their skills, knowledge and other endowments to weather this dramatically transformed economic, political and epidemiological landscape.

To understand this process, we first present results on the duration of settlement survival in 1,093 indigenous settlements over 242 years, from 1548 to 1790, that spans most of the colonial period of Mexican history. We exploit information from the *Matrícula de Tributos* [Table of Tributes], a unique document believed to have been given to Hernán Cortes by the last Aztec Emperor Moctezuma II Xocoyotzin himself, ca. 1522 (Townsend, 2019), detailing the pre-Conquest settlements under the rule of the Aztecs and their allies, as well as the forms of tribute they provided.

Building on a theoretical framework relating ethnic tolerance to interethnic complementarities developed in Jha (2007, 2013, 2014) and formalized in Jha (2018), we classify four key pre-Columbian tributary products — cochineal, cacao, gold and quetzal feathers — according to three conditions that support peaceful coexistence for vulnerable indigenous groups over long time horizons: complementarity between indigenous production and access to European markets, the relative cost to Europeans to replicate or expropriate the production process and their relative ability to monitor and thus coerce its production.

The first condition is the extent to which indigenous production was complementary to the new access the Spanish provided to European markets — i.e., there were potential gains to be had from interethnic trade. We contrast the iridescent green feathers of the quetzal, highly valued by the Aztecs and other indigenous elites as a component of ritual dress, but facing much more limited international demand, with the other three products, all of which were prized internationally and thus likely to gain in value with international market access.

In principle, improved access to global markets for their products could bring indigenous communities the opportunity for wealth and their settlements the chance for survival. However even if indigenous products are highly valued and there are potential gains from interethnic trade, these gains are less likely to accrue to indigenous communities if indigenous production processes can be easily transplanted and replicated if the source of the complementarity can be violently expropriated, or if it is relatively easy to monitor output, thereby facilitating labour coercion (Diaz-Cayeros and Jha, 2017; Jha, 2007, 2013, 2018). Hence the importance of looking at the other conditions of interethnic specialization, coercion and replicability, beyond opportunities afforded by foreign trade.

We thus compare the fate of settlements producing two pre-Columbian Mexican products that both enjoyed high demand in international markets and thus complementarity with Spanish market access, but could be transplanted or expropriated. Cacao, once a drink limited to indigenous Mexican elites, rapidly gained popularity in Europe, particularly when combined with another Mexican product, vanilla. However, Spanish, French and British traders rapidly introduced cacao beans into other colonies as well, competing with production by indigenous Mexicans (Kourí, 2004). Similarly, gold mines could of course be seized and labour in the mines coerced (e.g., Dell, 2010).[3]

In contrast, one pre-Columbian product satisfies all three conditions of complementarity, nonreplicability and high monitoring costs (Diaz-Cayeros and Jha, 2017). Cochineal was an indigenously domesticated insect that was the best source of red dye in the world until the development of synthetic pigments in the late 19th century, and would become the most valuable processed goods of New Spain (Baskes, 2000; Diaz-Cayeros and Jha, 2017). Unlike cacao, the fragile nature of domesticated cochineal stymied numerous attempts by French and British spies to transplant it overseas (Donkin, 1977; Greenfield, 2006). For the same reasons, cultivation of cochineal also called for high degrees of monitoring, indigenous skills and community organization that resisted attempts at plantation agriculture and coercion by the Spanish as well (Diaz-Cayeros and Jha, 2017; Donkin, 1977). Thus, cochineal production was left in the hands of indigenous populations, and these producers enjoyed a robust source of complementarity with access to world trade (Diaz-Cayeros and Jha, 2017).

Figure 1 previews these first set of results. It presents Kaplan–Meier graphs comparing the share of settlements surviving over the colonial period that produced each of these products in the pre-Columbian period to others that were also mentioned in the *Suma de Visitas*. Note that even in this raw comparison, cochineal-producing settlements are much more likely to survive throughout

[3]Gold mining in the 16th century Mexico was relatively short-lived, while silver was primarily found in areas to the North, outside of the historic Mesoamerican core region.

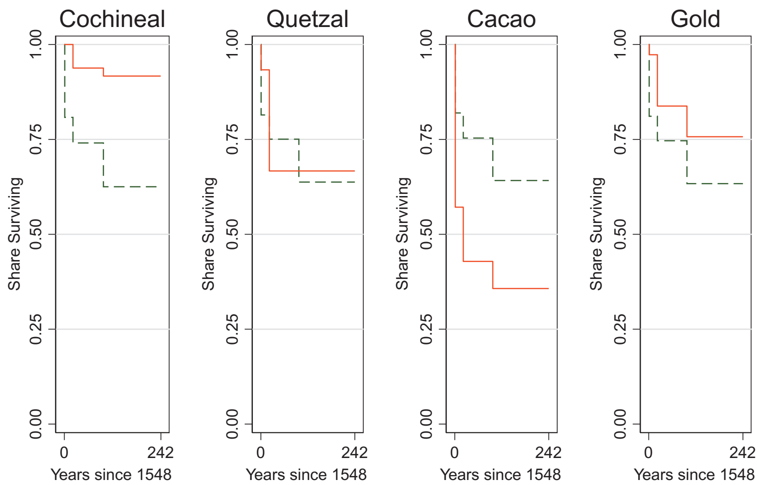

Figure 1: Kaplan–Meier graphs of settlement survival by type of pre-Hispanic tribute.

NB: Compared to other populated settlements recorded in 1548 (dashed line), those that produced Cochineal ($N = 74$) survive longer. In contrast, the survival advantages for producers of Quetzal feathers ($N = 41$), Cacao ($N = 44$) and Gold ($N = 77$) are less pronounced.

the colonial period. These differences prove to be robust. In fact, compared to other settlements with similar initial populations, climatic conditions and exogenous disease propensities, we find that indigenous settlements that produced cochineal at the time of the Conquest faced a five times lower hazard of disappearing each year during the colonial period, where 13 percentage points more likely to continue to exist in 1790 and enjoyed populations 1.7 times greater at the end of the colonial period. These patterns are robust to comparing altepeme with similar Aztec conquest histories and market access, comparing within the same province or lordship, and to accounting for potential spatial autocorrelation. They are also not driven by the choice of Spanish settlers to locate and settle in particular places. Thus, indigenous opportunities and agency appear to play important roles in shaping their own resilience.

In contrast, and consistent with the theoretical framework, settlements producing products that lacked one or more of the three conditions at the time of the Conquest enjoyed a less pronounced survival advantage. Comparing quetzal-producing settlements to otherwise similar settlements, we find the last appearance of quetzal-producing settlements in contemporary records occurs five to six times earlier during the colonial era, and their average populations are more than 86% *smaller* by 1790.

Of producers of goods that did enjoy high global demand, survival gains are also more modest when these production processes can be transplanted or expropriated. The sharp drop in the raw comparison in Figure 1 for cacao producers in part reflects the fact that pre-Hispanic cacao production was concentrated in the coastal zones of Mexico, areas that as we shall show, became heavily depopulated after the Conquest in general. Comparing to settlements matched on these and other characteristics, pre-Hispanic cacao-producing settlements do survive about twice as long in the records in the colonial era. However, the transplantable nature of this product takes its toll — they are no larger by the end of the colonial era. Similarly, pre-Hispanic gold-producing settlements, whose mines could be seized and whose labour could be coerced, while also surviving twice as long, also do not show population advantages by the end of the colonial period.

Our analysis suggests that local communities exhibited widely different demographic trends that reflected their ability to leverage their skills, knowledge and other endowments. Communities that had developed hard-to-steal or replicate production processes for goods (such as cochineal) whose value increased with the intercontinental market access provided by the Spanish were highly resilient. In contrast, indigenous communities that were primarily engaged in cultivating goods with now-defunct demand (such as quetzal feathers), or in easy to monitor or replicable economic activities such as cacao cultivation or gold mining were less so. Autonomous political decisions allowing for self-preservation were hence only possible, in a world of colonial rule, when the economic opportunities from trade for the original peoples were liberating, instead of forces of subjugation.

Our paper links to a literature on the role of interethnic complementarities on deterring violence and coercion against vulnerable minorities in South Asia (Jha, 2007, 2013, 2014), Europe (Becker and Pascali, 2019; Grosfeld *et al.*, 2020; Jedwab *et al.*, 2016), Mexico (Diaz-Cayeros and Jha, 2017) and more generally (Jha, 2018). We also build on a thriving literature examining the effects of colonial decisions and institutions on development (e.g., Acemoglu *et al.*, 2001, 2002; Banerjee and Iyer, 2005; Bobonis and Morrow, 2014; Dell, 2010; Engerman and Sokoloff, 2000; Huillery, 2009; Nunn, 2008; Valencia Caicedo, 2019). We complement this work while shifting our focus upon indigenous peoples as agents of their own destiny. Work by Angeles and Elizalde (2017), Arias and Girod (2011), and Elizalde (2020) correctly emphasize how indigenous institutions were often appropriated by colonists to structure their own imperial administration. But less is known about the conditions under which indigenous elites or the more vulnerable are better positioned to leverage these processes.[4] For the case of Mexico, Franco Vivanco (2019) shows how indigenous peoples

[4]See also Lee (2017) and Iyer (2010) on how indirect rule accommodated local elites in India.

used Spanish courts and rebellion in order to defend their rights and curb the extraction of rents by colonists.[5] Our paper uses indigenous sources and data to reconstruct their agency.[6]

Our work also links to an important literature on the role of locational fundamentals and urban development in history both in driving persistence and driving resilience to epidemic diseases and disruptions (e.g., Bleakley and Lin, 2012; Bosker, 2021; Jha, 2013; Michaels and Rauch, 2018; Nagy, 2020).[7] In our setting we examine the conditions of indigenous settlement survival, cognizant both of the locational fundamentals emphasized in this literature but also of the dramatic changes in the structure of political power, product demands and technologies of water and land transport, including the horse. In doing so, specifically for the case of New Spain and Mexico, our paper builds upon recent contributions by Alix-Garcia and Sellars (2020), Garfias and Sellars (2020, 2021), and Sellars and Alix-Garcia (2018), as we outline below.

Finally, we seek to give full credit to a long tradition of historical research. Our paper is connected to the historical demography and epidemiology research produced by the Berkeley historical demographers half a century ago, seeking to establish how many indigenous people were lost (Borah and Cook, 1960; Cook and Simpson, 1948; Gerhard, 1972). There is a recent vibrant discussion on the pathogenic origin of colonial epidemics, deemed to be the main explanation for the demographic loss (Acuña-Soto *et al.*, 2002; Vågene *et al.*, 2018). And there is an increased shift towards a city understanding of Mesoamerican societies (Fargher *et al.*, 2010; Smith, 2015). We build on these contributions, focusing on the political settlement as the unit of analysis, and connecting to theoretical frameworks that move beyond the description of the demographic processes. These, we argue, permit a novel and deeper understanding of the survival of indigenous communities and settlements in Mexico.

[5]It should be noted that an indigenous agency perspective is highly visible in other social sciences. Anthropologists, linguists and sociologists, particularly in Latin America, have been advancing an indigenous perspective, some of it produced by indigenous scholars (e.g., Gil, 2020; Navarrete, 2016). And many historians are keenly aware of the importance of using indigenous sources for their interpretations (e.g. Magaloni Kerpel, 2014; Mundy, 2015; Restall, 2021; Townsend, 2019; Tutino, 2017; Yannakakis, 2018).

[6]Contributions by Bruhn and Gallego (2012), Dell and Olken (2020), Dippel *et al.* (2016), Iyer (2010), Nunn (2008), Valencia Caicedo (2019), and Waldinger (2017), among others, have highlighted variation in the impact of colonialism in the modern era, as local resource endowments, preexisting forms of self-rule, differential structures of labour exploitation, or competing interests between Crown, religious orders and colonists are recognized. We build on their insights, focusing on demographic outcomes within the colonial period.

[7]Bosker (2021) provides a useful recent overview. See also Maloney and Valencia Caicedo (2016) who point out that in Latin America large agglomerations today are clearly correlated with regional pre-Columbian population densities; and findings by Arteaga (2013) showing greater historical persistence in the Mesoamerican core areas within Mexico.

Theoretical Framework

We follow the framework outlined in Jha (2007, 2013, 2014) and formalized in Jha (2018). He presents a model where two types of agents: 'locals' (or 'indigenous') and 'nonlocals' (nonindigenous) choose every period whether to leave a location, and if they stay, whether to produce a good (that may compete or complement others' production), and to target another agent with destructive, expropriative violence. The only initial difference between the two types of agent is that the nonindigenous have better outside options and can leave any particular location more cheaply than for indigenous groups, whose knowledge, networks and endowments tend to be more concentrated locally. Jha examines the conditions that can support peaceful coexistence even when the cost of organizing violence is relatively low for members of one group, leaving the other group vulnerable. While the *vulnerable nonindigenous* case arguably fits the situation of many expatriate minorities, the *vulnerable indigenous* case is arguably a better approximation of the conditions faced by many in Latin America at the moment of the Conquest.

As Jha (2018) describes, for a broad range of parameters, particularly when the vulnerable group produces potentially highly lucrative products, a necessary condition for a (subgame perfect) peaceful coexistence equilibrium over long horizons is not only that they produce complements (and thus do not compete with members of the 'stronger' group), but also that this complementarity is *robust* in a specific sense: the technology of complementary production cannot be easily replicated or seized by members of the other group. Further, vulnerable nonindigenous groups (often trading minorities) are better positioned than vulnerable indigenous groups to benefit from peaceful cross-ethnic interactions: while nonindigenous groups can credibly threaten to leave a specific location in the face of potential violence, the cost to indigenous groups of leaving their homelands is (by definition) higher.

Even if indigenous groups enjoy robust complementarities, the threat remains that they can simply be coerced into producing it. What is necessary then for vulnerable indigenous groups then is that there is a friction such as a high cost of monitoring effort or production, that makes coercion difficult. Like gold and silver, cochineal was in high demand in Europe. However unlike the former, where labour could be coerced, cochineal was not only domesticated by the indigenous and required specific know-how and skills to produce, it was incredibly fragile, requiring great attention for its cultivation and being susceptible to fluctuations in temperature, frost and rain. Unlike cacao, this made transplantation and monitoring difficult (Diaz-Cayeros and Jha, 2017; Donkin, 1977), and after a number of failed attempts by the Spanish to produce cochineal in plantations, it became a product left in the hands of the indigenous. But were the indigenous able to exploit these opportunities to enhance their chances of survival? We now turn to answer this.

Empirical Approach

To understand which indigenous settlements survived the Conquest and to what extent these patterns were driven by their ability to leverage production complementarities and monitoring costs, our approach is to use two fixed points in time where contemporaries sought, based upon primary census-taking, to obtain comprehensive coverage of the population of settlements for specific areas that encompassed most of the historic core of Mexico. We complement those two fixed points with a precolonial document. The first key data source is the *Suma de Visitas de los Pueblos*, published in 1548, and drawing from observations throughout the preceding decade.[8] This remarkable document lists the number of individual households in each settlement and was conducted by teams of travelling Crown officials each tasked with 'visiting' specific settlements throughout the then settled historic core of Mexico. The aim was to provide a comprehensive picture to the Spanish Crown of the extent and number of subjects owing tribute within his newly Conquered territories. As we describe in detail in online Appendix 1, we go through a painstaking process to geographically locate as many of the original settlements of the Suma as possible. We draw both upon existing secondary sources that attempt this, most notably Cook and Borah (1960), but also exploiting geographical references and clues in the document itself. We also trace the individual itineraries across the territorial landscape to help identify missing locations along their routes. Locating 1,093 indigenous settlements listed in the Suma is, in our view, in itself a contribution to the historical demography of Mexico, and an advance over the impressive but now 60-year-old previous attempt to do so by Cook and Borah (1960). We augment these with data from Cook and Simpson (1948) based upon other contemporary sources for settlements not covered in the Suma (see below).

We wed the resulting 1,093 settlements to a second fixed point, a comprehensive dataset of indigenous pueblos and Spanish villas and Ciudades assembled by Tanck de Estrada (2005) in her *Atlas de los Pueblos de Indios*. Her data reflects regional population counts and the first Census ordered by Viceroy Revillagigedo in 1790, near the end of the colonial period. We consider a settlement mentioned in 1548 to have 'survived' the colonial period if a pueblo also existed in the records for that specific location (see below) in 1790.

Our main empirical tests compare settlements of similar population levels in 1548, predicting both the probability that settlement survived until 1790 and the population level in 1790 as a function of the extent to which those settlements could leverage robust complementarities with global trade. We also assess the sensitivity of these patterns to matching on pre-Hispanic political

[8]The original document is kept in the Biblioteca Nacional de España, MS 2800, and is available in digital form at http://bdh-rd.bne.es/viewer.vm?id=0000051228&page=1.

conditions and market access, susceptibility to novel and existing diseases, as well as climatic and geographical endowments. In our main specifications, we therefore run regressions of the following form:

$$Y(Pop_{i,1790}) = \sum_j \tau_j \, Tribute\ Prod_{ij,ca.1521} + \sum_k \gamma_k Disease\ Indices_{ik} + \sinh^{-1}(Pop_{i,1548}) + X'_{ic}\beta_c + Se\tilde{n}or\acute{\imath}o_s + \varepsilon_i, \quad (1)$$

where an observation i is an individual settlement that existed in 1548. Y is a function of population — either an indicator that the settlement exists in 1790 or the inverse hyperbolic sine of population in 1790.[9] Our main coefficients of interest are τ_j — the coefficients on indicators for whether a settlement produced cochineal, quetzal feathers, gold or cacao at the time of the Conquest, drawing mainly from the Matrícula de Tributos and other contemporary sources. As we outline below, we also develop and add indices that predict four major diseases — hemorrhagic dengue, *tabardillo* (typhus), *yersenia pestis* (plague) and the drought conditions for the major outbreak of *cocolitzli* in 1576. To check robustness, in some specifications, we also include a series of controls for distances to Tenochtitlan, the Coast, navigable rivers, our novel reconstruction of the pre-Hispanic Road network, as well as linear and quadratic terms for latitude, longitude, altitude, cumulative precipitation and ruggedness, as well indicators for tropical and arid climatic zones. We also develop novel measures for how long each region had been under the rule of the Aztecs and their allies, as well as indicators for location with each independent lordship (*señorío*, according to Davies (1968)) or status as a Triple Alliance tributary province (according to Barlow (1949)) at the time of the Conquest.

The Spanish chose to establish their own cities in places that both benefited from existing locational advantages — like Tenochtitlan itself, that was, of course, refounded as Mexico City — and a new trade route centered around the annual convoys that left from Veracruz. These decisions were, of course, subsequent to the Conquest and therefore potentially endogenous to the relative success of survival of the indigenous settlements themselves. Nevertheless, to assess the extent to which our results are driven by these Spanish choices, rather than the possibility for indigenous action, in some specifications we also include controls for whether a settlement was adopted for residence by the Spanish, and the distance to Veracruz.

[9]NB. The $\sinh^{-1}$ function approximates — and can be interpreted like — a logarithm, but is defined at zero. Note also that in cases where the sources record only the name of a settlement but no population, we assign a lower bound population of 1 in our regressions on population levels. Our main results are robust to using log or Poisson specifications, as well only using recorded population numbers.

We are interested not just in the fact of survival of these settlements, but also the *timing* that settlements cease to appear in contemporary records. For those 36% of settlements in the Suma that do not survive to 1790, we also consult historical sources at two intermediate moments — ca. 1570 and in 1646 — when it is possible to join a number of different town lists to isolate the last recorded moment when a settlement exists. These data derive mainly from the second most comprehensive compilation of human settlements made by the Royal Cosmographer, Juan López de Velasco, *Geografía y Descripción Universal de las Indias* in 1570 and calculations from Cook and Borah (1971), drawing from the accounting papers of the Conde de Salvatierra, Viceroy of New Spain in 1646. We will use the information on when a settlement last appears in these sources explicitly when we estimate Cox proportional hazard regressions of settlement survival (see also Figure 1).

Units of Analysis

The advantage of exploiting and limiting our sample to those mentioned in the Suma de Visitas and other contemporary sources is that this allows us answer a key question of interest: which types of indigenous communities were better equipped to survive the Conquest and why?[10]

A major challenge in this enterprise is that of linking indigenous settlements over time, particularly as they expand and contract in geographical space. Thus, we expand our sample by partitioning Mexico's modern territory into 21,977 AGEB-localidades [census tracts — settlements], of which 11,888 lie within the historic core of central Mexico. These 11,888 *potential* locations encompass a number of settlements that were excluded in the Suma or appeared later in the colonial period.[11] The median area of the AGEB-localidades in the historic core is 58.7 sq. km (the scale of a square with a side stretching 7.7 km). The advantage of using AGEB-localidades, however, is not just that

[10] As we discuss in the online Appendix, as it was primarily a document to calculate tribute, the Suma itself does have some gaps. Among these, it does not include specific counts for Tenochtitlan itself, the independent (and relatively tax-exempt) *Señorío* of Tlaxcallan, a key ally of the Spanish, nor for settlements that were given in *encomienda* to Cortes himself within the *Marquesado del Valle*, chiefly in Oaxaca. We fill some of these by exploiting and newly georeferencing data in Cook and Simpson (1948), which draws upon other contemporary sources. We also control for señorío fixed effects. More details on the full 1548 dataset are provided in online Appendix 1.

[11] Further details are provided in online Appendix 2. For comparability, we exclude what the Aztecs referred to as the Chichimec ('barbarian') region, which included large areas of Nueva Galicia, and Nueva Vizcaya, as well as lands towards the North that were mainly nomadic, not to mention poorly documented, at the time of the Conquest. We also exclude the Mayan region which is a subject of our ongoing research. Instead we focus on the historic core, which includes the Colhua Mexica Triple Alliance (the Aztecs), the Phurepecha (Tarascan) Empire, and the independent lordships of Central Mexico and the frontier to the North, a region that reflects more faithfully the area of permanent settlements at the time. The sources for the data are further discussed below.

these are highly disaggregated units, but also they more accurately reflect the settlements of the time — and the level at which contemporaries thought of and collected the data — than other types of partition.

In doing this, we acknowledge the important contributions of, but depart from, the population reconstructions compiled by Peter Gerhard in his series of Guides to the Historical Geography of New Spain (e.g., Gerhard, 1972). The geographic entries in these texts provide arguably the prevailing image of the demographic decline in 16th century Mexico.[12] Gerhard aggregated information to the level of the *Alcaldía Mayor*, a set of civil jurisdictions emerging from the administrative reforms of the Bourbons near the end of the colonial era (in 1786–1787).[13]

While these units are potentially valuable for studying the late colonial period, when dealing with the patterns of individual settlement from the precolonial period, such aggregation is arguably not as appropriate. We also believe that our approach has some advantages over use of arbitrary grid-cells, e.g., of 15 km × 15 km, following some recent scholarship. Foremost, the advantage lies in allowing us to capture the level of aggregation at which our original data was collected and political jurisdictions were organized. But further, it allows us to reflect the geographic landscape, differences in local carrying capacities and the inheritance of territorial spaces that capture local institutional differences, while allowing for fine partitions that distinguish comparable potential locations as well.[14] The online Appendix provides an example of how the AGEB-localidades in the Oaxaca region reflect natural divisions as well as long-standing historical jurisdictional boundaries between settlements that might otherwise be obscured.

To summarize, existing work on the colonial era in Mexico has tended to focus on extrapolations of population estimates aggregated upto considerably larger units such as colonial-era *alcadia mayores*, modern *municipios* and in

[12]Those guides assembled information from a wide array of disparate sources in order to provide detailed monographs for the political jurisdictions of the New Spain, Nueva Galicia, Nueva Vizcaya and the sparsely populated North and Southern frontiers.

[13]For example, important work by Garfias and Sellars (2020, 2021) uses these larger units of analysis to study the sale of offices in those jurisdictions during the late colonial period and to assess the transition into direct rule during the colonial era in Mexico with the shift from *encomiendas* to *corregimientos* as a consequence of the threat of rebellion and demographic decline.

[14]Since historic data tends to be collected at the level of groups of people rather than arbitrary squares, arbitrary grid-cells, as used in historical research, tend to depend heavily on interpolated (and thus smoothed) data, if they are small. Similarly, if they are large, they face the challenge of smoothing over dissimilar microclimates and even political historical regions as they do not incorporate natural barriers, such as ridges and rivers, and do not, in and of themselves, reflect differing endowed carrying capacities, that lead to smaller but distinct political and historical units in some places and larger ones elsewhere.

some cases even whole modern Mexican states.[15] However working at high levels of aggregation means that many different historic altepeme or pueblos are grouped together, even though some may have thrived even while others failed to survive. We instead choose for our partition and our unit of analysis the fundamental census unit (AGEB) for potential and actual 1548 settlements, that now fall in rural areas, and localities (localidades) for those that have survived to the modern period as urban areas (please see online Appendix 2). We consider populations that belong to the same AGEB-localidad to belong to the same settlement.[16] To account for the possibility that errors in our estimations are not independent across geographical units, we cluster at the level of the pre-Hispanic independent political lordship or province (señorío), as well as reporting results from a spectral-weighted spatial generalized methods of moments regression that explicitly models and accounts for potential spatial dependence.[17]

Population in Indigenous Settlements

Table 1 shows summary statistics for the presence of settlements and the average populations of settlements listed in the Suma de Visitas and across all AGEB-localidades in the historical core in the years 1548, 1570, 1646 and 1790. The table shows two columns, one limited only to the 1,093 settlements of the (augmented) Suma, and the second the historic core of the Meso-American area. We also sum the populations to give an estimate of total population

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[15] For reference, municipios in the historic core of Mexico have a mean size of 224 sq. km, and Alcaldias Mayores at the end of the colonial period were much larger than municipalities. In the historic core Alcaldías Mayores had an average size of 2,374 sq. km.

[16] As we note in online Appendix 2, urban localities reflect individual historic pueblos' boundaries much more faithfully than the aggregate municipios, that may encompass many different historic pueblos. On the other hand, urban AGEBs are the equivalent to a few urban blocks, many of which falling within historic pueblo boundaries, and thus are too disaggregated. Hence we combine urban localidades with rural census tracts (AGEBs).

[17] We employ a spatial autoregressive model that accounts for spatial autocorrelation among the geographical units, as suggested by Drukker *et al.* (2013). In particular, we use a generalized method of moments (GMM) estimator to fit the following model:

$$Y(Pop_{i,1790}) = X\beta + (I - \rho W)^{-1}\varepsilon,$$

where X is a matrix with all the already-mentioned covariates, W is a $N \times N$ spatial weighting matrix (containing the inverse distances between all the pairs of geographical units), ρ measures the spatial correlation in the errors, and ε is the underlying spatially non-autocorrelated error vector. $(I - \rho W)^{-1}\varepsilon$ is the result of solving for $\epsilon = \rho W \epsilon + \varepsilon$, where ϵ is an error vector that may be subject to spatial autocorrelation. Accounting explicitly for potential spatial autocorrelation allows us to assess the sensitivity of our results to an alternative estimation of standard errors that would not be biased by potential clustering of similar geographical units.

Table 1: Population change over the colonial period in the historic core of Mexico.

	(1) Suma only mean (SD)	(2) Historic Core mean (SD)	(3) Suma only (Implied totals)	(4) Historic Core (Implied totals)
Panel A: Settlement survival and expansion				
Settled in 1548	1.00	0.09	1,093	1,075
	(0)	(0.287)		
Settled in 1570	0.74	0.07	813	813
	(0.437)	(0.252)		
Settled in 1646	0.75	0.09	819	1,018
	(0.434)	(0.280)		
Settled in 1790	0.64	0.25	697	3,027
	(0.481)	(0.436)		
Panel B: Population				
Population 1548	2377.42	207.96	2,598,516	2,472,223
	(5008.9)	(1566.6)		
Population 1570	429.80	38.11	469,774	453,108
	(1173.5)	(358.8)		
Population 1646	128.09	20.72	140,003	246,343
	(512.4)	(230.4)		
Population 1790	712.41	163.39	778,664	1,942,403
	(4474.7)	(1175.9)		
Observations	1093	11888		

NB: mean; sd in parentheses. An observation is an urban locality/rural census tract (localidad-AGEB). "Settled in X" indicates whether a settlement continued to exist, prior to 1790. "Population X" is a lower bound on population in year X. Column 1 includes only towns mentioned in the Suma de Visitas (1548). Column 2 includes all localidad-AGEBs (i.e. 'potential locations') in the Historic Core of New Spain. This excludes the Maya region and unsettled areas of the Chichimec frontier at the time of the Conquest.

for each set as a whole.[18] Notice that as early as 1570 there is a dramatic decline both in the number of settlements that exist, as well as their average population. There were 2,377 inhabitants in settlements listed in the Suma in 1548. This fell to only 430 in 1570. These numbers fall even further to only 128 inhabitants in 1646 (with some settlements reappearing). By the end of the colonial period, only 64% of the original settlements, with an average

[18]Note that these estimates aggregate up from settlement-level data and, as mentioned assign a lower bound number of 1 if a settlement is mentioned but with no associated population.

population of 712, remain.[19] Looking across actual and potential locations within the Historic Core shows similar catastrophic falls, with populations in 1646 a tenth of what they had been in 1548. However, by the 1790s the Historic Core shows an expansion, with close to a tripling of the number of settlements, and a recovery of population to 1.94 million by the end of the colonial period. Put together, these patterns suggest the grim fact that while there is some recovery over the colonial period, the original indigenous settlements of early Conquest Mexico tended not to be the major beneficiaries.

Predetermined Indigenous Production as derived from pre-Hispanic Tribute Rolls

We now turn to outlining the sources of other novel variables in our dataset (please also see the online Appendix). Table 2 provides summary statistics across both samples. As mentioned above, to reconstruct economic and political conditions at the time of the Conquest, we use the Matrícula de Tributos (Ferreras, 1997) that details the types of tribute that were to be supplied by tributary towns and provinces to the Aztecs and their junior allies in the Triple Alliance — the city-states of Tacuba and Texcoco (Smith, 2015).[20]

We build upon the work of existing scholars who have analyzed these documents, particularly Carrasco (2016) and Kobayashi (1993) to extract the composition of the goods provided in tribute by different settlements. As discussed above, we then follow the framework proposed by Jha (2007, 2013, 2014) and formalized in Jha (2018) to categorize indigenous products according to the degree to which they are *complementary* with the international market access provided by the Spanish, the extent to which their production processes can be *replicated* or expropriated, and the extent to which the labour process is easy to monitor and therefore to *coerce*. For simplicity, we limit the current analysis to four specific products that each highlight the importance of these three different conditions. As discussed above, these include the gathering of

[19]It is worth noting that the largest indigenous settlement in 1548 was not Tenochtitlan/Tlatelolco, devastated by the invasion, but rather Texcoco, its junior partner in the Triple Alliance on the shores of the lake that acted as a staging point for the invasion of the island capital. Texcoco's population fell from 64,589 in 1548 to 12,658 in 1570 to merely being mentioned as existing in 1646 (with no specific count). By 1790, its population is only 3851.

[20]It is believed that in 1522, Moctezuma gave a scroll containing the Matrícula to Cortes, hoping that the latter would agree to leave in exchange for tribute. A copy was prepared for Viceroy Mendoza in 1536 to be sent to the King in Spain but was captured by the English. Now housed at the Bodleian library at Oxford, the *Códice Mendoza* (Brito and Gutierrez, 2015), provides invaluable information on some pages that were lost in the *Matrícula*. A third version called the '*Información*' (Scholes and Adams, 1957) was requested by Prince Phillip in 1554 as a "reading" of the pictographic images and their meanings. This last source has no images, but is crucial to our understanding of the tribute structure, given that it provides monetary values for the various products as well as the overall revenue collected from each province.

Table 2: Descriptive statistics for explanatory factors of settlement survival.

	(1) Suma only mean (SD)	(2) Historic core mean (SD)
Cochineal Producer ca. Conquest	0.044	0.006
	(0.205)	(0.0787)
Quetzal Producer ca. Conquest	0.014	0.003
	(0.116)	(0.0586)
Cacao Producer ca. Conquest	0.013	0.003
	(0.113)	(0.0572)
Gold Tribute pre-Hispanic	0.034	0.006
	(0.181)	(0.0802)
Maize Tribute pre-Hispanic	0.076	0.017
	(0.265)	(0.130)
Mentioned in Matricula/Barlow	0.133	0.030
	(0.339)	(0.170)
Log. Dist. Tenochtitlan [km]	5.523	5.587
	(0.807)	(0.771)
Log. Dist. Coast [km]	4.454	4.605
	(1.047)	(1.080)
Log. Dist. pre-Hispanic Roads [km]	3.499	3.664
	(1.743)	(1.673)
Log. Dist. Rivers [km]	4.069	4.241
	(1.339)	(1.316)
Years since Aztec Conquest	15.215	13.109
	(23.74)	(23.02)
Independent Senorio	0.681	0.736
	(0.466)	(0.441)
Elevation [km]	1.216	1.331
	(0.826)	(0.872)
Av. temperature [C]	20.878	20.254
	(4.060)	(4.280)
Cum. precipitation [m]	1.096	1.046
	(0.556)	(0.574)
Ruggedness Index	0.108	0.104
	(0.125)	(0.116)
Disease index for yersenia: 0–1	0.082	0.075
	(0.268)	(0.255)
Disease index for hemorrhagic dengue: 0–1	0.091	0.091
	(0.260)	(0.259)
Disease index for tabardillo: 0–1	0.008	0.025
	(0.0673)	(0.122)

(*Continued*)

Table 2: (*Continued*)

	(1) Suma only mean (SD)	(2) Historic core mean (SD)
Disease index for Cocolitzli [1576]	−0.060	0.046
	(0.971)	(1.075)
Spanish city	0.014	0.004
	(0.116)	(0.0593)
Log. Dist. Veracruz [km]	5.953	5.931
	(0.603)	(0.669)
Observations	1093	11,888

NB: mean; sd in parentheses. An observation is an urban locality/rural census tract (localidad-AGEB). Column 1 includes only towns mentioned in the Suma de Visitas (1548). Column 2 includes all localidad-AGEBs (i.e., 'potential locations') in the Historic Core of New Spain. This excludes the Maya region and unsettled areas of the Chichimec frontier at the time of the Conquest. Cochineal and Quetzal producers ca. Conquest and "Mentioned in Matricula/Barlow" are indicators based upon sources prior to 1536, chiefly the Matricula de Tributos of the Aztecs (1532) and Barlow (1949). The disease indices represent suitability for yersenia (∼plague), dengue, tabardillo (∼typhus) and drought/climatic conditions in 1576 conducive for cocolitzli (following Garfias-Sellars 2018). For further details, please see online Appendix.

quetzal feathers that lacked complementarity (conducted in 41 settlements), cacao production that was easily replicated and transplanted (44 settlements), the presence of gold mines (77), which could be expropriated with its labour coerced. We follow Diaz-Cayeros and Jha (2017) in contrasting these to the production of cochineal (77 settlements), which satisfies all three conditions. To these, we also add an indicator for the indigenous staple — maize (see Figure 2).

Reconstructing pre-Hispanic Market Access & Political Conditions

Economic production does not take place in a vacuum but also depends on trade networks and market access. However, this transformed dramatically with the Conquest, as not only did the axis of trade swing towards the annual convoys to Cadiz out of the new port of Veracruz, but also the introduction of horses to the New World transformed the costs of traversing different terrain by land as well. To reconstruct pre-Hispanic market access, we follow Barlow (1949) to exploit the Matrícula to classify pre-Hispanic settlements into a system of provinces. The Matrícula also lists the main receptory towns from which the Aztecs and their allies collected the tributes from each province. We combine our knowledge of the presence of direct transportation links between these receptory towns to the Triple Alliance cities with terrain and water accessibility GIS layers to create a cost of traversing each possible pixel. Using

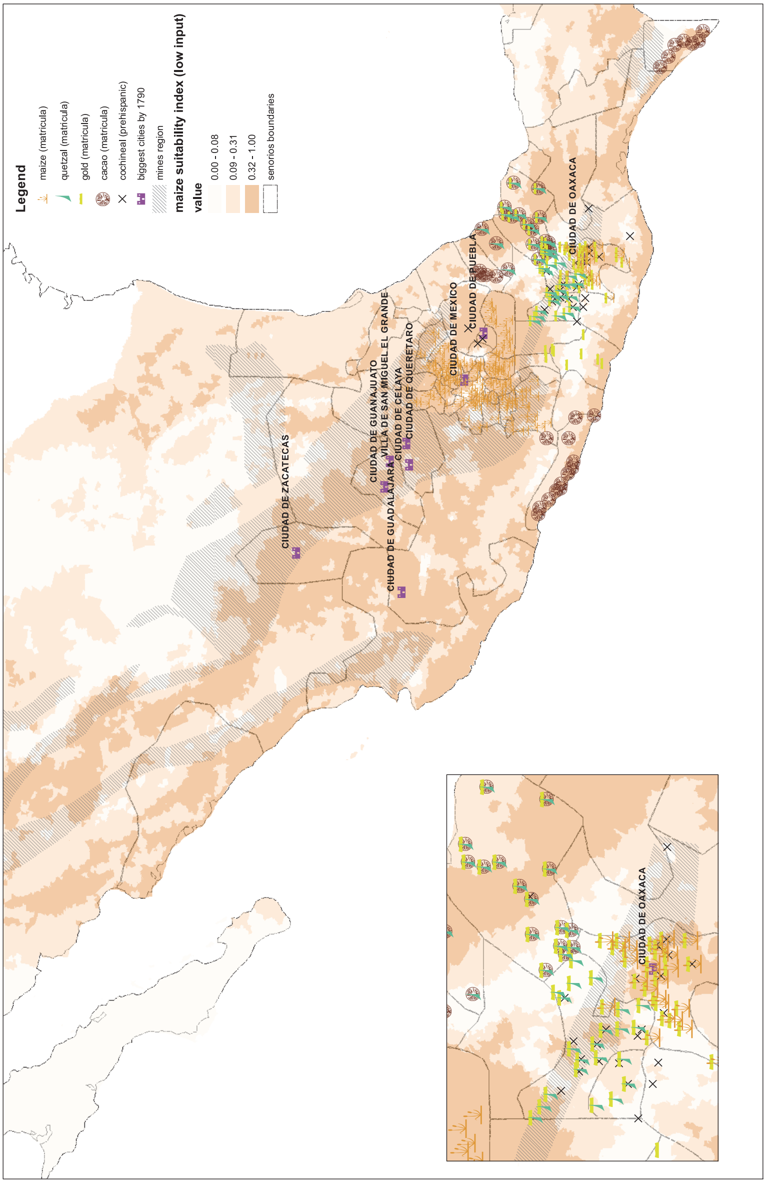

Figure 2: Geographical distribution of production of cochineal and other products.

Cochineal ($N = 74$), Quetzal feathers ($N = 41$), Cacao ($N = 44$) and Gold ($N = 77$) and Maize tribute prehispanic locations are noted, overlaid on GAEZv4 FAO Maize suitability index and mineral Ag and Au seams. Largest cities in 1790 are also noted for reference purposes.

a Tobler-style least-cost path to connect the network allows us to create a novel estimate of the pre-Columbian road network connecting the chief towns of the Aztec Empire, at the moment of conquest.[21] To these variables we add an indicator to control for whether a settlement appears in the Matrícula or Barlow's reconstruction of pre-Hispanic Meso-America at all. Thirteen percent of Suma settlements do so, indicating their relative importance, compared to only 3% of Historic Core locations.

Finally, we are careful to consider the existing political landscape beyond the Colhua Mexica Triple Alliance. The European colonists built their systems of political domination on top of preexisting social and political arrangements (Arias and Girod, 2011; Elizalde, 2020). The Mexica of Tenochtitlan were well-aware that showing weakness could lead even their Triple Alliance partners, such as those of Texcoco, to abandon them and join the Spanish (Townsend, 2019) not to mention the Tlaxcaltecas and other long-time enemies. Those that did accommodate the Europeans, such as the Purhepecha ruler Tangaxuan II in 1525, were rewarded with significant autonomy for some time. In order to control for the variation of such local political conditions, we correct Barlow's boundaries to match each settlement to the independent lordships (*Señoríos*) and Aztec provinces at the time of Conquest, and construct a novel measure of the length of time a settlement had been under Triple Alliance rule prior to the Conquest.

Disease Environments

Indigenous settlements did not just face exposure to new European markets and political arrangements but also to novel diseases as well. The most lethal of them became known as the *Huey cocoliztli*, which spread with particular virulence in 1545 and 1576, but whose true nature remains a subject of debate. Vågene *et al.* (2018) argue that the 1545 cocoliztli epidemic was caused not by an unknown pathogen, but by widespread salmonella infection. Acuña-Soto *et al.* (2002) instead suggest that cocolitzli was a hemorrhagic fever, perhaps a hantavirus, that afflicted the indigenous peoples well before the arrival of the Europeans to the Americas. Further, they argue that this disease had a clear climatic gradient, and that its effects cannot be distinguished from El Niño events and other climatic oscillations with a clear temporal profile. Most likely several diseases circulated simultaneously. However, it is clear that epidemics were more likely when droughts ended, followed by abundant rain, that allowed for the multiplication of disease vectors such as rats.

[21] We also include the potential use of waterways (Favila Vázquez, 2020) as means of transportation, which we proxy through the distance to the coasts in the Pacific and the Gulf of Mexico, as well as the distance to the two main navigable rivers in Central Mexico, the Balsas and the Papaloapan.

Since salmonella does not have a clear geographic envelope, we follow Sellars and Alix-Garcia (2018) and Garfias and Sellars (2021) in estimating climatic conditions conducive for cocolitzli based upon the model suggested by Acuña-Soto *et al.* (2002).[22] Even though there is some uncertainty about the exact nature of the disease, contemporary chronicles described the spread and the climatic conditions that accompanied it. Given the controversy related to 1545, we focus upon the cocolitzli epidemic of 1576. We are relatively agnostic as to whether the hemorrhagic fever disease that was characterized as cocolitzli was a specific known pathogen, instead providing a plausible range of possibilities, including other diseases such as plague, typhus and dengue. What we do know with some degree of confidence is that this disease was well known to the indigenous peoples, predating the arrival of the Europeans.

We use the Mexican Drought Atlas (Stahle *et al.*, 2016), that makes it possible to reconstruct the climatic shifts that occurred in the course of the colonial period, and in particular the shocks that may have been prevalent at the time of the cocoliztli epidemic, and identify locations where drought was followed immediately by anomalous rain.[23]

We also drew upon modern epidemiology to determine which climatic conditions that are favourable to the spread of known diseases that may have circulated in the colonial period. Rather than trying to adjudicate which pathogen produced the great epidemics of 1545–6 and 1576, we calculate various climatic conditions that may be conducive for different disease profiles. We take an inclusive approach, trying to describe various climatic gradients associated with potential disease candidates that may have afflicted indigenous peoples, including plague *yersenia pestis*, typhus *tabardillo* or *matlazahuatl*[24] and hemorrhagic dengue.

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[22]We adapt the approach to a shorter time period, limited to the climatic shocks before the second cocoliztli epidemic of 1576.

[23]The Drought Atlas analysis generates a 0.5 of a degree grid of longitude–latitude point estimates of the Palmer Drought Severity Index (PDSI) since 1400, estimated through an ensemble model using 252 tree ring chronologies. We thank Emily Sellars for making her shapefiles of this data available to us. We have analyzed the dendochronologies recognizing that the data is more sparse as few suitable trees for dendochronology are found in latitudes closer to the equator. As it turns out, only 11 tree chronologies cover the 16th century. In order to not rely too much on these historical reconstructions, most of our analysis is based on the climatic patterns of the 20th century.

[24]Tabardillo and matlazahuatl were probably a form of typhus in the Americas. Spaniards knew typhus as an emerging disease at least since the siege of Granada in 1489. Mexican Tabardete in the 1560s was explicitly compared by Francisco Bravo, the author of the first medical treatise published in the Americas in 1570, to an outbreak of typhus he had witnessed in Seville in 1554. But tabardillo and matlazahuatl were often conflated with cocoliztli, even though the characteristic nose bleeding of the later is not described in the etiology of typhus. Matlazahuatl corresponds to characteristic skin pustules, described as a "net like rash", and depicted as such in pictorial records. We cannot settle in this paper the exact nature of the disease. However, we use the conditions conducive to murine typhus, the modern epidemic form of the disease as the benchmark for its climatic gradient.

Each disease has a different climatological and seasonal signatures, which we use to determine geographic areas where temperature, rainfall and altitude conditions may be more conducive to transmission. For the case of plague (*yersenia pestis*) we create a six-point scale, that delimits a range of 15–27°C, and precipitation of less than 300 mm, in areas where altitude ranges from 500 and 900 meters (Ngeleja *et al.*, 2017; Schmid *et al.*, 2015).[25]

Similarly for hemorrhagic dengue fever, we delineate the regions where precipitation is between 180 and 360 mm and temperatures range between 25 and 32°C during the month of July, and between 15 and 27 in August–December. For dengue we only consider areas with an elevation of less than 1300 m.[26]

For tabardillo we use the wet season going from May to October with a range of 16–27°C of temperature and between 150 and 390 mm of precipitation.[27] As Table 2 suggests, it is worth noting that while the disease propensities seem quite similar for plague, dengue and tabardillo between Suma settlements and others in the historic core, it is for the one disease that was already endemic in the Americas — cocolitzli — where settlements that existed in the Suma appear *less* likely to have favourable conditions (an index of −0.06) relative to other nearby locations in the historic core which lacked populations in 1548 (average index value of +0.046).

Results

Figure 3 provides a novel reconstruction of the networks of settlement of the indigenous world in central Mexico at the point at which they first encountered the Spanish. Along with the population reconstructions, we include our corrected versions of Barlow's boundaries for the pre-Hispanic lordships and provinces (señoríos) and our reconstruction of the least-cost road network linking the receptory towns mentioned in the Matrícula to Tenochtitlan. Spanish towns are provided for reference.

Figure 4 superimposes the population ca 1790 in blue, on the same scale. Figures 5 and 6 further decompose the variation into indicators of survival and measures of population change, respectively. The picture is stark and

[25] This is calculated for each month, December to April, counting 1 point for each month where all there conditions are met, with an additional point (a step $y = 6$) if the conditions are met for all the five months of the year.

[26] Although the clinical literature suggests that some temporal effects may be driven by the end of the dry season (e.g., dengue is likely to emerge 8 weeks after the initial rain of the year) we cannot calculate this feature for each specific year (Gao *et al.*, 2020; Kuo *et al.*, 2017). This is a seven-point scale.

[27] According to the clinical literature, murine typhus is only likely to emerge at sea level, at altitudes between 0 and 35 m (Colón-González *et al.*, 2011; Lozano-Fuentes *et al.*, 2012). This variable is calculated as a six-point scale.

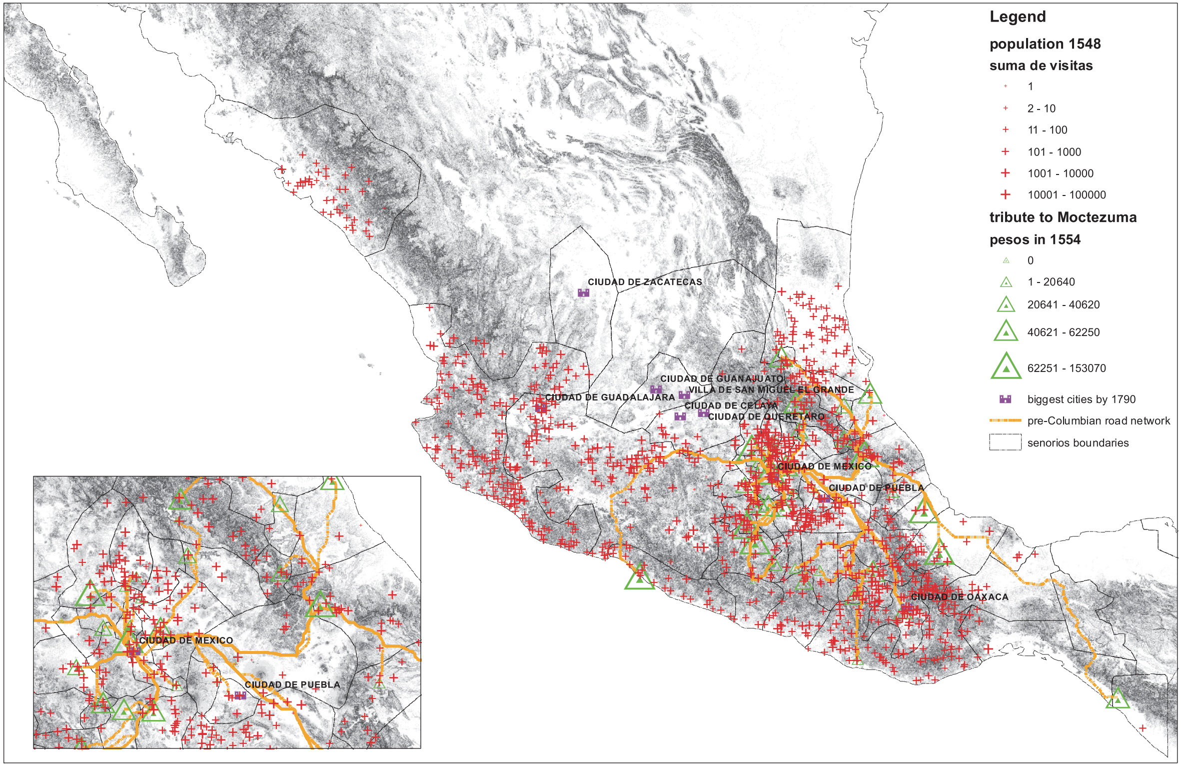

Figure 3: pre-Hispanic networks and indigenous settlements ca 1548.

Notes: Pre-colonial Mexico was divided in *señoríos* (in black) and provinces, each giving tribute to the Triple Alliance (in green). The population in 1548 is shown in red crosses using data from the *Suma de Visitas*, augmented by Cook and Simpson (1948). Source: please see online Appendix.

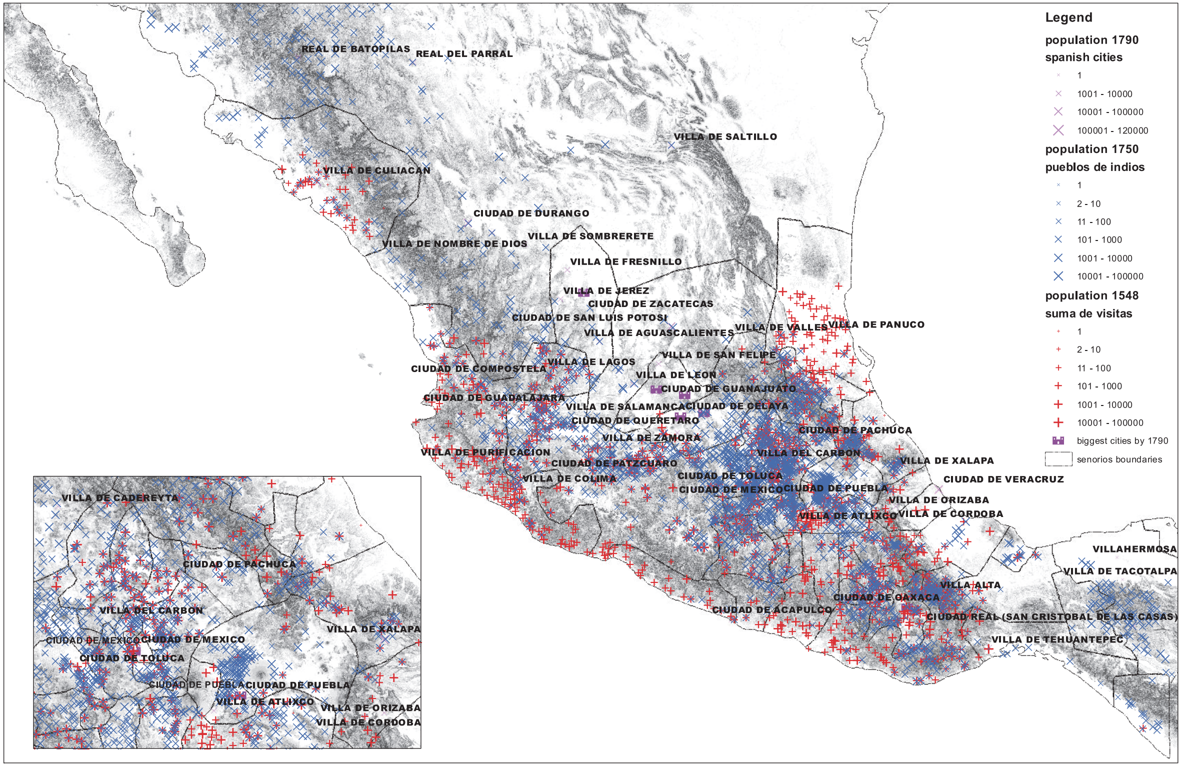

Figure 4: Indigenous settlement disappearance and survival, 1548–1790.

Note: Pre-colonial Mexico was divided into *señoríos* (in black) and provinces. The population in 1548 is shown in red crosses and the population in 1750 and 1790 is marked with blue and purple X marks.

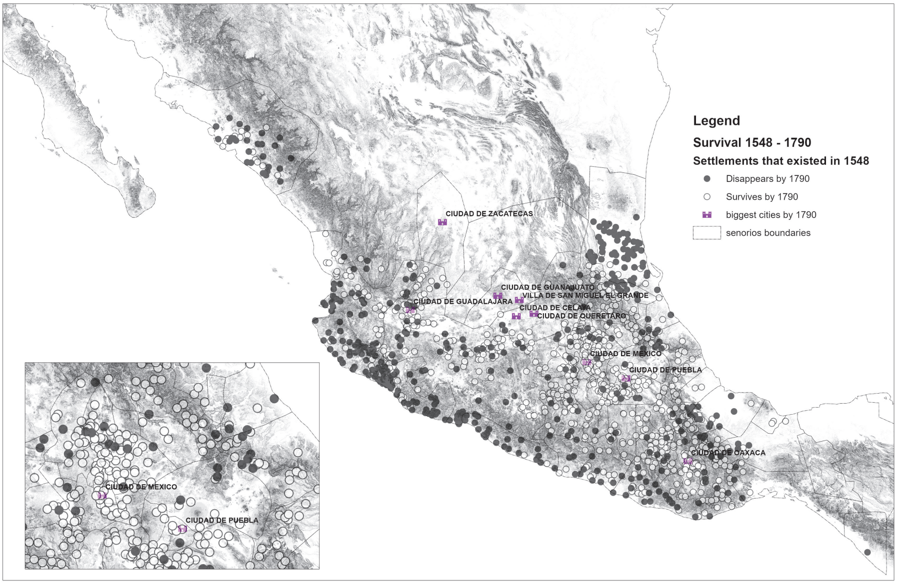

Figure 5: Settlement survival from 1548 to 1790.

Note: The black (white) circles denote the 1548 settlements that survived (disappeared).

revealing. First, note that unlike in Europe, where towns accessible to the Atlantic flourished with the discovery of routes to the New World (Acemoglu *et al.*, 2005), in Mexico, once thriving coastal settlements become completely depopulated. The main Spanish port of Veracruz on the Atlantic (and its minor counterpart, Acapulco, on the Pacific), rather than attracting new population growth, are surrounded by desolation, and remain isolated until the end of the colonial period. Thus exposure to global trade does not appear to be the great boon to the indigenous that it could be. Second, while there are new settlements during the colonial period, particularly with the expansion of mining in the north, the historic core shows a dramatic contraction of the populated zone into the more mountainous areas of Mexico. Finally, even with these broader patterns, there is much within-señorío variation, with some settlements disappearing while its neighbours survive, that is obscured when one aggregates to larger units. All together, these patterns seem inconsistent with an indiscriminate shock to population that one might expect given the virulence of novel diseases introduced to the 'virgin soil' of the New World. It is to understand the determinants of both these broader and more local patterns of indigenous settlement resilience and loss that we now turn.

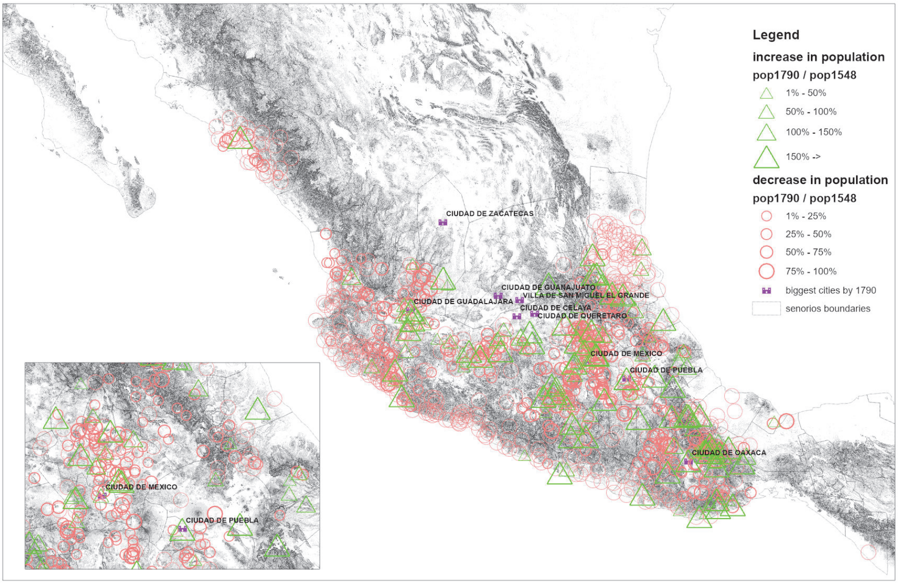

Figure 6: Population change from 1548 to 1790.

Note: The green triangles denote the size of population increase and the red circles denote the size of population shrinkage.

Table 3 estimates Equation (1), examining how economic and other factors predict population in 1790 among AGEB-localidades that housed indigenous settlements in 1548. As we are interested not just in large settlements, as noted above, we use the inverse hyperbolic sine transformation which approximates and can be interpreted as a logarithm, but is defined for zero values. We control for the inverse hyperbolic sine of the population in 1548 in all specifications. Thus, we compare settlements that had similar populations early in the Conquest, but produced goods with different degrees of robust inter-ethnic complementarities at the time of the Conquest (Col 1) and different disease propensities (Col 2).

Notice first that there is clear evidence of persistence over the colonial period — a 1% increase in a settlement's 1548 population raises its 1790 population by about 0.52% [s.e. 0.115] (Cols 1–2). However, among settlements of equal size in 1548, those that produced the product with robust interethnic complementarity — cochineal — at the time of the Conquest had 1.57 times greater populations in 1790 (Col 1, [s.e. 0.604]), a figure that is comparable to those tasked with supplying the staple crop, Maize, to Tenochtitlan (of around two times [s.e. 0.926]). In contrast, producing the other three goods — quetzales, gold and cacao — that lacked robust interethnic

Table 3: Regression: Population ca. 1790 in 1548 settlements.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Population ca 1790 [Inverse Hyperbolic Sine]	OLS	OLS	OLS	OLS	OLS	OLS	Spatial GMM
Cochineal Producer ca. Conquest	1.570**		1.685***	1.220**	1.637***	1.578***	1.625***
	(0.604)		(0.476)	(0.454)	(0.413)	(0.376)	(0.629)
Quetzal ca. Conquest	0.402		−1.823*	−1.781*	−1.559*	−0.862	−1.012
	(1.067)		(0.936)	(0.923)	(0.864)	(0.978)	(1.162)
Cacao ca. Conquest	−0.574		1.210	0.931	1.001	0.780	0.789
	(0.982)		(1.287)	(1.251)	(1.203)	(1.028)	(1.028)
Gold ca. Conquest	−2.139***		−0.461	0.144	−0.270	−0.129	0.037
	(0.564)		(0.632)	(0.619)	(0.580)	(0.695)	(0.864)
Maize ca. Conquest	2.065**		0.575	0.562	0.645	0.768	0.786
	(0.926)		(0.888)	(0.838)	(0.805)	(0.795)	(0.606)
Mentioned in Matricula/Barlow	−0.569		−0.693	−0.502	−0.594	−1.032**	−1.061**
	(0.734)		(0.654)	(0.529)	(0.495)	(0.451)	(0.508)
Disease index for yersenia: 0–1		−0.395	0.135	0.251	0.293	0.152	0.125
		(0.347)	(0.371)	(0.323)	(0.332)	(0.317)	(0.369)
Disease index for hemorrhagic dengue: 0–1		−0.821	−0.335	−0.105	−0.318	−0.418	−0.330
		(0.577)	(0.525)	(0.737)	(0.600)	(0.604)	(0.470)
Disease index for tabardillo: 0–1		−3.004**	−0.490	−0.276	−1.040	−0.354	−0.293
		(1.217)	(1.100)	(1.052)	(1.006)	(0.927)	(1.478)
Disease index for Cocolitzli [1576]		−0.410	−0.124	−0.086	−0.183	−0.176	−0.173
		(0.262)	(0.137)	(0.180)	(0.162)	(0.169)	(0.121)
Log. Dist. Tenochtitlan [km]			−0.716*	−0.819**	−0.551	−0.274	−0.277
			(0.345)	(0.339)	(0.393)	(0.469)	(0.356)
Log. Dist. Coast [km]			0.770***	0.479**	0.230	0.144	0.136
			(0.209)	(0.216)	(0.180)	(0.173)	(0.211)
Log. Dist. pre-Hispanic Roads [km]			0.177	0.159	0.126	0.045	0.050
			(0.188)	(0.204)	(0.186)	(0.182)	(0.097)

(*Continued*)

Table 3: (*Continued*)

Population ca 1790 [Inverse Hyperbolic Sine]	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) Spatial GMM
Log. Dist. Rivers [km]			0.008	0.032	−0.099	−0.048	−0.023
			(0.200)	(0.174)	(0.221)	(0.223)	(0.122)
Years since Aztec Conquest			0.050***	0.040***	0.024**	0.034***	0.031**
			(0.017)	(0.012)	(0.010)	(0.010)	(0.014)
Independent Senorio			1.964*	1.500	1.007	1.085	0.966
			(1.022)	(0.890)	(0.676)	(0.651)	(0.692)
Spanish city						5.741***	5.673***
						(0.720)	(0.791)
Log. Dist. Veracruz [km]						2.328***	2.308***
						(0.779)	(0.697)
Population 1548 [Inv. Hyp. Sine]	0.522***	0.510***	0.307***	0.200***	0.212***	0.198***	0.205***
	(0.115)	(0.126)	(0.079)	(0.069)	(0.063)	(0.066)	(0.060)
Geographic and Climatic Controls	No	No	No	Yes	Yes	Yes	Yes
Senorio Fixed Effects	No	No	No	No	Yes	Yes	Yes
Observations	1,093	1,093	1,093	1,093	1,093	1,093	1,093
R-squared	0.083	0.084	0.200	0.254	0.302	0.340	
Mean	3.344	3.344	3.344	3.344	3.344	3.344	3.344
SD	3.624	3.624	3.624	3.624	3.624	3.624	3.624

Notes: An observation is an urban locality/rural census tract (localidad-AGEB). The outcome is the inverse hyperbolic sine of the population ca 1790, which approximates a logarithm. The sample is limited to settlements mentioned in the 1548 Suma de Visitas. Cochineal, Quetzal, Cacao and Maize Tribute ca. Conquest and "Mentioned in Matricula/Barlow" are indicators based upon sources prior to 1536, chiefly the Matricula de Tributos of the Aztecs (1532) and Barlow (1949). Geographic and climatic controls include: linear and quadratic terms for latitude, longitude, altitude, cum. precipitation and mean temperature, as well as terrain ruggedness, and indicators for arid and tropical climatic zones. The disease indices include suitability for yersenia (∼plague), dengue, tabardillo (∼typhus) and drought/climatic conditions in 1576 conducive for cocolitzli (following Garfias-Sellars, 2018). Columns 1–6 show OLS estimates, with standard errors clustered at the pre-Hispanic Senorio level. Column 7 instead uses a spectral-normalized inverse distance matrix to estimate a spatial GMM regression, with spatially-corrected standard errors. Significant at: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

complementarity, do not sustain higher populations by the end of the colonial period — if anything the effects are either negative or insignificant.

Column 2 compares settlements of similar size in 1548, but with different exposure to the four geographical disease indices. The point estimates of the effect of exposure to all of these diseases are all negative, and tabardillo (typhus) is significantly so. Column 3 combines and tightens the comparisons, comparing how robust complementarities alter settlement populations that also had similar disease propensities, locational access to Tenochtitlan, the Coast, our pre-Hispanic road network, and navigable rivers, as well as had similar duration under Triple Alliance rule. These features are naturally correlated with maize surpluses, which ceases to be significant. Notice also that these pre-Hispanic market access and political factors are also capturing a substantial share of the persistence in population — the coefficient on the inverse hyperbolic sine of population in 1548 attenuates from 0.51% to 0.30%.

Further, comparing settlements with similar pre-Hispanic market access and historical administrative conditions accentuates the disadvantage of producing the once-valued quetzal feathers relative to those producing goods complementary to overseas trade. However, of these, only cochineal producing settlements, which as Diaz-Cayeros and Jha (2017) show, are largely dependent on micro-climatic conditions that prefer, among others, *low* precipitation, continue to show a robust long-term population advantage. The cochineal coefficient is little changed by controlling for either disease or market access.

Which pre-Hispanic market access and political conditions matter? Perhaps not surprisingly, a 1% increase in proximity to Tenochtitlan, which would become Mexico City, does increase a settlement's population in 1790 by 0.72% on average. Interestingly, settlements located in independent lordships, which had more latitude to join the Spanish at the time of the Conquest, and could thus maintain some autonomy in the early years, were also 1.96 times larger at the end of the colonial period. However, they are joined by some of the early participants in the Triple Alliance — all else equal, an additional year of Aztec rule actually *increases* a settlement's population in 1790 by 5%. This may reflect the shrinking and contraction of the population away back to the historic Meso-American core seen in Figure 4. Related to this, the patterns of dramatic population decline near the coast also proves to be robust.

Column 3 also hints at one reason why, in contrast to Acemoglu *et al.* (2005), access to global trade did not benefit coastal settlements in Mexico. Controlling for pre-Hispanic market access and political factors also attenuates the point estimates on all the disease indices, and particularly tabardillo [typhus]. Note that tabardillo suitability is associated with a dramatic population reduction of three times as one goes from completely unsuitable to perfectly suitable among settlements of similar initial population sizes (Col 2) to having an insignificant effect with the addition of market access and proximity to coast controls (Col 3). It turns out that settlements on the coast happened to also be highly suitable for typhus.[28] These results suggest the intriguing but tragic possibility that one reason for the decline of the indigenous populations was not simply that the indigenous populations were unprepared in terms of internal germ resistance, but rather that they were unprepared in part because of where they had previously located their settlements. Investing in fixed capital in places that, with the advent of the Europeans, also turned out to be excellent breeding grounds of novel communicable diseases, suggests an alternative model of transmission to the virgin soil hypothesis. Put differently, one could imagine a counterfactual world where the indigenous with the same disease susceptibilities had happened to place their settlements in different locations outside these disease envelopes prior to the Conquest, and ultimately faced very different patterns of overall population decline.

The coefficient on cochineal, and these basic patterns more generally, are robust to adding a set of geographic and climatic controls (Col 4), including linear and quadratic terms for latitude, longitude, altitude, cumulative precipitation and ruggedness, as well indicators for tropical and arid climatic zones. They are also similar when comparing settlements within the same señorío (Col 5), and controlling for the settlement's proximity to the port of Veracruz, and whether a settlement would later be designated a Spanish city or villa (which increases population by around five times) (Col 6). Finally, we also relax the assumption that standard errors are arbitrarily correlated within señorío but independent between them, and use a spectral-normalized inverse distance matrix to estimate a spatial GMM regression, with spatially corrected standard errors (Col 7). The results are again very similar.

Table 4 shows precisely the same specifications, but instead turns from the population level effects to the probability a settlement that existed in 1548 survives at all in 1790. Again, we find that there is evidence of persistence: larger settlements in 1548 are more likely to survive to 1790. However, comparing among settlements of the same initial size, robust interethnic complementarities lead to an increased probability of survival, a robust effect of about 13 percentage points when matching along similar disease conditions, pre-Hispanic market access and political conditions, comparing within the same señorío, and accounting for spatial dependence. This is relative to an average survival probability of 63.8% in this sample. The point estimates on production of pre-Hispanic commodities that lacked robust interethnic complementarities are smaller, in contrast, and again insignificant over the long term. Quetzal producers are, if anything, 17pp less likely to survive.

The other patterns noted above are also evident. Once again the disease indices, particularly tabardillo, tend to have negative effects on the long-term chance of survival (Col 2), but these effects attenuate when we control for

[28]The coefficient of a simple bivariate regression of the z-score index of tabardillo suitability on log distance to the coast in the historic core sample is -0.317 [0.0076], with an R-squared of 0.13.

Table 4: Regression: Probability a 1548 settlement continues to exist ca 1790.

Settlement exists in 1790 [0/1]	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) Spatial GMM
Cochineal producer ca. Conquest	0.408***		0.280***	0.127***	0.130***	0.132***	0.132*
	(0.076)		(0.066)	(0.043)	(0.045)	(0.045)	(0.079)
Quetzal ca. Conquest	0.078		−0.195	−0.108	−0.188	−0.174	−0.174
	(0.134)		(0.114)	(0.120)	(0.117)	(0.121)	(0.146)
Cacao ca. Conquest	−0.052		0.149	0.054	0.144	0.115	0.115
	(0.201)		(0.121)	(0.123)	(0.089)	(0.082)	(0.129)
Gold ca. Conquest	−0.205*		0.037	0.066	0.065	0.058	0.058
	(0.106)		(0.085)	(0.110)	(0.121)	(0.124)	(0.108)
Maize ca. Conquest	0.221*		0.073	0.087	0.075	0.082	0.082
	(0.126)		(0.107)	(0.085)	(0.083)	(0.085)	(0.076)
Mentioned in Matricula/Barlow	−0.128		−0.172*	−0.157**	−0.150**	−0.157**	−0.157**
	(0.112)		(0.089)	(0.067)	(0.066)	(0.065)	(0.064)
Disease index for yersenia: 0–1		−0.119**	−0.049	−0.034	−0.038	−0.033	−0.033
		(0.052)	(0.065)	(0.051)	(0.054)	(0.053)	(0.046)
Disease index for hemorrhagic dengue: 0–1		−0.006	0.060	0.046	−0.012	−0.009	−0.010
		(0.068)	(0.062)	(0.061)	(0.051)	(0.052)	(0.059)
Disease index for tabardillo: 0–1		−0.609**	−0.155	−0.112	−0.146	−0.155	−0.155
		(0.258)	(0.295)	(0.275)	(0.252)	(0.243)	(0.185)
Disease index for Cocolitzli [1576]		−0.019	0.012	−0.003	−0.014	−0.009	−0.009
		(0.024)	(0.014)	(0.015)	(0.012)	(0.014)	(0.015)
Log. Dist. Tenochtitlan [km]			0.025	−0.067	−0.051	−0.048	−0.048
			(0.047)	(0.043)	(0.036)	(0.040)	(0.044)
Log. Dist. Coast [km]			0.147***	0.046*	0.033	0.037	0.037
			(0.017)	(0.025)	(0.025)	(0.026)	(0.026)
Log. Dist. pre-Hispanic Roads [km]			−0.030***	−0.009	−0.008	−0.005	−0.005
			(0.009)	(0.011)	(0.009)	(0.010)	(0.012)

(*Continued*)

Table 4: (*Continued*)

Settlement exists in 1790 [0/1]	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) Spatial GMM
Log. Dist. Rivers [km]			−0.032	−0.007	−0.020	−0.024	−0.024
			(0.024)	(0.012)	(0.018)	(0.019)	(0.015)
Years since Aztec Conquest			0.005**	0.002*	0.001	0.001	0.001
			(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Independent Senorio			0.185*	0.081	0.043	0.060	0.060
			(0.095)	(0.068)	(0.074)	(0.070)	(0.085)
Spanish city						0.228**	0.228**
						(0.082)	(0.099)
Log. Dist. Veracruz [km]						−0.130	−0.131
						(0.083)	(0.087)
Population 1548 [Inv. Hyp. Sine]	0.076***	0.071***	0.036**	0.021*	0.021*	0.021*	0.021***
	(0.020)	(0.023)	(0.015)	(0.011)	(0.011)	(0.011)	(0.008)
Geographic and climatic controls	No	No	No	Yes	Yes	Yes	Yes
Senorio fixed effects	No	No	No	No	Yes	Yes	Yes
Observations	1,093	1,093	1,093	1,093	1,093	1,093	1,093
R-squared	0.098	0.082	0.252	0.382	0.410	0.414	
Mean dependent variable	0.638	0.638	0.638	0.638	0.638	0.638	0.638
SD	0.481	0.481	0.481	0.481	0.481	0.481	0.481

Note: An observation is an urban locality/rural census tract (localidad-AGEB). The outcome is an indicator for whether a settlement existed in that location ca 1790. The sample is limited to settlements that existed according to the Suma de Visitas (1548). Cochineal, Quetzal, Cacao and Maize Tribute ca. Conquest and "Mentioned in Matricula/Barlow" are indicators based upon sources prior to 1536, chiefly the Matricula de Tributos of the Aztecs (1532) and Barlow (1949). Geographic and climatic controls include: linear and quadratic terms for latitude, longitude, altitude, cum. precipitation and mean temperature, as well as terrain ruggedness, and indicators for arid and tropical climatic zones. The disease indices include suitability for yersenia (∼plague), dengue, tabardillo (∼typhus) and drought/climatic conditions in 1576 conducive for cocolitzli (following Garfias and Sellars, 2018). Cols 1–6 show OLS estimates, with standard errors clustered at the pre-Hispanic Senorio level. Col 7 instead uses a spectral-normalized inverse distance matrix to estimate a spatial GMM regression, with spatially-corrected standard errors. Significant at: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

pre-Hispanic market access and distance to the Coast. And once again these effects are not dependent on the choice of location by the Spanish (Cols 6–7).

So far we have been mainly studying how pre-Conquest and disease conditions affect the long-term 'stock' of existing indigenous settlements and population at the end of the colonial era. However, some effects may be catastrophic and lasting, while others could be severe but short-term, and still others could induce migration and adaptation.[29] We now to turn understanding the flows. We exploit the intermediate censuses available in 1570 and 1646 to focus on when a settlement that did not survive to 1790 last appears in the records. As we have already seen, Figure 1 presents raw Kaplan–Meier graphs comparing the share of settlements surviving over the colonial period that produced each of these products in the pre-Columbian period to others that were also mentioned in the Suma de Visitas. Note that even in this raw comparison, cochineal-producing settlements are much more likely to survive throughout the colonial period. In contrast, settlements producing products that lacked one or more of the three conditions at the time of the Conquest enjoyed a less pronounced survival advantage. These patterns are evident in the Cox proportional hazards regressions in Table 5 as well, which uses the same sets of controls and sample as in the previous tables. The patterns of the timing of survival are again similar to those above. Cochineal producers enjoy a five times lower hazard of disappearing each year than otherwise similar settlements, while that for quetzal producers is about five times greater. The point estimates suggest that cacao and gold producing settlements also enjoy half the hazard of disappearing in any year over the course of the colonial period, though as we have seen, lacking a durable source of complementarity, they do not enjoy a population advantage by its end.

Again, not surprisingly, having a higher suitability for the different diseases increases the hazard of disappearing in any year. This is again particularly marked for tabardillo (by around three times), which once more attenuates when we control for coastal proximity and market access.

So far we have limited our analysis to understanding which altepeme that existed early in the Conquest were able to survive. This, of course, does not allow us to study the conditions that led new indigenous settlements to emerge afterwards. Following the city-seeding literature, we now partition all of the historic core in 11,888 potential and actual locations, using the same specifications as above to analyze the determinants of the distribution of

[29] We should note that we do not necessarily have the data to demonstrate the flow of people out of indigenous towns towards Spanish cities, or within indigenous pueblos or new settlements. Contemporary chronicles suggest there were important population movements, particularly towards the mining towns in the North. Where precisely those settlers came from is probably an impossible question to answer with the available data. However, the migratory patterns that might have been present at the time would probably be characterized by more intense "push" factors in places witnessing higher burdens of disease and offering less economic opportunities.

Table 5: Survival analysis (Cox proportional hazards).

Survival [1548–1790]	(1)	(2)	(3)	(4)	(5)	(6)
Cox proportional hazards regression	Haz. Ratios	Haz. Ratios	Haz. Ratios	Haz. Ratios	Haz. Ratios	Haz. Ratios
Cochineal producer ca. Conquest	0.122***		0.126***	0.226***	0.199***	0.210***
	(0.037)		(0.051)	(0.075)	(0.088)	(0.089)
Quetzal ca. Conquest	1.638		5.344***	4.542**	6.844***	6.184***
	(1.004)		(2.886)	(2.774)	(3.992)	(3.387)
Cacao ca. Conquest	0.905		0.451*	0.550*	0.428**	0.525**
	(0.634)		(0.196)	(0.183)	(0.148)	(0.143)
Gold ca. Conquest	1.203		0.664	0.480	0.438	0.431
	(0.606)		(0.363)	(0.266)	(0.253)	(0.245)
Maize ca. Conquest	0.397**		0.875	0.938	1.031	0.987
	(0.179)		(0.358)	(0.338)	(0.361)	(0.326)
Mentioned in Matricula/Barlow	1.462		2.184***	2.247***	2.353***	2.476***
	(0.505)		(0.596)	(0.495)	(0.455)	(0.437)
Disease index for yersenia: 0–1		1.463***	1.177	1.113	1.170	1.166
		(0.186)	(0.195)	(0.154)	(0.218)	(0.218)
Disease index for hemorrhagic dengue: 0–1		1.052	0.908	1.078	1.293	1.257
		(0.207)	(0.143)	(0.259)	(0.313)	(0.310)
Disease index for tabardillo: 0–1		2.968**	0.920	0.933	0.953	0.958
		(1.475)	(0.424)	(0.531)	(0.494)	(0.452)
Disease index for Cocolitzli [1576]		1.053	1.006	1.095	1.209***	1.200***
		(0.089)	(0.056)	(0.069)	(0.061)	(0.058)
Log. Dist. Tenochtitlan [km]			1.170	2.167**	2.816***	2.733***
			(0.257)	(0.777)	(0.704)	(0.720)
Log. Dist. Coast [km]			0.749***	0.975	1.020	1.023
			(0.040)	(0.078)	(0.064)	(0.067)
Log. Dist. pre-Hispanic Roads [km]			1.114*	0.996	1.032	1.026
			(0.062)	(0.046)	(0.044)	(0.045)

(*Continued*)

Table 5: (*Continued*)

Survival [1548–1790] Cox proportional hazards regression	(1) Haz. Ratios	(2) Haz. Ratios	(3) Haz. Ratios	(4) Haz. Ratios	(5) Haz. Ratios	(6) Haz. Ratios
Log. Dist. Rivers [km]			1.122	1.096	1.149	1.156*
			(0.090)	(0.076)	(0.101)	(0.100)
Years since Aztec Conquest			0.971***	0.988*	0.996	0.996
			(0.010)	(0.006)	(0.004)	(0.004)
Independent Senorio			0.347***	0.685*	0.810	0.772
			(0.129)	(0.138)	(0.160)	(0.139)
Spanish city						0.000***
						(0.000)
Log. Dist. Veracruz [km]						1.545
						(0.536)
IHS Population 1548	0.797***	0.830***	0.858***	0.910*	0.916*	0.914*
	(0.024)	(0.027)	(0.030)	(0.044)	(0.043)	(0.044)
Geographic and climatic controls	No	No	No	Yes	Yes	Yes
Senorio fixed effects	No	No	No	No	Yes	Yes
Average survival probability	0.638	0.638	0.638	0.638	0.638	0.638
Observations	1,093	1,093	1,093	1,093	1,093	1,093
Ln L	−2672	−2687	−2594	−2526	−2507	−2502

Note: This regression reports hazard ratios from Cox proportional hazards regression of the survival of a settlement. An observation is an urban locality/rural census tract (localidad-AGEB). The sample is limited to settlements that existed according to the Suma de Visitas (1548), and survival length is defined by the last time a population is reported in that location until ca 1790. Cochineal, Quetzal, Cacao and Maize Tribute ca. Conquest and "Mentioned in Matricula/Barlow" are indicators based upon sources prior to 1536, chiefly the Matricula de Tributos of the Aztecs (1532) and Barlow (1949). Geographic and climatic controls include: linear and quadratic terms for latitude, longitude, altitude, cum. precipitation and mean temperature, as well as terrain ruggedness, and indicators for arid and tropical climatic zones. The disease indices include suitability for yersenia (∼plague), dengue, tabardillo (∼typhus) and drought/climatic conditions in 1576 conducive for cocolitzli (following Garfias and Sellars, 2018). Standard errors are clustered at the pre-Hispanic Senorio level. Significant at: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 6: Regression: Population ca. 1790 throughout the historic core.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Population ca 1790 [Inverse Hyperbolic Sine]	OLS	OLS	OLS	OLS	OLS	OLS	Spatial GMM
Cochineal producer ca. Conquest	1.094**	1.172***	0.909**	0.950**	0.914**	0.944**	
	(0.393)		(0.401)	(0.411)	(0.420)	(0.369)	(0.405)
Quetzal ca. Conquest	−0.247		−1.184**	−1.117**	−1.091**	−0.784	−0.839
	(0.588)		(0.542)	(0.530)	(0.510)	(0.540)	(0.567)
Cacao ca. Conquest	−0.351		0.380	0.263	0.486	0.356	0.439
	(0.579)		(0.640)	(0.649)	(0.610)	(0.549)	(0.473)
Gold ca. Conquest	−1.559***		−0.675*	−0.434	−0.526	−0.537	−0.497
	(0.325)		(0.351)	(0.344)	(0.343)	(0.384)	(0.486)
Maize ca. Conquest	1.197**		0.502	0.411	0.456	0.516	0.503*
	(0.455)		(0.442)	(0.419)	(0.437)	(0.431)	(0.292)
Mentioned in Matricula/Barlow	0.094		−0.241	−0.087	−0.170	−0.315	−0.347
	(0.467)		(0.455)	(0.402)	(0.416)	(0.399)	(0.243)
Disease index for yersenia: 0–1		−0.368	−0.114	−0.060	−0.053	−0.079	−0.080
		(0.267)	(0.223)	(0.132)	(0.129)	(0.125)	(0.094)
Disease index for hemorrhagic dengue: 0–1		−0.272	−0.145	−0.456**	−0.370*	−0.374*	−0.343***
		(0.175)	(0.167)	(0.214)	(0.189)	(0.184)	(0.115)
Disease index for tabardillo: 0–1		−0.928***	−0.250	0.240	0.082	0.120	0.098
		(0.271)	(0.268)	(0.155)	(0.146)	(0.130)	(0.220)
Disease index for Cocolitzli [1576]		−0.187*	−0.089*	−0.053	−0.080	−0.080	−0.088***
		(0.092)	(0.047)	(0.069)	(0.059)	(0.061)	(0.026)
Log. Dist. Tenochtitlan [km]			−0.438***	−0.741***	−0.436*	−0.419*	−0.433***
			(0.135)	(0.210)	(0.245)	(0.234)	(0.084)
Log. Dist. Coast [km]			0.193*	0.168**	0.148**	0.154**	0.161***
			(0.103)	(0.077)	(0.068)	(0.065)	(0.042)
Log. Dist. pre-Hispanic Roads [km]			−0.082*	−0.024	−0.004	−0.015	−0.010
			(0.047)	(0.058)	(0.058)	(0.059)	(0.025)

(*Continued*)

Table 6: (*Continued*)

Population ca 1790 [Inverse Hyperbolic Sine]	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) Spatial GMM
Log. Dist. Rivers [km]			−0.054	−0.074	−0.073	−0.073	−0.068**
			(0.074)	(0.071)	(0.081)	(0.075)	(0.030)
Years since Aztec Conquest			0.010	0.004	−0.002	−0.001	0.002
			(0.013)	(0.013)	(0.016)	(0.016)	(0.004)
Independent Senorio			0.402	0.152	0.075	0.085	0.168
			(0.532)	(0.503)	(0.574)	(0.567)	(0.174)
Spanish city						6.678***	6.654***
						(0.475)	(0.364)
Log. Dist. Veracruz [km]						0.187	0.210**
						(0.161)	(0.087)
Population 1548 [Inv. Hyp. Sine]	0.314***	0.320***	0.312***	0.300***	0.293***	0.283***	0.282***
	(0.042)	(0.040)	(0.040)	(0.036)	(0.036)	(0.036)	(0.010)
Geographic and climatic controls	No	No	No	Yes	Yes	Yes	Yes
Senorio fixed effects	No	No	No	No	Yes	Yes	Yes
Observations	11,888	11,888	11,888	11,888	11,888	11,888	11,888
R-squared	0.075	0.083	0.138	0.180	0.201	0.223	
Mean dependent variable	1.220	1.220	1.220	1.220	1.220	1.220	1.220
SD	2.658	2.658	2.658	2.658	2.658	2.658	2.658

Note: An observation is an urban locality/rural census tract (localidad-AGEB). The outcome is the inverse hyperbolic sine of the population ca 1790, which approximates a logarithm. The sample encompasses the Historic Core of New Spain. This excludes the Maya region and unsettled areas of the Chichimec frontier at the time of the Conquest. Cochineal, Quetzal, Cacao and Maize Tribute ca. Conquest and "Mentioned in Matricula/ Barlow" are indicators based upon sources prior to 1536, chiefly the Matricula de Tributos of the Aztecs (1532) and Barlow (1949). Geographic and climatic controls include: linear and quadratic terms for latitude, longitude, altitude, cum. precipitation and mean temperature, as well as terrain ruggedness, and indicators for arid and tropical climatic zones. The disease indices include suitability for yersenia (∼plague), dengue, tabardillo (∼typhus) and drought/climatic conditions in 1576 conducive for cocolitzli (following Garfias and Sellars, 2018). Columns 1–6 show OLS estimates, with standard errors clustered at the pre-Hispanic Senorio level. Column 7 instead uses a spectral-normalized inverse distance matrix to estimate a spatial GMM regression, with spatially-corrected standard errors. Significant at: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

population among the 3,027 pueblos de indios that existed in the historic core in 1790.

Table 6 presents these results. The results on robust interethnic complementarities seen in Table 3 are robust with this expanded sample. Furthermore, once again the effect of tabardillo attenuates with coastal controls. Interestingly, the impact of the other diseases are more pronounced. In particular, comparing within the same scenarios, both the suitability for dengue and cocolitzli significantly reduce populations by 1790. The point estimates are similar to those in Table 3, however, suggesting that the effects are coming not just from new settlements that did not grow because of these diseases but because of the impact of these diseases on older settlements as well.

Discussion

In this paper, we examine who survived one of the most traumatic moments in history — the Conquest of the Americas. Indeed, at the very moment that Crown officials were enumerating settlements for the document that would become the Suma de Visitas, Fra Bartolome de las Casas was denouncing the violence and exploitation faced by the indigenous peoples at the hands of the Conquistadores, giving rise to the so-called 'Black Legend' of Spanish colonialism. Indeed, to this day, much of the debate about the devastating population collapse in the Americas that followed the Conquest continues to be about whether it reflects 'germs', on one hand — the blanket unpreparedness of the indigenous populations that provided 'virgin soil' for novel diseases to spread — or 'guns and steel' the violent coercion that so troubled de las Casas on the other.

To shed new light on this long debate, we take two approaches. First, we combine new disaggregated data on settlement populations and survival at the level of indigenous settlements with modern epidemiological models to trace which individual populations survived and the extent to which their fates were shaped by location with specific disease envelopes. Second, we highlight the agency of the indigenous themselves, using a theoretical framework and data on the production processes that indigenous populations were engaged in at the moment of Conquest to classify which communities were better positioned to maintain autonomy and resist violent coercion.

Disaggregating the data to the level of settlements reveals new patterns. We show that the disappearance and survival of indigenous settlements was not an indiscriminate process but instead varied systematically with their economic and political endowments at the time of the Conquest. This qualification is probably true for any epidemic disease: the impact of pathogens is always mediated by human responses. One important set of these is the extent to which the indigenous could leverage robust interethnic complementarities and high monitoring costs that made it more lucrative for the Spanish to trade with the indigenous than to dispossess and coerce them. As a result, populations did not fall uniformly instead, there is remarkable diversity in the extent to which indigenous settlements survived and even, in 13% of cases, grew, during the colonial period. While 36% disappeared, the pre-colonial altepeme that survived would, in many cases maintain their identities as private encomiendas and corregimientos to eventually become the pueblos de indios, that are still recognizable today as the thousands of settlements scattered throughout Mexican municipalities.

Further, combining economic theory, modern epidemiological models and disaggregated data helps us to nuance our understanding of the exploitation practiced by the European colonial settlers and to consider different counterfactuals as well. We document a long-term decimation of populations in Mexican coastal regions, once flourishing areas of indigenous settlement, that appears at first to well-reflect de las Casas' dark vision of the Conquest. One Conquistador, Nuño de Guzman in particular, has been singled out for his extreme violence and coercion, including the use of slavery, that may have facilitated the collapse of these settlements. Yet, the actions of de Guzman, and those like him, are endogenous to the incentives they faced. Despite being well-positioned to benefit from the new inter-continental trades, indigenous settlements on the coasts lacked robust inter-ethnic complementarities, being instead well-suited for cacao production, that could be transplanted and replicated. Elsewhere, where cochineal was cultivated, encomenderos realized the benefits of giving the indigenous autonomy, instead of forcing their labour. Such autonomy might have allowed the indigenous the ability to better respond to the disease environments that they faced, as epidemics were a regular occurrence in pre-Columbian America. Had the micro-climatic conditions been different, perhaps the incentives for joint gains from exchange may have also helped stay the hand of ruthless de Guzman and others like him.

Another consideration, as we uncover, is that the coastal indigenous settlements also had climatic conditions that turned out to be highly favourable to the epidemic spread of tabardillo (typhus). With the preponderance of their fixed capital and networks located in a now vulnerable place, indigenous communities faced the Faustian bargain of remaining with the disease and with the coercion of encomenderos unchecked by interethnic complementarities, or leaving as destitutes. With either choice, the coastal regions of Mexico would never be the same, and Mexico itself, despite its access to two oceans, would become a country where contests over land, rather than maritime power or inter-continental trade, would direct its political destiny.[30]

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[30]Many open questions remain that we seek to explore in a series of companion papers (e.g., Diaz-Cayeros and Jha, 2017). For example, what extent do interethnic complementarities and the technologies of monitoring and coercion shape patterns of indigenous assimilation and the preservation of indigenous identities and institutions? To what extent does its legacies continue to shape culture and politics? We find that cochineal production shaped colonial contract arrangements and indigenous well-being in the colonial period, and despite the death-knell of the industry with Mexican independence and synthetic dye production, it has left indelible marks in their heirs, particularly in Oaxaca, where communities exercise agency and autonomy in more decisive ways than perhaps any other group in Mexico.

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