Free and Protected: Trade and Breaks in Long-Term Persistence*

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Job Market Paper

November 1, 2020

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Abstract

The spatial distribution of economic activity depends largely on market access and history, but countries differ greatly in the extent to which their geography reflects these two determinants. What explains these differences? This paper explores this question using a staggered lifting of restrictions on direct trade with Europe across the Spanish Empire. I combine a difference-in-differences approach with a dynamic spatial equilibrium framework and detailed georeferenced data on maritime travel from historical logbooks to examine this issue. I show that the increase in market access induced by the reform led to a substantial reconfiguration of the economic geography in places that were initially less-densely settled. Moreover, I show that modern-day settlement patterns depend less on pre-colonial population density, and more on coastal access in areas subjected to the reform. Taken together, the findings show that a key determinant of persistence in economic geography is the level of development of a country as it opens up to trade.

JEL Codes: F620, F63, N760, O190, O430

*I thank Maria Petrova and Giacomo Ponzetto for their support and supervision on this project. I thank Dávid Nagy, Luigi Pascali, Jaume Ventura, Marta Reynal-Querol, James Robinson, Richard Hornbeck, Stephan Maurer, Jørgen Juel Andersen, Jenny Chan, Andreas Kotsadam, András Jagadits, Alessandro Tarozzi, Felipe Valencia, Gianmarco Leon as well as seminar participants at the CREI International Lunch, the 2020 UEA PhD Student Workshop in Urban Economics, the Labor, Political Economy and Development Breakfast at Pompeu Fabra, the Frisch Center for Economic Research, the Econometric Society World Congress 2020, the Development and Political Economics Graduate Student Conference at Berkeley, the Young Economist Symposium 2020 at UPenn, the 42nd Annual Meeting of the Norwegian Association of Economists, the Pompeu Fabra Student Seminar, and the BGSE PhD Jamboree 2019 and 2020 for valuable comments and suggestions that substantially improved the paper. Replication files are available on the author's Github account (http://github.com/sebastianellingsen). Department of Economics and Business, Universitat Pompeu Fabra and IPEG. sebastian.ellingsen@upf.edu.

1 Introduction

The spatial distribution of economic activity is shaped largely by market access and history. However, the economic geography in different countries and regions differs greatly in the extent to which they reflect each of these two determinants. Market access is particularly important for city location in the United States, as can be seen from the fact that the two largest cities are the two largest international ports (New York and Los Angeles). Other urban systems reflect historical precedent to a much larger extent, such as systems of cities centered around former imperial capitals (e.g., Rome, Beijing, and Delhi). What determines the relative importance of market access versus history in determining the spatial distribution of economic activity in different places? Can urban systems adapt to changes in the trading environment and thus break spatial persistence? If so, under what conditions?

To study these questions, I exploit a large-scale historical experiment — the expansion of direct trade with Europe in the Spanish Empire. To promote a comparative advantage in the extraction of bullion, early Spanish commercial policy severely restricted the direct trade of goods with Europe. However, driven by political developments in Europe, these restrictions were gradually lifted in the second half of the 18th century. While only four ports were permitted to trade goods directly with Europe in 1765, by 1800 this number had increased to 50. By this time, no major ports in the Empire were being subjected to restrictions on direct trade in goods with Europe (see Figure 1). The reform reduced trade costs in different years and in different locations. For several reasons, this variation is very well suited to study the impact of trade costs for several reasons. First, while I show that the reform caused large and spatially heterogeneous variation in international trade costs, these changes were limited to the costs of trading goods. This contrasts with standard approaches relying on changes in effective distance for identification, which typically alter numerous aspects of long-distance communication.[1] Second, the geographic scope of the reform allows me to consider its heterogeneous effects while keeping formal institutions and legal origins fixed. Finally, compared to studies of single countries or regions, the geographic scope of this setting also provides significant benefits in terms of external validity.

I study the long-run impact of these policies in three steps. First, I quantify how the reform affected empire-wide bilateral shipping times. To this end, I construct a grid of $0.5° \times 0.5°$ covering the full extent of the Spanish Empire in the 18th century. On this grid, I construct a directed network of bilateral trade costs between all adjacent cells, accounting for shipping on land and sea. For maritime shipping, I estimate accurate sailing speeds from historical maritime logbooks and georeferenced wind data. Travel on land accounts for a variety of geographic features that determined mobility such as elevation, landcover, as well as infrastructure such as roads and ports. I cross-validate the resulting shipping times with various historical sources, which confirms the accuracy of the approach. As there are many potential routes between any two cells, I use the route that minimizes shipping cost, subject to the restrictions on direct trade with Europe in place in a given decade. This results in bilateral shipping time matrices for each decade between 1710-1810. These time-varying measures of bilateral shipping times and market access are then matched with data on geographical characteristics, agricultural productivity, and the location of settlements to construct a balanced panel covering Spanish America between 1710 and 1810.

[1] Examples in the literature are technological innovation to transportation technology such as the diffusion of the steamship (Pascali, 2017), maritime technology (Bakker et al., 2018), air travel (Feyrer, 2019; Campante and Yanagizawa-Drott, 2018), the construction of inter-oceanic canals (Maurer and Rauch, 2019), or disruptions to transportation networks induced by conflict (Feyrer, 2009; Juhász, 2018).

I use this dataset to study the reduced-form effect of lower international trade cost on the formation and incorporation of new settlements as well as population growth. At the heart of the research design is a difference-in-differences approach, which compares changes in the prevalence of settlements and population growth in localities where trade costs changed differentially because of the reform. The identification assumption is that changes in the prevalence of cities in such localities would have been the same in the absence of the reform. Pre-trend checks and several robustness exercises support a causal interpretation of the estimates. I also examine the economy-wide effects of lower international trade costs, recognizing that improving the connectivity in one location may affect the population growth in other localities through trade and migration linkages. To capture these spatial interdependencies, I follow Donaldson and Hornbeck (2016) and calculate the market access for each cell by decade. To account for potential endogeneity and market size effects, I instrument local market access with the change in shipping time to Europe induced by the reform.

I find that the reform had large and heterogeneous effects on trade costs between Europe and the Americas. While the median reduction in shipping time is 16 days, the average is 12 days. The reduction ranges from 0 to 55 days, which is roughly half of the average voyage duration.[2] These changes in trade costs affected population growth and the incorporation of towns into the empire. In the preferred specification, a ten percent reduction in shipping times increases the probability of a cell containing a city, town, or village by 0.5 percentage points. The elasticity of the population size with respect to market access mirrors these results, with a one percent increase in market access increasing the population by 0.2 percent in the baseline specification. Next, I look at the heterogeneity of these effects and three patterns emerge. First, the effect is substantially larger in localities with lower population density. Second, it is larger in the peripheral regions of the Spanish Empire, showing that the economic geography was much more sensitive to changing fundamentals in areas that were less densely populated.[3] Finally, the effect was substantially larger in coastal areas. Consistent with these patterns, I show that the correlation between pre-colonial density and population density in the year 2000 is substantially smaller in areas more intensively treated by the reform. Taken together, the findings provide evidence that once trade was opened, this restructured the economic geography in places that were initially less densely settled. In the long-run, the economic geography in these areas then came to reflect locational fundamentals associated with trade. The economic geography in places that did not adjust to the changes in trade costs remained reflective of pre-colonial settlement patterns.

I explore different mechanisms potentially mediating this effect. Data on trade volumes and prices of Spanish American exports provide evidence of large increases in trade volumes with Spain. Consistent with increased reliance on commodity exports, I show the effects are larger in areas with higher suitability for high-value export crops.[4] Also, I show the effect is larger in places where the reform changed the shortest sailing route to Europe than in places that gained through less transshipment. Taken together, the findings are therefore consistent with the hypothesis that faster sailing promoted growth in coastal areas suitable for exports of agricultural commodities. In turn, this stimulated population growth in coastal areas as well as the establishment of new population centers to intermediate trade in agricultural

[2]The calculated travel times are cross-validated with several historical and contemporary datasets. For example, I provide evidence that it is highly correlated with mail dispatch times and recorded travel times in the 18th century.

[3]This is consistent with findings in Redding and Sturm (2008) and Banerjee, Duflo and Qian (2020) who also find market access leads to a dispersion of economic activity, albeit in very different contexts.

[4]I consider the average suitability of cacao, cotton, sugarcane, and tobacco which accounted for 27.3 of total exports and around 62 percent of non-bullion exports in the late 18th century (Fisher, 1993).

commodities.

In order to further assess the mechanisms and account for general equilibrium effects, I develop a dynamic spatial general equilibrium model, building on Allen and Arkolakis (2014) and Allen and Donaldson (2020).[5] I adapt this framework to my setting by incorporating land as a factor of production as well as time-varying trade costs. In the model, regions with heterogeneous amenities, productivities, endowments of arable land, and initial endowments of workers are linked through costly migration and trade. Mobile workers choose where to live subject to migration costs and the utility derived from each location depends on locational fundamentals as well as agglomeration and congestion forces. Agglomeration forces are a function of both contemporaneous and lagged population density and therefore allows for spatial persistence to play a potentially important role. The parameters governing persistence are estimated from the data. The identification of these parameters relies on the assumption that *changes* in the value of geographical fundamentals (such as proximity to natural resources or potential agricultural yield) are zero throughout the reform period. While this is an untestable assumption, the reduced form evidence and in particular, the absence of pre-trends provides support for it.

I use the quantitative framework to simulate the spatial impact of the reform. Having confirmed that the model matches first-order patterns in the data, I simulate the reform and find that the model matches salient features of the reduced-form exercise. The trade cost shock induced by the reform increased population density in areas with higher reductions in shipping times to Europe. Moreover, the reform increased the coastal population density and had larger effects in the periphery than in the core. I then use the model to run a series of counterfactual simulations. First, I find that lower initial population density tends to increase the effect of the reform and coastal population density. Second, I find an earlier opening of trade would have increased the coastal population density in 2010. Finally, I find that the *long-run* population distribution depends on the timing of the trade-cost shock. An earlier opening of long-distance trade would have increased the coastal population density in the long-run. The findings show that the changes in trade costs changed the equilibrium distribution of economic activity in areas where the initial population density was low, and the size of the change in trade costs large. This provides further evidence that the initial conditions as a country opens up to trade shape the importance of history versus trade in determining the spatial distribution of economic activity. Locational fundamentals associated with trade, such as coastal access, became more important in explaining the spatial distribution of economic activity in places that were sparsely populated as access to maritime trade was widened.

This paper contributes to a literature on persistence in urban geography (Davis and Weinstein, 2002; Redding, Sturm and Wolf, 2010; Bleakley and Lin, 2012; Jedwab and Moradi, 2015; Maloney and Valencia, 2016; Jedwab, Kerby and Moradi, 2017; Alix-Garcia and Sellars, 2020).[6] The spatial distribution of economic activity has been shown to be persistent even in the presence of large shocks in a variety of settings (Davis and Weinstein, 2002, 2008; Redding, Sturm and Wolf, 2010; Miguel and Roland, 2011). These findings are consistent with location-specific factors such as geographical fundamentals, fixed capital, and market access, playing an important role. However, Bleakley and Lin (2012) show population centers persist around historical portage sites after the technology has become obsolete, which points to

[5]More generally, the model builds on recent quantitative models of trade and geography, which accommodate a large number of locations that are asymmetric in their locational characteristics as well as frictions to trade and migration Redding and Sturm (2008); Ahlfeldt et al. (2015); Redding and Rossi-Hansberg (2017); Monte, Redding and Rossi-Hansberg (2018); Nagy (2020).

[6]The literature distinguishes between "first nature" locational advantages (agricultural productivity, resource abundance, presence of natural defenses, or access to trade) and "second nature" locational advantages (agglomeration economies).

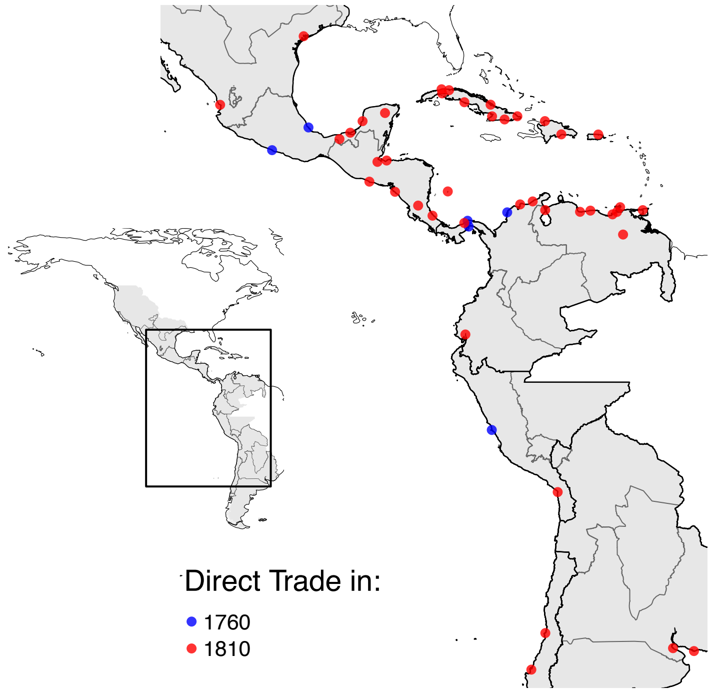

Figure 1: The map shows the extent of the territory claimed by the Spanish Empire in 1790 with its ports according to status. Ports marked in blue were licensed for long-distance trade prior to 1765 (Callao, Cartagena, Veracruz, Panama, Acapulco), while those marked in red were licensed to trade with Europe in 1810. Callao, Cartagena, Veracruz, Panama traded with Europe while Acapulco was a hub for trade with the Philippines.

an important role played by agglomeration economies.[7] Indeed, Henderson et al. (2018) finds that only 35 percent of the within-country variation in population density is explained by geographical fundamentals. While spatial persistence remains well-documented in a range of settings, little is known about what determines the relative importance of market access and history in determining the spatial distribution of economic activity. This paper shows that large trade cost shocks can disrupt spatial persistence when they are large and the initial population density is low. More broadly, the findings provide evidence that what determines the relative importance of history versus market access in determining the location of cities is the *sequencing* by which a location attains high population density and lower trade costs. History will tend to explain the population distribution in places that attain high population density in an environment of high trade costs, while market access will explain the population distribution in places that had low density prior to opening up to trade. The paper therefore contributes to the literature by shedding light on when persistence in the spatial allocation of economic activity matters, and the conditions under which it breaks down.

This paper also contributes to a literature exploring the long-term economic impact of historical institutions, (Acemoglu, Johnson and Robinson, 2001, 2002; Banerjee and Iyer, 2005; Dell, 2010; Dell and Olken, 2020), and the economic legacy of the Spanish Empire in particular (Grafe and Irigoin, 2006, 2012; Coatsworth, 2008; Bruhn and Gallego, 2011; Engerman et al., 2012). In particular, the results in this paper

[7]Historical precedent has been shown to be a key determinant of contemporary income differences through a wide range of mechanisms such as historical institutions (Acemoglu, Johnson and Robinson, 2001, 2002; Banerjee and Iyer, 2005; Dell, 2010), social attitudes (Alesina, Giuliano and Nunn, 2013; Satyanath, Voigtländer and Voth, 2017; Nunn and Wantchekon, 2011), and state centralization (Michalopoulos and Papaioannou, 2013; Alsan, 2015; Dell, Lane and Querubin, 2018).

shed light on the findings of a seminal paper, Acemoglu, Johnson and Robinson (2002). They establish a negative relationship between population density in 1500 and 2000 at the country-level. They argue that the population density at the time of settlement shaped incentives faced by early European settlers. In particular, lower initial population density necessitated institutions enabling broad participation in the economy to ensure subsistence. These institutions were more compatible with modern economic growth and thus caused divergence between areas with different initial population density starting in the second half of the 18th century. This paper complements their findings by highlighting the role of trade-related institutions in generating the increased growth in the periphery that they document. The results are consistent with the view that the *reversal of fortune* is rooted in institutional change, but highlight the importance of factors that shaped institutions governing trade, such as the transition from Habsburg to Bourbon rule in Spain, in addition to property rights which they emphasize the importance of. More broadly, this paper therefore provides evidence on the impact of trade-related institutions on economic geography, which has received less attention in the literature (Acemoglu, Johnson and Robinson, 2005; Jha, 2013; Jia, 2014; Alvarez-Villa and Guardado, 2020).

Finally, the paper relates to a literature which considers the impact of trade on national income. Several papers have documented large and positive elasticities national income with respect to trade (Frankel and Romer, 1999; Noguer and Siscart, 2005; Feyrer, 2009, 2019; Feyrer and Sacerdote, 2009; Pascali, 2017).[8] This is puzzling since the quantitative literature provides modest effects (Arkolakis, Costinot and Rodríguez-Clare, 2012). This paper builds on the literature in two main ways. First, I use time-variation in trade costs to study the impact of trade in goods on city location. Second, I estimate the effects without relying on changes in transportation technology. These features are important for several reasons. For one, changes in transportation technology do more than lowering trade costs. In particular, changes in effective distance affect travel and migration costs.[9] Moreover, within-country variation allows for analyzing effect heterogeneity. This is difficult in cross-country studies partly due to sample size and the number of potential confounders. In sum, the results in this paper shed light on the mechanisms through which lower trade costs affect national income. I show that trade increased density and promoted the formation of settlements situated in locations with higher market access.

The paper is structured as follows. Section 2 presents the historical background. Section 3 presents the data sources. Section 3 details the calculation of trade costs. Section 5 elaborates on the reduced-form research design, results, and mechanisms. Section 6 presents the model and the results of the quantitative exercise. Section 7 concludes.

2 Historical Background

This section provides the historical background for the analysis. I discuss the background for the trade reform and the historical relationship between trade reform and economic development within the Spanish Empire, and how the policies could influence long-run regional development patterns.

The Spanish Commercial System. Spanish commercial policy sought to promote state wealth acquisition through trade surpluses (Walker, 1979; Findlay and O'Rourke, 2007). To this end, several

[8]There are several challenges to the earlier literature working mainly with cross-sectional data. In particular, Rodriguez and Rodrik (1999) have shown that Frankel and Romer's estimates are vulnerable to the inclusion of controls. These issues are typically addressed by exploiting time variation in bilateral trade costs (Feyrer, 2009, 2019; Feyrer and Sacerdote, 2009; Pascali, 2017).

[9]See for example Campante and Yanagizawa-Drott (2018) or Söderlund (2019).

policies restricted the free flow of goods across the Atlantic. First, it restricted the points of entry and exit by directing Atlantic trade through the four main ports in the Americas (Cartagena, Callao, Portobello/Nombre de Dios, and Veracruz) and only Seville/Cádiz in Europe. Second, it restricted participation to Spanish merchants. Foreigners who wanted to participate in the trade needed to partner with Spanish companies. Third, the frequency of travel and the routes were limited. Typically, only two fleets left Spain every year: the New Spain *flota* destined for Veracruz, and the *Tierra Firme galeones* destined for Cartagena and Portobello. In the Pacific, shipping was conducted by *Armada del Sur*, which carried goods from the trade fairs in Portobello to Pacific ports in South America.[10][11] Finally, there were high tax rates on imports and exports. The duties typically depended on the origin of the goods, with lower rates on goods originating from Spain.[12]

The system was designed to ensure the steady flow of bullion across the Atlantic and to prevent economic diversification to sectors competing with Spain. It achieved this in several ways. For one, it facilitated the naval defense of convoys, which could concentrate on fewer ports. Moreover, it limited imports to the Americas, thus ensuring a favorable trade balance. This limited the flow of bullion to other places than Spain. However, it also served to keep prices for Spanish exports artificially high (Baskes, 2013). Naturally, it marginalized large areas that remained isolated from the official trade routes.[13] According to Fisher, "The inevitable consequences ... were economic underdevelopment in the peripheral regions of America, at least until the liberalisation of trade in the second half of the eighteenth century", Fisher (1997) p. 73.

Reforming Trans-Atlantic Trade. Beginning in the 18th century, Spanish reformers were induced by geopolitical considerations, originating mainly in Europe, to overhaul the external trading system (Mahoney, 2003, 2010). In the immediate aftermath of Spain's defeat in the Seven Years' War, a technical commission (the *junta de comercio*) was appointed under Charles III to assess and reform the system. The *junta de comercio* proposed the abolition of the Cádiz monopoly as well as the fleet system. Further, it proposed opening 14 ports on the Iberian Peninsula as well as 35 ports in the Americas (Fisher, 1997).[14] Four ports in the Caribbean were opened already in 1765.[15] The liberalization measures culminated in the decree of free trade in 1778 which opened several of the remaining ports.[16] In the 1780s, the remaining

[10]Moreover, the Manilla galleon would sail between Acapulco and Manilla. For a detailed account of the economics of the Manilla Galleon see Mejia (2019).

[11]Register ships (*registros*) supplied ports that were too remote relative to the large trade routes. These were ships that sailed under special permission of the crown. This was mainly the case for ports in Central-America, Buenos Aires, and Caracas. However, this was never done at a sufficiently large scale. As a consequence, these areas were often ignored by Spanish merchants and relied heavily on contraband (Walker, 1979). The extent of contraband trade is unsurprisingly not known but is believed to have been sizeable (Christelow, 1942). Official information was carried by *aviso* ships, which were light carriers operating separately from the commercial system and were not permitted or equipped to carry freight.

[12]The slave trade was not subject to these rules. Trade in slaves was allowed for British ships from early to the mid 18th century as a result of the treaty of Utrecht, the *asiento* (Walker, 1979).

[13]The system, consolidated under Phillip II in the 1560s largely remained in place until the second half of the 18th century. Two notable exceptions were the change from using Nombre de Dios to using Portobelo on the Caribbean coast of Panama. In Spain, the merchant guild of Seville was moved to Cadiz in the early 18th century, partly due to the silting of the Guadalquivir.

[14]The ports that were opened on the Iberian peninsula in this period was Malaga, Almería, Cartagena, Alicante, Tortosa, Barcelona, Santander, Gijón, La Coruña, Palma de Mallorca, Santa Cruz de Tenerife. While the reform is believed to have a role in promoting the rise of the Barcelona textile industry, in the early 19th century around 80 percent of Spanish trade with the Americas still went through the port of Cádiz (Fisher, 1997).

[15]Santo Domingo, Puerto Rico, Margarita, and Trinidad were opened for direct trade with Spain in 1765.

[16]This was with the exception of the Captaincy Generalacy of Venezuela (Caracas), where it was believed the Caracas companies tobacco monopoly was worth protecting, and New Spain (Campeche), where it was believed it would have diverted too much trade away from other regions. *Reglamento y aranceles reales para el comercio libre de España a Indias de 12. de octubre de 1778*, and Fisher (1997). Even so, especially Veracruz was affected by the changes before the late 1780s since due to the abolition of the convoy system and the increased prevalence of *registros*.

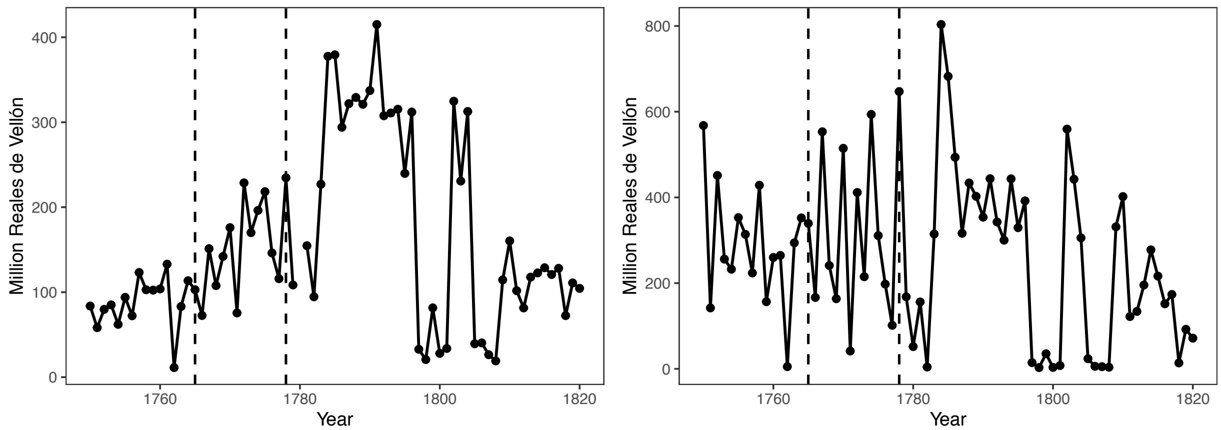

Figure 2: The left figure the value of non-bullion exports from Spain to American ports from 1750-1820. The right panel denotes bullion exports to Spain for a 1750-1820. The vertical lines denote the beginning and end of the main part of the liberalization. The large drop in 1797 is due to the British blockade of Cadiz as part of the Anglo-Spanish War 1796-1808. The lower level after 1807 was due to the Peninsular War as well as the Spanish American wars of independence. Data for 1780 is missing in the original data source. Source: Cuenca-Esteban (2008).

ports followed. Spanish communication with the Americas was disrupted during the Napoleonic wars. As a result, trade with neutral nations during the Napoleonic war was allowed. The 18th century marked the definitive end of Spain's ability to enforce protected trade with the colonies. As a result, by the beginning of the 19th century, Spanish America enjoyed *de facto* although not *de jure* unrestricted trade with foreigners (Fisher, 1998).

The historical literature emphasizes the role of European interstate competition and Spanish state-building as being the motivation for undertaking the reform. Thus, the drive to reform the Spanish commercial system should be understood as being embedded in a logic of interstate competition between the European powers of the 18th century (Kuethe and Andrien, 2014). A single event highlighted in the historical literature as an important impetus for the reform was the "humiliating" capture of Havana by the British during the Seven Years' war. This opened a window of opportunity for reform-minded policymakers in Spain who now could rationalize reforming the external trading system with reference to concerns about national security. As a result, the reform was implemented rapidly after the Seven Years' War (Fisher, 1997). Therefore, the timing of the reform is mainly driven by intensified interstate competition in Europe, rather than economic development in the Americas directly. Moreover, the reform was implemented from above and no significant ports in which the policies were applied were excluded. This is also apparent from the fact that the policies were resisted by several actors in the Spanish Empire (Baskes, 2013). Finally, the policies undoubtedly broadened access to international trade across the Spanish Empire which is apparent in trade statistics (Fisher, 1985; Cuenca-Esteban, 2008).

"Free Trade" and Economic Growth. The reform affected economic growth in different regions. Formerly neglected regions such as *Rio de La Plata*, Venezuela, and Cuba became important exporters of hides, indigo, tobacco, sugar. Largely unrestricted sailing of individual ships allowed for specialization in a wider range of commodities, such as more perishable goods, to be exported. However, bullion remained an important export commodity (Fisher (1997) p. 38). Fisher (1993) provides data on the composition of Spanish imports from Spanish America between 1782 and 1796 for the ports of Cadiz and Barcelona (which accounted for around 88 percent of imports from Spanish America). Precious metals still accounted for 56.4 of imports through this period. The other commodities were typically high-value agricultural commodities (tobacco 13.6, cacao 7.8, sugar 5.5, indigo 5.2, cochineal 4.2, hides 3.4 and cotton 0.4 percent) (Fisher, 1993).

While it is generally agreed upon that the reform had large effects on trade volumes, the magnitudes are disputed (Escosura and Casares, 1983; Cuenca-Esteban, 2008). Colonial imports to Spain increased tenfold and exports from Spain to the colonies fourfold (Fisher, 1985), while more modest estimates are found in Cuenca-Esteban (2008) which also suggests large effects (see Figure 2). However, there is little doubt that trade increased substantially during the period. As a result of these developments, several formerly marginal areas in the Spanish empire became important economic regions. "...for the first time, the metropolis succeeded in unleashing the agricultural potential of its American possessions, whilst also promoting the continued expansion of mining production. The relationship between this economic growth and the liberalization of trade is abundantly clear", (Fisher (1997) p. 197). Moreover, the population and economies of previously stagnant peripheral colonies in Spanish America grew rapidly (Mahoney, 2003; Bulmer-Thomas, 2003).[17] In summary, the historical literature suggests the restrictions imposed on trade in goods with the Americas stunted economic development, and efforts induced by European interstate competition to relax these had large effects on trade and regional development in the second half of the 18th century.[18]

3 Data

To quantitatively assess the impact of the reform, I construct a dataset containing geographical, demographic, and economic data of the Spanish Empire in the 18th century. The dataset consists of 6,662 grid-cells of 0.5°×0.5° which approximates an upper bound of the distance an adult can travel per day on flat terrain.[19] See Figure 12 for a snapshot of a grid-cell and its six adjacent cells and Figure 4 for a depiction of the full extent of the study area, which covers the territories of several contemporary nation-states.[20] I aggregate the dataset by decade for the 100 years spanning 1710-1810. This period roughly covers the rule of the Bourbon dynasty, beginning just after the War of Spanish Succession and ending with the outbreak of the Wars of Independence, and results in a balanced panel of $6,662 \times 11 = 73,282$ observations. I aggregate several data sources to this level. Details about the datasets and the implementation can be found in the Appendix while summary statistics of the main variables can be found in Table 1.

[17] Cadiz remained the dominant port for trade with Spanish America between 1778 and 1796 (76.4 percent of total exports and 84.2 percent of imports). The remaining important ports were Barcelona (9.6 and 3.8 percent), Malaga (4.8 and 1.3 percent), Santander (3.3 and 2.6 percent), and La Coruña (3 and 6.8 percent) (Fisher (1993) p.20 and p.25).

[18] In some parts of the Spanish Empire, the crown was confronted with local elites not keen on losing privileged access to long-distance trading opportunities (Mahoney, 2010). In the *Audiencia* of Guatemala "... a monopoly - an undesirable weed in an atmosphere of liberalized commerce - which already had taken deep root and was in full flower before the implementation in America of laws enacted to increase production and trade.", and "...Bourbon commercial reforms were too narrowly conceived and did not take into account the deep entrenchment of commercial interests established before reform efforts in America were attempted," (Floyd, 1961). The *Audiencia* of Mexico faced a similar situation. With the reform, two competing groups of merchants emerged, in Veracruz and Mexico City. Merchants in Mexico City blocked the rise of Veracruz by purchasing and distributing directly to Mexico City (Mahoney, 2010).

[19] This constitutes around 50km at the equator. I also analyze different spatial resolutions and obtain similar results. These are reported in the Appendix.

[20] The countries partly or entirely covered are Argentina, Brazil, Chile, Bolivia, Peru, Uruguay, Ecuador, Colombia, Paraguay, Venezuela, Panama, El Salvador, Honduras, Costa Rica, Guatemala, Mexico, Nicaragua, Cuba, the United States, and the Dominican Republic.

3.1 Population and and Settlements

Settlements. A key outcome of interest is the formation of new settlements and population growth. I construct the main sample from a territorial gazetteer of 15,000 places that existed in the Spanish Empire during the 18th and early 19th-century. The dataset is based on official records as well as various secondary sources (Stangl, 2019*b*).[21] It contains the founding, legal status, position in the ecclesiastical hierarchy, as well as the longitude and latitude of each settlement. In the main analysis, I restrict the sample to places with the status of *city*, *town*, or villages in order to capture the location of population centers. This avoids common pitfalls associated with using population thresholds for defining a city. The status of *city* was the highest legal status afforded a population center in Spanish America and was typically granted by the crown. Below the city in the hierarchy was the town (*villa*). In some cases, settlements were abandoned (such as Buenos Aires) or moved (such as Guatemala). In these cases, the date of founding is the founding of the first city in both cases. Moreover, different places could have very different functions. The location of the place is determined by the functional center.[22] Altogether, the final dataset contains 2,125 places spanning 1710 and 1810. Henceforth, I refer to these as settlements. This results in slightly above ten percent of decade $\times$ cell combinations containing a settlement in the final dataset. Figure 13 shows there is a secular increase in the share of grid-cells containing a settlement throughout the period.

Population. I compile population data from several sources. First, I use demographic data consisting of historical census data (Stangl, 2019*c*). It contains demographic data for various administrative entities between 1710 and 1810. Unfortunately, this data is cross-sectional. As a result, it does not lend itself to the panel dimension of the main dataset. Therefore, I use population estimates from HYDE 3.1 (Klein Goldewijk et al., 2011). The dataset is a raster file of population density spanning the whole study region at 10-year intervals.[23] It extrapolates from various historical population statistics to create granular population data spanning the whole globe. This dataset has been used in the economics literature to study long-run growth and urbanization patterns (Motamed, Florax and Masters, 2014; Delventhal, Fernandez-Villaverde and Guner, 2019; Fernández-Villaverde et al., 2020). I assess the quality of this extrapolation in the particular context of this study by cross-validating against historical census data. In the Appendix, I show that population density data from Hyde 3.1 is highly correlated with the census data.[24] Further, I use city-level population data from Buringh (2013). A city is included in the database when it has more than 4,000 inhabitants. I restrict the dataset to cities for which there is data in 1750. This constitutes 211 cities which are observed in 1750 and 1800. This further validates the rasterized population data and enables studying city-level growth in more detail which I do exploring mechanisms. Finally, I add three datasets to measure contemporary outcomes. Following Henderson, Storeygard and Weil (2012) and later work, regional development and population density is proxied using satellite imagery on light density averaged annually since 1992. Data on contemporary population

[21] "Sources include archival material like census tables, mission reports, visitations of dioceses and provinces, but also more ephemeral documents like petitions of some city council which were mostly not written for giving geographic information but may touch one specific detail or incidentally expose some relevant information. Non-archival contemporary sources include mostly highly systematic sources for information like so-called "Foreigner Guides" (printed calendar-manuals which included also lists of office holders of many parts of the Empire), maps, or geographical descriptions both printed and manuscripts." (Stangl, 2018).

[22] For example, a place served as a market place, the dataset includes the location of the market place. A place with a primarily religious function records the location of the church and so on.

[23] The dataset has been used extensively in economics already. The years used in this analysis are 1500, 1600, 1700, 1710-1820 (by decade).

[24] The correlation coefficient between the population implied by the two datasets is 0.77.

density is from the Gridded Population of the World which is distributed by the (CIESIN) at Columbia University. These two data sources are highly correlated and capture urban agglomeration and economic activity which is the main outcome of interest in this part of the analysis.

3.2 Sailing and Trade

Sailing data. To infer the sailing speeds, I combine information on maritime logbooks with data on wind patterns. I calculate voyage durations using logbooks from the CLIWOC database (Climatological Database for the World's Oceans) (García-Herrera et al., 2005). The data was originally compiled for studying historical oceanic climate conditions and contains around 280,000 logbook entries for Spanish, Dutch, French, English, and Swedish ships between 1750 and 1850. The logbook entries contain the daily longitude and latitude, wind speed and direction as well as several voyage-level characteristics such as the ship name, origin, and destination, captain name, and ship type.[25] I use the daily change in longitude and latitude to infer the average daily travel speed. I follow Kelly and Ó Gráda (2019) and remove observations for which either the inferred speed is implausibly high (above 10 knots), or are located in coastal areas. Next, I calculate the relationship between average wind speed, direction, and travel speed. To do this, I combine the logbooks with information on the average velocity and direction of the sea-surface winds. This dataset is provided by the US National Oceanic and Atmospheric Administration (NOAA). I download and average speed and direction by $0.5° \times 0.5°$ cells for each week between 2011 and 2017.[26] The strength of this data is the higher spatial resolution. However, using contemporary data to proxy historical wind conditions could introduce measurement error. Therefore, I cross-validate the contemporary and historical wind data as recorded in the logbooks. Table 2 shows that these measures are highly correlated.

Trade data. Data on trade flows come from two separate sources. First, data on trade between Spain and America at the port-level between 1797-1820 is from Fisher (1993). These data have been compiled from primary sources mainly from the General Archive of the Indies in Seville. It contains data on the share of Spanish foreign exports to the 19 largest American ports as well as the total value (measured in *reales de vellón* in constant prices). Moreover, it contains estimates of the composition of trade. I use this data to assess the relationship between changes in trade costs and trade volumes. To estimate the parameters of the model one needs to estimate the gravity equation. To do this I use data on bilateral trade flows at the country level (Fouquin and Hugot, 2016). The full dataset contains 1.9 million bilateral trade observations. I restrict this dataset to be between 1820 and 1870 which roughly proxies the period prior to the introduction of steamships. Next, I restrict the sample to the countries in the analysis which results in 801 bilateral trade pair observations.

3.3 Geography and Infrastructure

Geography. I add several controls for geographical fundamentals and variables to explore mechanisms. First, I use high-resolution data on agricultural yields to proxy for agricultural land quality and suitability for important high-value export crops in Spanish America in the second half of the 18th century. Crop suitability for cotton, tobacco, sugarcane, and cacao is provided by FAO's Global Agro-Ecological

[25]In the case of Spanish ships these are *paquebote*, *fregata*, and *navio*.

[26]For cells covering land, the wind speed is set to zero to prevent routes from crossing land.

Zones and averaged at the grid-cell level. These constitute around 27.3 of total exports from Spanish America to Spain in this period and measure the potential yield under rain-fed, low-input agriculture, thus reflecting agricultural suitability using traditional technology. Second, I incorporate data on the potential agricultural output (measured in calories) to proxy income. I use a measure of agricultural potential constructed by Galor and Özak (2015, 2016). The data measure the maximum attainable yield measured in calories that can be achieved for a variety of crops. A compelling feature of the Galor and Özak measure is that it captures features of the natural environment affecting attainable yields, but that are exogenous to human intervention. Furthermore, I calculate the terrain ruggedness index, average slope, and elevation by grid-cell. To proxy for the disease environment, I construct a dummy variable that takes the value one if the average elevation is below 1500m.[27] This helps account for the time-variant impact of geographical features that could be correlated with changes in remoteness through a variety of mechanisms (Scott, 2009; Nunn and Puga, 2012). Finally, information on climatic variation is from Hijmans et al. (2005). For the data which cannot be cross-validated with historical sources (such as agricultural yields, geographical characteristics), proxying 18th and 19th-century geographical characteristics with high-resolution geographical data requires further assumptions. In particular, for these outcomes, I assume that these have remained fixed, or only changed with the same factor across different locations.

Infrastructure. The trading status of each port is from the decree itself *Reglamento y aranceles reales para el comercio libre de España a Indias de 12. de octubre de 1778*, as well as Fisher (1997). I cross-check these sources with various other secondary sources and list the ports, their location, as well as trading privileges is listed in the Appendix. In addition to measures of potential agricultural productivity, I include the location of the principal mining centers in the 18th century. In total 78 locations across the Spanish Empire that mined for silver, mercury, gold, salt, emeralds, copper, platinum, or iron. This data is from Fisher (1997). Together, mining, cotton, tobacco, sugarcane, and cacao exports make up around 83.7 of all imports from Spanish America to Spain in the period. Finally, I use land routes for mail to proxy for the location of roads (Stangl, 2019*a*). These data have largely been reconstructed from historical sources. I include controls on potential vegetation to proxy for different geographical fundamentals as well as using landcover to calculate travel speeds (Ramankutty and Foley, 1999). Navigable rivers played a less important role in trade than in Europe and the United States. Therefore, I only control for time-varying effects of distance to waterways and fresh-water access by using data on river flows from (Lehner, Verdin and Jarvis, 2008).

4 Trade Costs and Market Access

To estimate the impact of the reform, I calculate bilateral shipping times and market access. This serves two purposes. First, changes in shipping times provide a time-varying instrument for actual trade costs. Second, I use trade costs to calibrate the quantitative model and estimate the parameters determining the strength of the agglomeration spillovers. In this section, I detail how the bilateral shipping times are calculated.

[27]There is no data on the disease environment at high geographical resolution available for Spanish America in the 18th century. However, as pointed out in Bruhn and Gallego (2011), Hong (2007) shows that the main predictors of deaths due to malaria in North American frontier forts in the 19th century are variables related to climate and elevation which I do control for.

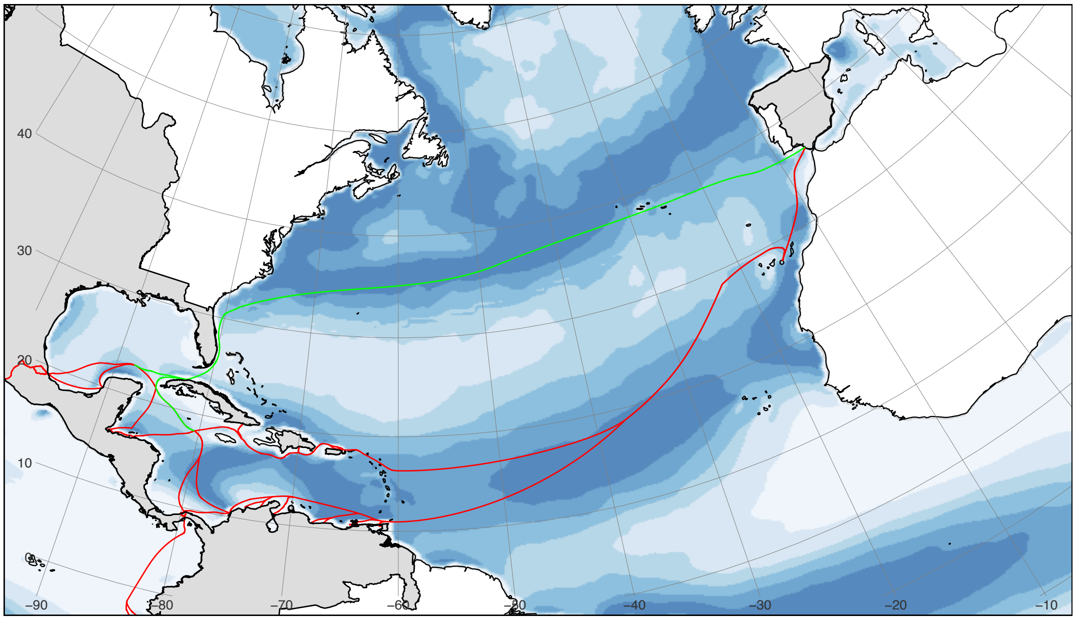

Figure 3: The figure shows the cost surface of maritime travel between 1750 and 1850. The map plots the average cost for each $1° \times 1°$ grid-cell where darker colors indicate that the cell can be crossed at higher speed. Grey areas denote territory claimed by the Spanish Empire in 1790. The cost surface is calculated from predicting sailing speeds from wind direction and speeds. The estimated relationship is the extrapolated on gridded data of wind direction and wind speeds covering the world oceans. The red and green lines denote historical trade routes. Red denotes the westward journey while green denotes the eastward journey. Source: NOAA and CLIWOC.

4.1 Calculating Trade Costs

Maritime Transport. I calculate maritime transportation costs by estimating sailing speeds from logbooks using georeferenced data on wind patterns. To do this, the world was divided into a matrix of $0.5° \times 0.5°$ cells.[28] For each square, weekly data on wind direction and speed was averaged over the period 2011 - 2017 (see Figure 18). I impose the following flexible relationship for the sailing time between adjacent grid-cells i and j,

$$T_{ij} = \exp\{f(\theta_{ij}, s_i) + \epsilon_{ij}\}, \tag{1}$$

where s_i measures the wind speed in grid-cell i, θ_{ij} measures the deviation of the angle between node i and j with the wind direction, and T_{ij} measures the predicted sailing speed between cells i and j. Since the relationship between travel times and wind conditions is potentially non-linear, $f(\cdot)$ is a function of polynomials of s_i, θ_{ij} and their corresponding interactions.

Estimating T_{ij} requires a large sample of historical travel times as well as granular data on wind conditions. I estimate the function relying on data from CLIWOC (García-Herrera et al., 2005). Three restrictions are made on the sample to facilitate the calculations. First, observations, when the ship is anchored in port, are dropped. Second, logbook entries in coastal waters are removed. This is because coastal navigation faced additional constraints than wind conditions. Finally, to reduce measurement error, observations with implausibly high speeds are dropped which I define as average daily speeds above ten knots. This results in 234,950 logbook entries in the final dataset. The estimated travel time function $\hat{T}_{ij}$, is obtained by estimating T_{ij} using a Lasso-regression where the tuning-parameter

[28] Approximately 50km at the equator.

is determined by cross-validation (Tibshirani, 1996). The resulting average travel time by ship in the sample is around 4 knots, which corresponds closely to other estimates of speed under sail. Figure 4 illustrates the resulting cost surface.

Overland Transport. Long-distance shipping overland relied on pack animals and ox-carts at least until the second half of the 19th century. To calculate the costs faced by travel with pack animals, I use several geographical attributes. The pace of movement will depend on whether movement occurs on a road, the slope of the terrain, as well as the land cover. A key feature determining movement speeds in this context is the slope of the topography which either impede or facilitate movement. I model this using the Tobler-function (Tobler, 1993), which forms the basis of the calculations. The number of days it takes to travel between i and j is given by the following expression,

$$\hat{T}_{ij} = \kappa_i \times 3.77 \times \exp\{3.5|slope_{ij} + 0.05|\} \tag{2}$$

where $slope_{ij}$ measures the slope between cells i and j and κ_i is a coefficient determined by the landcover in cell i. I assume that travel on flat terrain on a road happens at 4.5km per hour.[29]

I rely on data on official travel routes in the Spanish Empire during the Bourbon period to measure the location of roads. I follow the literature and assume pace off the path to only be sixty percent of the pace on the path. Additional geographical attributes can further facilitate or impede movement and I rely on the literature for the terrain coefficients.[30] Six terrain types have a natural mapping between historical land cover data and the terrain coefficients. These are dense forests, grassland, deserts, open shrubland, and dense shrubland.[31] Finally, major rivers and lakes are included. In contrast to Western Europe and the United States, navigable rivers played a more limited role in Spanish America. I interpret rivers and lakes mainly as obstacles to mobility. In the baseline case, I assume that lakes have to be circumnavigated, while rivers can be crossed at every point by reducing the pace by 50 percent. Further, I assume the location of rivers and lakes to be time-invariant, which is a reasonable assumption at the level of aggregation used in the analysis. The left map in Figure 4 shows the resulting cost surface.[32]

4.2 Least-Cost Path Problem

Once the time of passing between all adjacent cells is known, one can calculate the bilateral shipping times between all grid-cells by searching for the time-minimizing route of getting from a cell i to any other cell j. The estimates of shipping times between each adjacent cell are used to construct a matrix of bilateral travel times between all the cells, $\mathbf{T}_t$, which I refer to as the transition matrix in decade t. This matrix has $R \times R$ dimensions and is calculated by decade between 1760 and 1810.[33] Since there will be many alternative paths to ship a good between localities i and j, I assume goods shipping follows the time-minimizing path according to the Dijkstra algorithm (Dijkstra, 1959). An entry in the matrix, T_{ij}^t

[29] Fernández-Villaverde et al. (2020) point out that roman recruits were required to complete about 30 km in 6 hours in loaded marches. In the U.S. Army, the average march rate for foot soldiers is estimated to be between 20 to 30 km per day.

[30] For simplicity, I assume a linear relationship between travel speed and the metabolic rate.

[31] The terrain factor makes the pace off-path 0.6 of the initial pace, 10/11 on grassland, 5/6 on dense and open shrubland, 2/3 in forests, and 10/21 in deserts.

[32] Özak (2018) develops a *Human Mobility Index* to calculate pre-modern travel times. This measure is not appropriate in the current context because I take into account infrastructure and travel routes in Spanish America in the 18th century. Moreover, the estimates of seafaring measures pre-modern maritime travel times.

[33] In the baseline case R = 6,662.

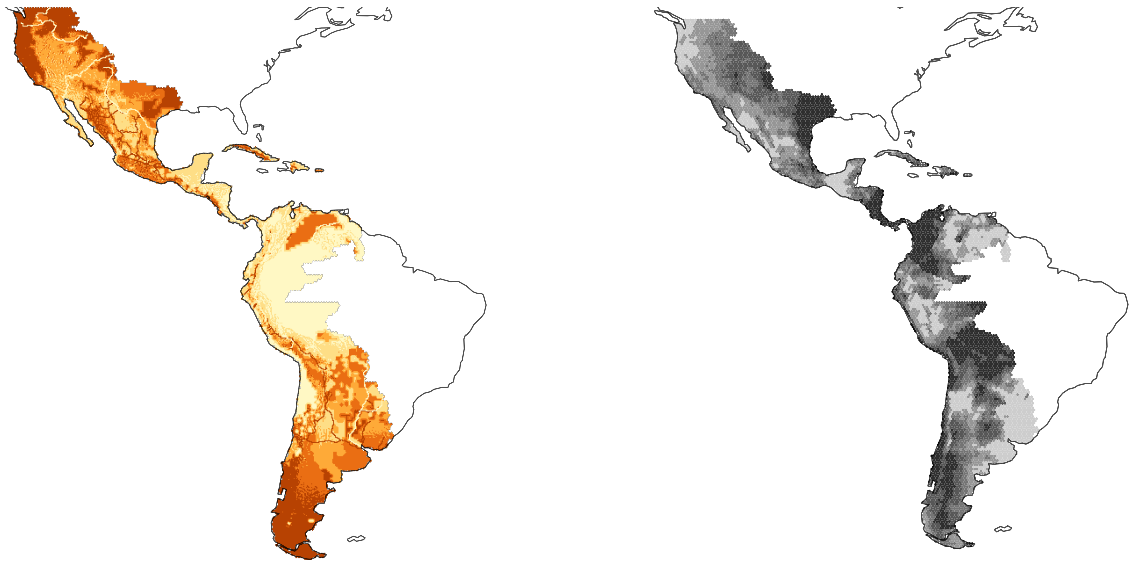

Figure 4: The left figure plots the cost surface for travel over land. Darker colors indicate that the cell can be traversed faster. The figure on the right shows the residualized change in shipping times 1760 and 1810 at the level of 6,662 $0.5° \times 0.5°$ grid-cells. Lighter colors indicate larger reductions in shipping times. Controls include elevation, distance to the coastline, terrain ruggedness, agroclimatic suitability for various cash crops, and whether the grid-cell overlaps an active mine.

denotes the travel time in decade t between (not necessarily adjacent cells) i and j measured in days. Denote $\mathbb{1}^{n}_{ij}$, an indicator variable which is defined in the following manner,

$$\mathbb{1}^{nt}_{ij} = \begin{cases} 1, & \text{if cell } n \text{ is on the shortest path between } i \text{ and } j, \\ 0, & \text{cell } n \text{ is not on the shortest path between } i \text{ and } j. \end{cases} \tag{3}$$

Each entry in the transition matrix is calculated as the sum of travel times between adjacent cells on the least-cost path. In particular, the entry at the i-th row and j-th column at time t, T^{t}_{ij}, denotes the travel time between cell i and j in year t and is given by the following expression,

$$T^{t}_{ij} = \sum_{k=1}^{R} \mathbb{1}^{kt}_{ij} T^{t}_{ik}. \tag{4}$$

$\mathbf{T}_t$ is calculated for each decade from 1710 to 1810 to capture the effect of the reform and I assume $\mathbf{T}_k = \mathbf{T}_{1760}$ for all $k \leq 1760$. This transition matrix forms the basis for both the reduced form and the structural exercise. Particular emphasis will be put on the column containing bilateral travel times between Europe and each cell in Spanish America. To incorporate trade with Europe, I model Europe as a point-like country centered on Cadiz containing the population mass of Western Europe for each decade. I choose Cadiz because the majority of legal trade with Europe was channeled through this port throughout the period.[34]

The definition of market access used here follows Donaldson and Hornbeck (2016). The market access ($MA_{i(t)}$) for a given locality is the sum of the population of all other localities, discounted by

[34]For the case of Great Britain the share of direct trade with Latin America became the most dominant towards the end of the colonial period, starting in the early 18th century (de la Escosura, 1984).

bilateral travel times, scaled by a trade elasticity ζ. Having estimates for bilateral travel times for all localities, the main explanatory variable is the actual market access of a given grid-cell which is given by the following expression,

$$MA_{i(t)} = \sum_{j \in R} T_{ij}^{-\zeta} L_{jt}, \tag{5}$$

where T_{ij}^{t} measures the number of days shipping from i to j at time t, L_j^t the population size in j at t, and ζ captures the shipping time elasticity. When $\zeta = 1$, the expression for $MA_{i(t)}$ then corresponds to the market potential (Harris, 1954). In this case, $MA_{i(t)}$ will increase with one unit if an area one day away grows with one person. The literature has produced several estimates of the trade elasticity ζ. Following Simonovska and Waugh (2014) and Morten and Oliveira (2018) I therefore set ζ to 4 as a starting point. Donaldson and Hornbeck (2016) find a trade elasticity of 3.88. In a robustness exercise, I follow Jedwab and Storeygard (2017) and set $\zeta = 3.8$ because their distance measure also reflects travel time.

4.3 Results and Assessment of the Shipping Times

Results. Figure 5 documents a substantial change in both shipping times and market access between 1760 and 1790. The average shipping time is around 11 percent lower, while the average market access increases by around 30 percent. These averages mask significant heterogeneity. The median reduction in shipping times is around 16 days of travel. This ranges from the largest reduction of 60 days' shorter travel to no change in shipping times. The average shipping time before the reform is around 130 days. Figure 3 shows the geographical variation in the reduction of shipping time where darker colors indicate larger changes. Localities with the largest reductions are in the River Plate region, Venezuela, and parts of Central America. These areas experienced large changes in market access and shipping times as a result of the reform. Changes in market access largely mirror the changes in shipping times.

Assessing the Shipping Times. How precise are these estimates? As a first pass, the cost-minimizing routes reflect routes used during this period. For example, Pacific and Atlantic ports are connected by the Panama isthmus. Mexico City is connected through Veracruz and Acapulco, and Potosi and Arica with Callao. I also quantitatively assess the precision of the estimates. To do this, the results are cross-validated against several other data sources. First, I compare the results to measures sailing times according to a database of bilateral sailing times.[35] For each port, I calculate the sailing time from Europe (Cadiz) to all the ports in the dataset for which the website records information. The average speed of 3.9 knots is used, which makes up the average speed of Spanish freight ships in 1750 (Kelly and Ó Gráda, 2019). As can be seen in Figure 16, these two measures are shown to be highly correlated and robust to including controls. Next, I assess the correlation between predicted time travel and the duration of mail between major ports. Data on the speed of mail is from Baskes (2013). Again, there is a strong correlation between predicted distance and the speed of mail in the dataset. This pattern is robust to controlling for geodesic distance, viceroyalty, as well as longitude, and latitude. Finally, I assess the correlation between historical and modern wind patterns. The CLIWOC database contains daily georeferenced data on wind speed and direction between 1750 and 1850. As can be seen in Table 2, there is a strong correlation between wind speed and direction in these two datasets. Taken together, these exercises show that the calculated shipping times coincide well with the historical sources.

[35] A free database of bilateral sailing times between major ports around the world. Data available at `seadistances.org`.

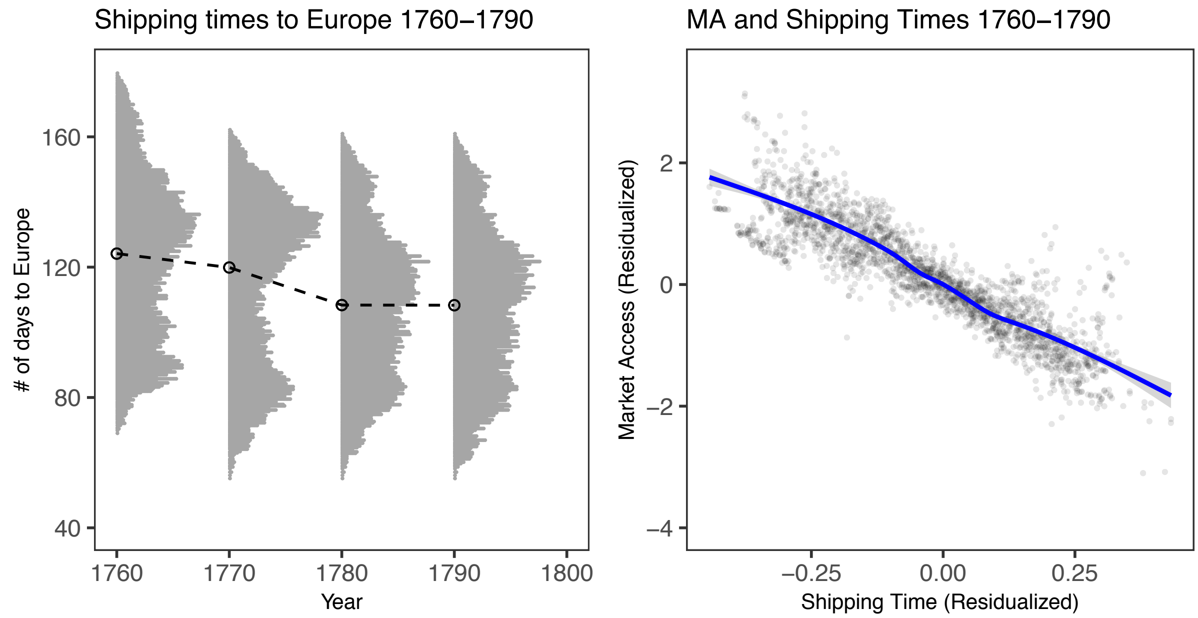

Figure 5: The figure shows shipping times and market access for the 0.5°×0.5° grid-cells used in the main analysis. The left panel displays number of days' travel from a grid-cell to Europe. The right panel displays the residualized relationship between the logarithm of market access with $\zeta = -4$ and shipping times to Europe. The specification includes *audiencia* as well as *audiencia* times decade fixed-effects. The geographical controls contain elevation, crop suitability, the location of active mines, (log) distance to the coastline, and terrain ruggedness. Standard errors are clustered at the port-level.

5 Reduced-Form Evidence

In this section, I present the main empirical specification, reduced-form results, and mechanisms. The section aims at identifying the *causal* effect of lower international trade costs on the spatial distribution of economic activity. While I provide evidence that the timing of the reform is not related to population growth and the formation of settlements prior to the reform, there are other potential challenges. For one, there are likely to be spillovers between treated and less treated areas due to trade and migration linkages. Moreover, measurement error is likely to be non-trivial in this context. For these reasons, I also provide several robustness checks of the main results towards the end of this section.

5.1 Methodology

Difference-in-Differences. I begin by documenting the impact of the changes in shipping times on the formation of new settlements. To quantify the effect, consider the following regression model,

$$y_{i(a,t)} = \alpha_i + \gamma_a \times \tau_t + \beta T_{i(t)} + \phi x_{i(t)} + \epsilon_{i(t)}, \tag{6}$$

where $y_{i(a,t)}$ is an indicator equal to one if a settlement is present in cell i at time t and zero otherwise. $T_{i(t)}$ measures the number of days of travel from the grid-cell to Europe in decade t. I include the vector of controls, $x_{i(t)}$, to capture the geography, climatic characteristics, and historical resource availability of a given cell. The baseline model controls for elevation, distance to the coastline, terrain ruggedness, agroclimatic suitability for various cash crops, and whether the grid-cell contains an active mine. In some specifications, these variables are interacted with decade indicator variables, which allows each feature to vary in importance over time.[36] Given the long time-horizon this is an important issue for several reasons. For example, while elevation or the location of bodies of water are fixed over time, the effect of these factors could have changed with irrigation techniques or the disease environment. Next, I include *audiencia*-by-decade fixed effects in the baseline specification, $\gamma_a \times \tau_t$. These account for shocks affecting all localities within a given *audiencia* in a particular decade.[37] Here $\epsilon_{i(t)}$ is an error term potentially spatially correlated across nearby cells. In the baseline specification, standard errors are clustered at the level of the treatment assignment (Abadie et al., 2017).[38] In this case, the treatment is assigned at the port-level which results in 50 clusters. The coefficient β captures the change in the probability of a cell containing a settlement for a one-unit change in shipping time to Europe. My key identification assumption is that *changes* in the rate of the formation of new settlements in areas with different *changes* in trade costs, would have been the same in the absence of the reform. I challenge this assumption in several ways which I elaborate upon below.

Next, I consider the relationship between market access and the formation of settlements. Market access will account for spatial linkages, reflecting both the direct and indirect effects of increased accessibility. To isolate the variation in market access that is induced by the reform, I use an instrumental variable approach. In particular, changes in market access is instrumented by the change in shipping time to Europe, using the following equation,

$$y_{i(a,t)} = \delta_i + \lambda_a \times \psi_t + \beta \widehat{MA}_{i(t)} + \omega x_{i(t)} + \mu_{i(t)}, \tag{7}$$

where $\widehat{MA}_{i(t)}$ is market access for cell i in decade t as predicted by shipping time to Europe. The parameter of interest, β, measures the change in the probability of a settlement in grid-cell i given a one percentage change in market access. The interpretation of β as a local average treatment effect relies on further assumptions. I assume that the reform only affected market access through its effect on shipping times to Europe. This is a plausible assumption as the reform changed rules for trade in goods, not maritime communication more generally. Moreover, I assume that the change in shipping time is correlated with the change in market access during the period. Under these additional assumptions, the coefficient β will identify the effect of increased market access for localities that increased their maritime connectivity to Europe as a result of the reform.[39]

Event Study. To assess the dynamics, I calculate the time-varying impact of the changes in shipping

[36]Elevation is an indicator variable taking the value one if the average elevation is above 1,500m. Agroclimatic suitability if measured as the average suitability for cocoa, tobacco, cotton, sugar cane, and coffee. The appendix provides more details about the data sources. Other controls are included as robustness exercises.

[37]The viceroyalty was subdivided into audiences, which were political bodies in charge of various policies. The *audienca* was further divided into governorships or provinces and further into principal mayoralties *corregimientos*. The smallest administrative unit considered in this paper is the *audiencia*. Figure 5 as well as Figure 15 shows the geographical extent of the *audiencia* and viceroyalties in 1790. In robustness checks, I consider borders in place for earlier periods and find the same results.

[38]Standard tests can over reject the null with few clusters (Cameron, Gelbach and Miller, 2008). Therefore, I estimate bootstrapped p-values using the wild cluster bootstrap to account for this as robustness. This correction matters little. Further, I also account for spatial dependence in the error term by explicitly allowing for spatial correlation (Conley, 1999). The distance kernel chosen has a cutoff at 5,000km. This correction matters little for the size of the standard errors as can be seen in the Appendix.

[39]The monotonicity assumption is satisfied by construction.

times on city formation. Consider the following dynamic regression model,

$$y_{i(a,t)} = \alpha_i + \gamma_a \times \tau_t + \sum_{s=1710}^{1810} \mathbb{1}[t = s]\Delta T_i \times \tau_s + \phi x_{i(t)} + \epsilon_{i(a,t)}, \tag{8}$$

where $y_{i(a,t)}$ is an indicator equal to one if a settlement is present in cell i at time t and zero otherwise, α_i is an *audiencia* fixed-effect, x_{it} is a vector of the main time-varying controls measured at the grid-cell level, and $\Delta T_i = T_{i(1760)} - T_{i(1810)}$. As a robustness check, I also include the log of the pre-reform population size. This is to capture potentially different trends in large and small locations, for example driven by local increasing returns or mean reversion (Duranton and Puga, 2014). τ_s, which are the coefficients of interest, non-parametrically trace out the probability of a settlement forming around the time of the reform. Hence, it captures the average difference in the probability of a cell containing a settlement relative to the omitted year for a one-unit change in shipping costs. $\epsilon_{i(a,t)}$ is again clustered at the level of the port. This specification is also useful for assessing the validity of the research design. In the absence of pre-trends, the coefficients preceding the reform will be zero.[40]

Cross-sectional Design. Finally, the long-run effects are estimated. In essence, the specification compares patterns of regional development between localities with different treatment intensity, i.e larger reductions in shipping times as a result of the reform. To this end, contemporary population density is treated as the main outcome. The following equation is estimated,

$$y_{i(a,c)} = \alpha_a + \gamma_c + \beta\Delta T_i + \lambda X'_i + \epsilon_i, \tag{9}$$

where $y_{i(a,c)}$ denotes population density in year 2000 and X'_i a vector of control variables. The vector includes the distance to the closest port in 1750, the distance to the coastline for each grid-cell as well as the population size in 1750. Standard errors are again clustered at the port-level in the main specifications.[41] The interpretation of the coefficient rests on changes in shipping times to be independent of counterfactual long-run outcomes.[42] This is naturally a stronger assumption than required for the specifications relying on exogenous timing. I therefore provide several exercises that support the identifying assumptions below.[43] Finally, because several of the variables in the analysis exhibit fat-tailed distributions which sometimes include 0, I transform variables using the inverse hyperbolic sine function. This allows me to interpret coefficients as approximately percentage changes (Card and DellaVigna, 2020).

[40] An added benefit of the specification is that it avoids the bias induced by using early-treated units as controls and time-varying treatment effects in the two-way fixed-effects model (Goodman-Bacon, 2018).

[41] Recent studies have shown the difficulty of conducting statistical inference with spatially correlated data. To address this concern, I report Conley standard errors in the tables and explicitly test and report Moran's I test statistics for all the specifications (Conley, 1999).

[42] More formally, the identification assumption is $y_{k,i} \perp\!\!\!\perp k_i | X_i$ where $k_i = \Delta T_i$ and X_i is a vector of observable control variables.

[43] Table A10 presents several placebo-checks showing that the change in maritime remoteness is only related to the population after the opening of trade, and not before, also in the cross-section. Second, I calculate the bias-adjusted estimates in line with Altonji, Elder and Taber (2005) and Oster (2019) to show that a very strong selection on unobservable characteristics is necessary to explain the estimated coefficients for most of the specifications.

5.2 Results

The results are presented in three parts. First, I summarize the main results showing the impact of market access on the formation of new settlements and population growth. Second, I discuss several robustness checks. Finally, present evidence on the mechanisms.

5.2.1 Shipping Times, Market Access, and Settlements

Table 3 and Figure 5 show the strong first-stage relationship between shipping times to Europe and market access. Figure 4 shows that a one percent increase in the shipping time reduces market access by around 5 percentage points ($\beta = -5.061$ in the preferred specification). Column (1) shows the most parsimonious specification, only controlling for year and *audiencia* fixed-effects. In light of the large geographical area, different places are likely to experience different shocks. Columns (2) addresses this by controlling for viceroyalty times decade fixed-effects. This absorbs all time-variant shocks common to the viceroyalty. Different development trajectories within viceroyalties can still give rise to differences in the formation of settlements unrelated to changes in shipping times. As a result, the controls interacted with decade effects are included in Columns (3) and (4), absorbing time-variant effects of geographical fundamentals. Finally, Column (5) controls at the level of the closest port which I refer to as the port's catchment area. This specification includes catchment area as well as catchment area times decade fixed effects.

Table 3 shows the relationship between market access, shipping times, and the formation of new settlements. Panel A presents the IV-estimates for the coefficient β in Equation 7, Panel B the reduced form, and Panel C the corresponding OLS estimates. In the preferred specification, Column (4), I find that a 100 percent increase in market access increases the probability of a settlement forming by around 4 percentage points ($\beta = 0.039$). The IV-estimates are smaller than the corresponding OLS estimate in Panel C ($\beta = 0.056$). This suggests that positive biases from omitted variables or reverse causality are more relevant than attenuation bias in this context. The estimated parameters are stable across the different specifications, ranging from 0.048 to 0.039. A weak first-stage will bias the estimates towards the OLS estimates. However, there is a strong first stage in all the specifications as can be seen in Table 4, ($F = 35$ in the preferred specification).[44] Finally, Table 5 shows the effect on population growth. These estimates mirror the ones for city formation, a one percent increase in market access, increases the population size by around 0.2 percent in the preferred specification ($\beta = 0.245$). The next sections examine the timing of the average effect as well as effect heterogeneity.

5.2.2 Timing of the Effect

This section looks closer at the timing of the effects in Table 3. The identification assumption in the reduced form is that other things equal, the formation of new settlements would have happened at an equal rate in areas with different reductions in shipping costs in the absence of the reform. This assumption is more compelling if the change in the formation of new settlements is the same in these localities before the reform. Moreover, to understand the long-run effect, the adjustment dynamics after the reform are considered by estimating the event-study specification in Equation 8.

[44] To account for clustering I report the effective F-statistic (Olea and Pflueger, 2013)

Table 3: Shipping Time, Market Access, and Settlements

Dependent variable:	Indicator variable for grid-cell containing a settlement				
	(1)	(2)	(3)	(4)	(5)
Panel A: IV					
Market Access (log)	0.048^{***}	0.050^{***}	0.043^{***}	0.039^{***}	0.051^{***}
	(0.015)	(0.016)	(0.014)	(0.012)	(0.0089)
Panel B: Reduced-form					
Shipping Time (log)	-0.215^{***}	-0.254^{***}	-0.216^{***}	-0.200^{***}	-0.41^{***}
	(0.066)	(0.088)	(0.076)	(0.058)	(0.071)
Panel C: OLS					
Market Access (log)	0.054^{***}	0.054^{***}	0.054^{***}	0.048^{***}	0.056^{***}
	(0.008)	(0.009)	(0.009)	(0.008)	(0.006)
First stage F-statistic	121.51	126.13	172.06	35.06	129.12
Viceroyalty × Decade FE		✓			
Audiencia × Decade FE			✓	✓	
Controls				✓	✓
Port catchment FE					✓
Port catchment × Decade FE					✓
Observations	73,282	73,282	73,282	73,282	73,282

Note: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **Dependent variable:** An indicator variable taking the value 1 if the grid-cell contains a settlement. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The full dataset contains **11 × 6,662 = 73,282 observations**. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain *audiencia* fixed-effects. **First-stage F-statistic:** Accounts clustering following Olea and Pflueger (2013). **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Figure 7 shows the estimated coefficients using the baseline specification (decade × *audiencia* fixed effects, *audiencia* fixed effects, and geographical as well as agroclimatic controls). The plotted coefficients give the estimated difference between exposed and unexposed localities in year j relative to 1760, which is the last year prior to the reform. The right-panel shows the impact of exposure to the reform on the formation of new settlements. Consistent with the identification assumption, there is no significant difference in the change of settlement in areas with high or low exposure to the reform prior to the reform.[45] After the reform, the difference is increasing relative to 1760. Areas with a 100 percent higher reduction in shipping time to Europe have a 0.5 percentage point higher probability of having a city than in 1760 ($\tau_{1790} = 0.005$). The effect is precisely estimated and an effect size of zero can be rejected at conventional levels by 1800. The left panel shows the corresponding estimates for market access. This effect also coincides with the reform. A 100 percent reduction in the shipping time to Europe increases market access by 0.04 percent relative to 1760 ($\tau_{1790} = 0.04$).

Table 6 summarizes several alternative approaches to get these estimates. The table shows the estimated coefficients for different specifications. Column (1) presents the estimate only including time fixed-effects. Column (2) adds grid-cell fixed-effects to control for differences in levels between areas with different treatment intensity. To control for different trends in areas differentially affected by the

[45] I also conduct a formal test of the joint significance as well. In all specifications, the hypothesis that the pre-trend coefficients are zero cannot be rejected.

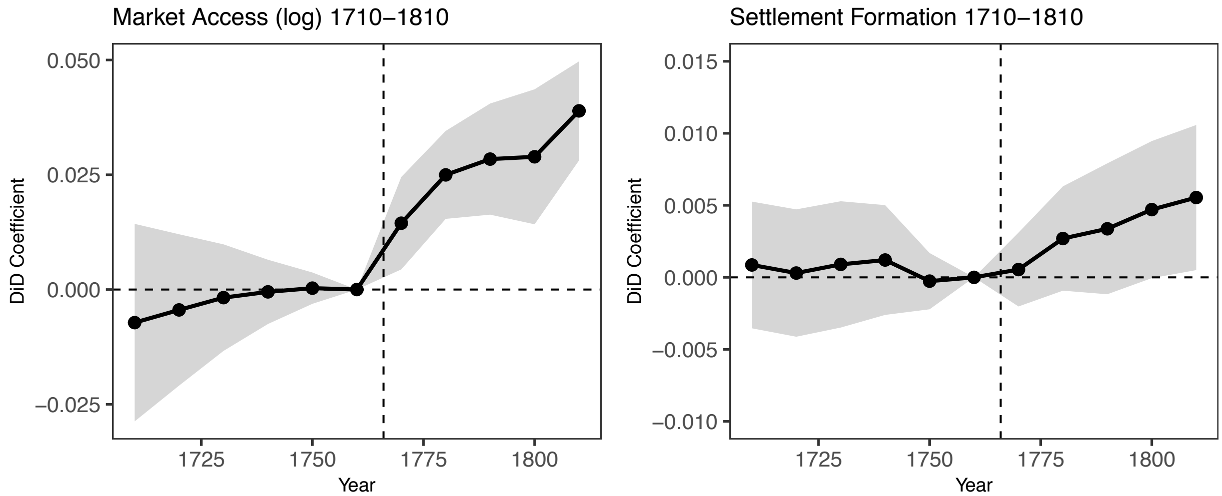

Figure 6: The figure shows the estimated coefficients of the difference in the formation of settlements and market access in grid-cells according to the reduction in shipping times to Europe. **Dependent variable left figure:** Market access (log) with $\zeta = -4$. **Dependent variable right figure:** An indicator-variable taking the value one if the grid-cell contains a settlement **Observations:** The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. The dataset is a balanced panel at a 10-year frequency for the period 1710-1810 for 6,662 grid cells. 1760 is the omitted year. The full dataset thus contains 10 × 6,662 = 66,620 observations. **Controls:** The specification includes *audiencia* as well as *audiencia* times decade fixed-effects. The geographical controls contain elevation, crop suitability, the location of active mines, (log) distance to the coastline, and terrain ruggedness. **Standard errors:** Clustered at the port-level.

reform, Column (3) includes *audiencia* × decade fixed-effects. Column (4) interacts the post-dummy variable with geographical controls. Column (5) adds various agro-climatic controls to the specification, for the same reasons. Finally, Figure 17 displays the coefficients from specifications where the leads and lags of the main explanatory variables are included. Consistent with the identifying assumption there is no relationship between the lead and the outcome. Taken together, these exercises provide support for the identifying assumption.

5.2.3 Heterogeneity

Cores and Peripheries. The average effects documented in Table 3 potentially mask important heterogeneity. Exploring the effect heterogeneity may suggest which mechanisms that are driving the main findings. Redding and Sturm (2008) and Baum-Snow et al. (2018) find that the effect of market access on population density depends on the initial population distribution. To assess this, I study heterogeneity by the initial level of development as well as population density in 1750. I divide the sample into a core, semi-periphery, and periphery.[46] The core constitutes the most developed and densely populated areas under the Habsburgs and early Bourbon colonial regimes. The core region is denoted the *Audiencia* of Lima as well as the *Audiencia* of Mexico. The periphery is all *audiencias* that were sparsely populated at the time of the reform. The semiperiphery contains all *audiencias* with intermediate levels of population density. I estimate the baseline specification separately for these different areas.

The results can be seen in Table 8. The first column estimates the baseline specification with *audiencia* × decade fixed effects, while the second column adds the main set of controls used in the analysis. The

[46] The core denotes the *audiencias* of Charcas, Lima, and Mexico (1,009 cells $\times 11 = 11,099$ observations), the periphery the *audiencias* of Buenos Aires, Santiago, Caracas, (1,284 cells $\times 11 = 14,124$ observations) and the semiperiphery Quito, Santa Fe, Confines, Santo Domingo, Guadalajara, Cuzco (1,534 cells $\times 11 = 16,874$ observations). 2,835 cells do not pertain to an *audiencia*.

estimated effect in the core is somewhat mixed. There is a negative effect estimated for the core areas. However, part of the effect can be attributed to differences captured by the controls. When adding these controls there is no statistically significant impact. The semi-periphery shows larger effects than the core. The largest effects are found in the peripheral areas. A ten percent increase in market access increases the probability of a settlement with 1.3 percentage points in the periphery. Taken together, these results show that the effect is mainly driven by the periphery.

A possible interpretation of this pattern is that it is driven by congestion costs. If congestion costs are high in this context, then growth in large cities will react less to changes in market access. However, Figure 13 shows that population density was increasing for all cells on average which is not consistent with large congestion costs. An alternative interpretation is that it is driven by a non-linear impact of changes in trade costs. If a marginal increase in trade costs has a larger effect for large changes this could potentially explain the discrepancy between the different samples since they also differ in the size of the shock. However, controlling for non-linearities and considering different subsamples gives very similar results. Finally, since I consider the effect of market access, the effect of lower distance does not depend on interactions with the local market size. Taken together, the effect is therefore more consistent with the mediating factor being initial population density.

Coasts and Hinterlands. With few navigable rivers, transportation mainly relied on mule and ox-carts at least until the second half of the 19th century. This prevented the production of export commodities, except for commodities with very high value to weight ratio such as bullion, from taking place outside of the coastal areas. The main effect of increased access to international trading opportunities should be concentrated in coastal areas. To assess this, I split the sample into a coastal area (cells within 100km of the coastline) and a hinterland (above 100km from the coastline).[47] The results from this exercise can be seen in Panel C and Panel D of Table 8. In the preferred specification a hundred percent increase in market access increases the probability of city formation by nine percentage points ($\beta = 0.090$). This is significantly higher than in the hinterland where the corresponding estimate is around a third ($\beta = 0.030$). These results are therefore supportive of the effect being stronger in coastal areas.

5.2.4 Variation in Spatial Persistence

So far the findings show that the reform increased various measures of density. This effect was particularly strong in locations that were initially less densely settled. Did the reconfiguration of the urban system documented above result in lower spatial persistence? To examine this question, I match data on pre-colonial population density with the data on shipping times.[48] I define spatial persistence here as how correlated pre-colonial population density is with the population density in 2000. To examine the relationship between the reform and spatial persistence, I split the sample into whether the province has a high or low exposure to the reform as measured by above or below change in shipping times to Europe in the period 1760 and 1810.

Figure 7 shows the relationship between pre-colonial population density and the current population for the different samples. To left figure shows the correlation for all regions in the study-region. There is a strong positive relationship within country between pre-colonial population density and population

[47]This corresponds to around two days of travel on the calculated cost raster.

[48]Data on pre-colonial population density is from Maloney and Valencia (2016) and Bruhn and Gallego (2011).

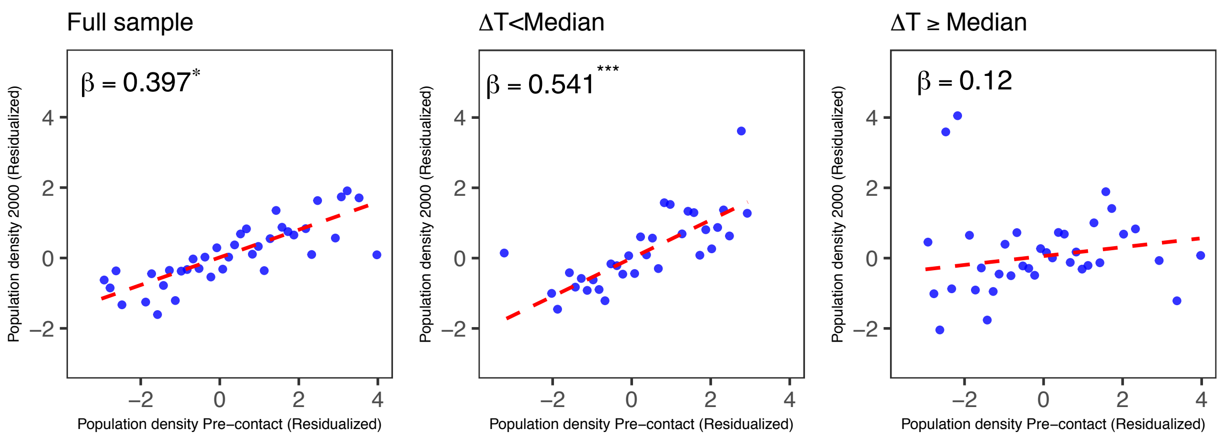

Figure 7: The figure shows the relationship between pre-contact population density and the population density in year 2000 at the level of the province. The left figure shows the relationship for the full sample. The middle figure shows the relationship for provinces with below median change in the distance to Europe between 1760 and 1810. The right figure shows the relationship for the sample above median reduction in shipping time to Europe between 1760 and 1810. Pre-colonial population density is the number of indigenous people per square kilometre before the arrival of Columbus from Maloney and Valencia (2016). The dependent variable is the log of people per square km in 2000. The full sample contains 258 observations. **Geographical controls:** Altitude, ruggedness, rainfall, and inverse distance to the coast (see Maloney and Valencia (2016) for details). **Standard errors** are clustered at the country-level.

density in 2000. Hence, the relationship documented in Maloney and Valencia (2016) also holds for the subsample of regions located in the area claimed by the Spanish Empire in 1790. The plot in the middle shows the relationship between the two variables for the sample of provinces that experienced low changes in shipping costs after the reform. The figure shows that persistence is more pronounced for this subsample. Finally, the figure to the right shows the relationship to be weak in the subsample of provinces that experienced large changes due to the reform. Table 9 documents that this pattern is robust across several specifications. Taken together, these exercises show that spatial persistence is substantially weaker in areas that experienced changes in trade costs due to the reform.

Why is the spatial persistence so much lower in areas more intensively treated by the reform? Consistent with the results in Section 5.2.1, I find that these areas are substantially more concentrated in coastal areas today. Table 10 uses the same approach to compare the differences in coastal access for areas more or less intensively treated by the reform. Taken together, this table shows that the distribution of the population is more spatially clustered in coastal areas for places more intensively treated by the reform. I further analyze this relationship in Table 11. This table shows that coastal population density is higher in areas that experienced a higher exposure to the reform. The difference in population density between coasts and hinterland is higher for places more exposed to the reform. Moreover, cells with higher exposure to the reform are also more likely to contain a coastal city in 2000.[49] In sum, the results from Table 10 and Table 11 support the interpretation that the reform increased the population in coastal areas.

Taken together, the reduced-form results point towards the timing of sequence with which a region reaches high levels of population density and opens up to trade to be an important factor in determining

[49] This is estimated using Equation 7 as a linear probability model (LPM). While it prevents a structural interpretation of the coefficients, it approximates the conditional expectation function and hence provides a simple approximation of the marginal effects of interest (Angrist and Pischke, 2008).

the long-run spatial distribution of economic activity. I find that places that reached a high population density early, were less responsive to changes in the trading environment. The economic geography in these places reflects locational fundamentals important for trade to a lesser extent, as can be seen from the lower coastal concentration in these areas. On the other hand, the geography in places that had low population density was much more sensitive to changes in trade costs. The geography in these places became more dictated by locational fundamentals associated with long-distance maritime trade. As a result, history and spatial persistence matter less as a determinant for economic geography in late-developing places in the Americas.

5.3 Robustness

Both the long-run and medium-run effects are robust to samples used in estimation and to concerns about endogeneity. I summarize the robustness exercises below.

Other Policy Changes. The main assumptions underlying a causal interpretation of the estimated effects are similar trends in the absence of the reform. Moreover, it is assumed no other changes happening at the same time that affect the units in similar ways. One potential concern is the effect of a territorial reorganization that was implemented in the 18th century. The Viceroyalty of *Rio de la Plata* was separated from the Viceroyalty of Peru in the second half of the 18th century. It remains a possibility that this induced economic growth to be reoriented towards Buenos Aires in a way that was correlated with the reduction in travel times. To investigate this possibility, I conduct two exercises. First, I drop all grid-cells in the Viceroyalty of *Rio de la Plata*. The estimated coefficients are very similar. Second, I exploit the fact that the viceroyalty of *Nueva Granada* with the capital in Bogota separated from the Viceroyalty of Peru already in 1717. I do not find evidence that this reform affected settlement patterns in a similar as the change in trade costs. Taken together, these two pieces of evidence are not supportive of the notion of territorial reorganization driving the main results. Next, I collect data on the formation of intendancies between 1750 and 1800. I control for explicitly in the regression and find that they do not explain any of the main effects. Finally, I consider the formation of new merchant guilds during this period. I control for these in the same manner and find the effects remain unchanged.

Assessing Spatial Autocorrelation. Kelly (2019, 2020) shows that in the studies spatially correlated treatment variables, p-values of statistical tests can be biased downward. Moreover, the issue is not remedied by traditional methods such as Conley standard errors or clustering methods. To explore whether the results in Section 5 suffer from this, I conduct two exercises. I first test for spatial correlation of the residuals in the baseline specification.[50] Second, I estimate the effect in placebo regressions using randomly-generated spatially-autocorrelated noise instead of the explanatory variable. I do this under different assumptions on the strength of autocorrelation. Taken together, these exercises provide some evidence that the residuals in the regressions presented in Section 5.2.4 exhibit spatial autocorrelation. To remedy this, I use the covariance matrix estimator suggested in Kelly (2020). This approach corrects for spatial correlation by making parametric assumptions about the distribution and spatial dependence of the residuals. As shown in that paper, how well this functional form assumption captures the structure

[50]This is done both using the distribution under the null derived from the analytical approach as well the distribution under the null using Monte-Carlo simulation.

of the residual is testable by looking at the correlation between the residuals implied by the model and the residuals backed out from the regression.

Varying the Cell Size. So far, specifications use administrative borders of *audiencias* and viceroyalties to control for unobserved geographical heterogeneity. However, there might be unobserved variables that are clustered in a way not captured by these borders. I address this in two ways. First, I use viceroyalty and *audiencia* borders between 1710 and 1750 as additional controls. Second, I use virtual country fixed-effects to account for other sources of unobserved regional heterogeneity. Taken together, the estimated effects are robust to these exercises. This suggests that the geographical controls in the main specification capture time-varying geographical heterogeneity well. Next, I assess the robustness of the results to choosing different grid-cell sizes. The choice of grid-cell size has been shown to have sizeable effects on point estimates (Briant, Combes and Lafourcade, 2010). I construct two additional datasets with different resolutions and re-estimate the main effects in Table 3. While reducing the resolution naturally lowers the precision, the point estimates remain economically and statistically significant.

Changes in Maritime Technology. It is unlikely that the changes in shipping times are correlated with changes in maritime technology for at least four reasons. First, the consensus among economic historians has been that maritime technology remained fairly stagnant between the 16th and 19th centuries and the introduction of the steamship (North, 1968; Harley, 1988). These studies have largely been based on voyage durations and freight rates. A notable exception is Kelly and Ó Gráda (2019). As pointed out in this paper, the absence of growth in maritime technology in this period is surprising given historical scholarship maritime inventions such as iron-reinforced hulls, copper sheathing, and the marine chronometer. Also using data from García-Herrera et al. (2005), they find evidence that sailing speeds for British East India Company and the British Navy increased from around 1770. However, they find no increases in sailing speeds for Spanish ships, which stood for the largest share of legal trade with Spanish America during this period. Third, the increase is gradual and hence does not coincide with the timing of the changes in trade volumes shown in Table 2. Finally, it is unlikely that general increases in maritime productivity should differentially impact ports by their change in trading status during this period. As a result, it seems implausible that the effects capture changes in maritime technology rather than changes in the regulation of trade. As a result, any potential secular changes in trade costs are likely to be captured by the *audiencia*$\times$ decade fixed-effects. I also assess the role of secular changes in trade costs induced by changes in maritime technology further using the quantitative model in the next section.

5.4 Mechanisms

So far, the findings point towards a strong relationship between changes in shipping time and the formation of new settlements. This section explores the mechanisms. First, I consider the role of lower shipping times creating export opportunities for high-value agricultural commodities. In turn, this could have promoted the formation of settlements to manage increased population density or as intermediating long-distance trade in new commodities. Second, I therefore look at the effect on population density and urbanization. Third, I consider the role of transshipment versus the opening of new trade routes. Finally, I look at the effect of the reform on the slave trade and whether increased market access promoted frontier expansion which in turn lead to the formation of new settlements.

Spanish Trade Volumes. I first look at the relationship between changes in travel times and trade with Spain using data on trade between Spain and American ports from 1797-1820 from Fisher (1993). Table 12 shows that reductions in shipping times increased the trade volume with Spain. The explanatory variable is the change in shipping time between 1760 and 1810. The dependent variable is the share of Spanish exports to 19 American ports. Column (1) shows the baseline results without any controls. Column (2) includes the geodesic distance to Europe (Cadiz) as control while Column (3) adds viceroyalty fixed-effects. Column (4) combines the two controls while Column (5) adds the longitude and latitude as additional controls. In sum, there is a robust relationship between shipping times and increases in the export share from Spain 1800-1820. A one-unit reduction in ΔT increases the trade share by around 10 percentage points. Hence, if the distance to Europe is reduced to half, this increases the trade share with around 8 percentage points. The estimates are stable when gradually adding control variables, although precision is lost when adding the full set of controls in Column (5). Taken together, the results are consistent with the reform increasing Atlantic trade. Ports with larger reductions in remoteness increase their trade shares more.

Commodity Prices. If the reform increased trade volumes, this can be expected to have led to lower prices where these commodities traded, at least in the short-run. In this section, I consider the prices of commodities produced in the Spanish empire. Posthumus (1946) and Jacks, O'Rourke and Williamson (2011) provide monthly price data on 49 commodities traded in Amsterdam between 1750 and 1800. Out of these 49, three commodities were important agricultural exports in the Spanish Empire. These were sugar, tobacco, and cocoa.[51] I consider if the prices of these commodities dropped more relative to the others after 1778 which was the year most ports were liberalized. Consider the following specification,

$$Price_{c(t)} = \alpha_c + \beta \text{America}_c \times \text{Post}_t + \phi \text{War}_t \times \text{America}_c + \epsilon_{c(t)}, \tag{10}$$

where $Price_{c(t)}$ measures the price level of commodity c in year t (in guilders), $America_c$ is a dummy for American export commodities, $Post_t$ is a dummy variable taking the value one after 1778, and $\epsilon_{c(t)}$ is an error term. To account for disruptions of Atlantic trade induced by naval conflicts, $America_c$ is interacted with the indicator variable War_t. The variable equals one for years in which Atlantic maritime powers were among the belligerents (Seven Years' War, American Revolutionary War, and the French Revolutionary War). The standard errors are clustered at the commodity-level to account for time-varying volatility, as documented in Jacks, O'Rourke and Williamson (2011). Table 13 shows the results. For all the specifications there is a negative estimate of the interaction between $America_c \times Post_t$, suggesting the reform induced higher quantities of these traded commodities. Column (4) shows the effect is robust to controlling for a differential impact of disruption of Atlantic trade for the different commodities. In sum, both the increase in trade volumes and price reductions are consistent with the reform spurring increased trade within the Spanish Empire.

The Role of Export Crop Suitability. If increased export opportunities were important in driving the observed effects, one would expect the effects to be stronger in areas suitable for the production of agricultural exports. To assess this, I use measures of crop suitability from FAO. In particular, the suitability for cacao, sugarcane, cotton, and tobacco is averaged by the grid-cell level. These commodities

[51] In a robustness check I include commodities that were produced elsewhere, but that were close substitutes of commodities produced in Spanish America (indigo and cotton). I find similar effects when including these commodities in the regression.

constitute 27.3 of exports from Spanish America between 1782 and 1796. If new settlements formed as a result of new commercial opportunities, presumably the effect is stronger in areas with higher agroclimatic suitability for export agriculture. Table 14 presents the results. The average agroclimatic suitability is interacted with the change in the distance to Europe. The estimates in Table 14 support the notion that agroclimatic suitability is an important mediating factor. Across all the specifications longer shipping times to Europe are associated with a lower probability of a grid-cell containing a settlement. This effect is significantly smaller in localities with higher suitability for export agriculture.

The slave trade. The above results suggest increased importance of high-value agricultural exports. This section considers if this stimulated increased demand for slaves. Did the slave trade contribute to increased population growth in places with increased market access? To investigate this, I use data from Eltis (2018). This database contains 36,000 trans-Atlantic voyages which make up around 80 percent of voyages disembarking captives in the Americas. In the database there are 71 ports in Spanish America that took part in the slave trade.[52] For each port, I count the number of ships with the port as a first destination.

Figure 19 shows the time-variation in the number of ships disembarking captives at Spanish ports from 1710 to 1810. The time-variation in the number of arriving ships for Spanish ports tracks the reform for both the trans-Atlantic and intra-American slave trades. The exercise is repeated with the North American and Brazilian ports, which do not display such a pattern. This provides suggestive evidence that the reform increased the demand for slave labor in Spanish America. To assess this more in detail, the number of ships arriving at each port is aggregated by year and the differential across ports affected by the reform is estimated. To do this, I calculate the shipping time to Europe for each slave port by decade between 1710 and 1810. This will capture how intensively a given region is treated by the opening in the trade of goods. Table 15 displays the results. The first column contains only controls for decade fixed-effects, while Column (2) and (3) also include port fixed effects. Column (3) also controls for port level linear time-trends. While the relationship between the trade reform and the number of arrivals from the trans-Atlantic slave trade is mixed, there is a negative relationship between arrivals from the intra-American slave trade and shipping times to Europe. The estimates suggest that places that reduced their shipping times to Europe more had more arrivals of slave ships, which is consistent with the increased importance of high-value agricultural commodity exports.

Urbanization and Population Density. Next, I analyze if urbanization and increased population density is a factor promoting the formation of cities and towns. To explore this, I use two data sources. First, I use spatially disaggregated data on the size of the urban population and population density (Klein Goldewijk et al., 2011). The data is averaged at the grid-cell level and included as the dependent variable in the baseline specification. Second, I use information on the city population from Buringh (2013) which contains the population size for the largest cities in the Spanish Empire. A city is included in the database

[52]These were Samana Monte Christi, Santo Domingo, Ocoa, Nizao, Puerto de Plata, Isla Saona, San Juan, Ponce, Bahia Honda, Banes, Cabanas, Caibarien, Canasi, Cardenas, Cienfuegos, Estuary of River Guane, Guanimar, Havana, Isla de Pinas, Manzanillo, Mariel, Matanzas, Nuevitas, Puerto Padre, Sagua, San Juan de los Remedios, Santiago de Cuba, Trinidad de Cuba, Batabano, Baracoa, Punta Macurijes, Puerto Principe, Holguin, St. Andreas, Campeche, Veracruz, Guatemala, Santo Tomas, Portobelo, Cartagena, Santa Marta, Borburata, Caracas, Cumana, La Guaira, Margarita, Orinoko, Rio de la Hacha, Darien, Nombre de Dios, Rattan, Puerto Cabello, Isla de Aves, Coro, Maracaibo, Nueva Barcelona, Guayana, Tucacas, Caye de San Juan, Trujillo, Buenos Aires, Montevideo, Colonia de Sacramento, Maldonado, Rio Negro, Ensenada de Barragain, Punta del Este, Lima, Valparaiso, Talcahuano.

when it has more than 4,000 inhabitants. I restrict the dataset to cities for which there is data on the population in 1750. This constitutes 211 cities which are observed in 1750 and 1800.

The main results of this exercise are presented in Table 16. Panel A shows the relationship between market access and population density. The point estimates are economically and statistically significant. Across the different specifications, a one percent increase in market access increases the population density between 0.6 and 0.7 percent. Panel B shows the corresponding estimates for the size of the urban population. The estimates are smaller and somewhat less precise. A one percent increase in market access increases the population designated as urban by between 0.11 and 0.16 percent. Finally, I look at the corresponding estimates for the city size of the 211 cities. Since the sample is significantly smaller, the first stage is weak (between 0.3 and 1). Therefore, I only provide the reduced form estimates. Due to the smaller sample size, the estimates are less precise. The point estimates suggest a one percent increase in the shipping time to Europe, reduces the city size by around 0.8 percent over the 1750 to 1800 period. Including grid-cell fixed effects tends to increase the precision of the estimates coefficients. Taken together, these estimates are consistent with trade induced population growth and urbanization driving the formation of new settlements.

Rerouting and Transshipment. The opening of ports to direct trade with Europe could affect the trade costs of a locality in two ways. First, in some cases, the fastest route changed because shipment no longer needed to be channeled through other ports. This would reduce the travel time directly and be particularly be the case for places on the Caribbean and Atlantic seaboard. Second, transshipment could be costly in and of itself, due to various taxes and rents. This could induce gains of port openings that work beyond reductions in shipping times. This would particularly be the case for localities located on the Pacific seaboard.

To investigate which of these two effects dominates, the sample is split into localities for which the shortest path to Europe changed and not. This captures areas that gained from the reform due to less transshipment and the areas that gained from faster sailing. The results can be seen in Table 17. The table shows that the largest effect is found for localities that experience changes in routes. For places that only saved in transshipment costs the effect is small and imprecise. Taken together, the findings in this section point to the effect being driven by the establishment of new trade routes, but that less transshipment also mattered.

Frontier expansion. During the second half of the 18th century, Spanish policymakers promoted the formation of *presidios* and missions in frontier areas (Parry, 1990). Table 8 shows that the effect of increased market access was larger in the peripheral locations of the Spanish Empire. Did increases in market access promote town and city formation through facilitating settlement in frontier areas? To investigate this, I contrast the effect of reductions in shipping costs in areas with low vs. high state presence. Two approaches are taken to proxy for state-presence. First, similar to Acemoglu, García-Jimeno and Robinson (2015) I use the distance to infrastructure as a proxy. In particular, I use a dataset on around 900 post offices in Spanish America in the 18th century. Second, the level of state presence is assumed to be lower in areas outside *audiencia* borders. These different approaches delineate roughly similar areas. The estimated effects are presented in Table 18. Taken together, it shows city formation was more responsive to changes in shipping times and market access in areas with *more* state presence. While there is a larger effect of market access in places with less colonial presence, having at least some state capacity seems important for increases in market access to translate into increased population growth.

6 The General Equilibrium Effect of the Reform

To further explore mechanisms, account for general equilibrium effects, and conduct counterfactual exercises I build and calibrate a spatial general equilibrium model. The model builds on Allen and Donaldson (2020) but adapts the model to the setting in two ways. First, since the economies considered are pre-industrial I include land as a factor of production. Second, to model the reform I consider time-varying trade costs and migration costs. This allows me to study the forces shaping this spatial reallocation in greater detail.

6.1 Theoretical Framework

Geography. The geography of the framework is defined on a finite grid. The R localities (indexed by i) have some geographical surface of similar size and the population is concentrated at the center of the cell where all consumption and production happens. This geography can be represented by a graph of edges (shipping time) and vertices (settlements). Each grid-cell is connected to the adjacent cells in a network through costly trade and migration. Furthermore, each location has fundamental productivity $\bar{A}_i$ which determines the total factor productivity in location i, and each location also has an amenity value of $\bar{u}_i$ which governs the utility associated with settling in locality i. Europe is modeled as a point-like country centered on Cadiz and containing the population mass of Western Europe for each decade. Moreover, I assume that the amenity and productivity is the average of the sample.

Timing. The timing of the model follows an overlapping generation (OLG) structure. Each period is inhabited by agents who are either young or old. Every agent lives for two periods. Adults supply labor inelastically and consume. Every adult in the economy receives one child, then dies and leaves the model. Young agents in the economy do not supply labor or consume. However, they do make decisions on where to live as adults and move there. In the model, each period is assumed to represent 50 years. This structure greatly simplifies the problem as the equilibrium in each period can be solved separately.

Consumption. The demand side of the model consists of three parts. First, preferences are defined over a set of differentiated varieties, such that each location can produce one variety specific to the location.

$$U_{it} = u_{it} \sum_{j \in R} \left(q_{jit}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{11}$$

where $\sigma > 1$ is the constant elasticity of substitution across varieties. The consumer is assumed to maximize utility and P_{it} is the consumption goods price index. Second, the utility of a representative agent in region $i \in R$ depends on the local amenity value as well as spillovers. In particular,

$$u_{it} = \bar{u}_i L_{it}^{\beta_1} L_{it-1}^{\beta_1}, \tag{12}$$

where L_t denotes the labor force in region i in decade t, and β_1 and β_2 denote the strength of contemporaneous and past amenity spillovers respectively. $\bar{u}_i$ is an exogenous demand shifter that is specific to each location but assumed to be time-invariant. The strength of the contemporaneous spillover, determined by β_1, captures such features as costs related to congestion, while the lagged spillover, determined by β_2 could capture the housing stock or other persistent amenities. Finally, the utility of a worker in location i depends on a draw of a vector ϵ_i from a Fréchet distribution with shape parameter θ which determines the spread of preferences across all the other localities.

Production. Production in each region is characterized by perfect competition with constant returns to scale technology with labor and land as inputs. Each period, firms maximize profits taking wages, prices, productivity, as well as the supply of labor and land available in each locality as given. In each locality, a continuum of firms indexed by ω produce a good with a Cobb-Douglas production function.

$$q_{it}(\omega) = \bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2} l_{it}(\omega)^{\mu} h(\omega)_i^{1-\mu} \tag{13}$$

where $l_{it}(\omega)$ denotes the amount of labor used by ω, $h_i(\omega)$ the amount of land, $\bar{A}_i$ an exogenous productivity shifter, and L_{it} the total population in region i at time t. α_1 and α_2 denote the strength of contemporaneous and historical agglomeration spillovers respectively. Each period the markets for land and labor clear, hence $\int l_{it}(\omega)d\omega = L_{it}$ and $\int h_i(\omega)d\omega = H_i$. Moreover, since there is perfect competition, $p_{it} = w_{it}/A_{it}\mu l_{it}(\omega)^{\mu-1}h_i(\omega)^{1-\mu}$. While the production technology rules out increasing returns at the level of the firm, the agglomeration spillovers as captured by α_1 and α_2 opens for the possibility of dynamic increasing returns and therefore persistence at the level of the region as a whole. The contemporanous increasing returns could reflect increasing returns at the level of the firm, knowledge spillovers, labour market pooling, or input sharing. While the lagged returns could reflect factors such as fixed capital.

Land. The market for land is competitive such that the price of land equals its marginal product in each locality. That trade is balanced in each locality and the assumption that income from land is allocated lump-sum to all inhabitants implies that the following relationship between income in locality i, income from land ($(1-\mu)L_{it}v_{it}$), and from labor ($L_{it}w_{it}$) holds,

$$v_{it}L_{it} = (1-\mu)L_{it}v_{it} + L_{it}w_{it} = \frac{L_{it}w_{it}}{\mu}, \tag{14}$$

where v_{it} is the per capita income in locality i at time t.

Trade. The framework described above is amenable to incorporating both international and intra-national trade. Trade costs between region i and j are time-varying and take the iceberg form. For one unit q_{ijt} to arrive in j at time t, τ_{ijt} units of the good need to be shipped ($\tau_{iit} = 1$). Using the expenditure function, the demand function for $q_{ij,t}$, and the competitive price gives the following gravity relationship for the trade-flow between i and j at time t,

$$X_{ijt} = \frac{1}{\mu}\tau_{ijt}^{1-\sigma}\left(\frac{w_{it}}{\mu A_{it} L_{it}^{\mu-1} H_i^{1-\mu}}\right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{15}$$

The equation shows that trade between i and j increases with lower prices in i, lower trade costs between localities, and higher income in j. Proofs of existence and uniqueness of the equilibrium depend on symmetric bilateral transportation costs (but not migration costs).[53]

Migration. The young at time $t-1$ choose a location in t in order to maximize expected utility. The utility of a particular location depends on the deterministic utility V_{it} which depends on the real wage of the locality in addition to the utility derived from local amenities as captured by u_i. In addition, there is an idiosyncratic component to preferences, ϵ_{it}, which enters multiplicatively and is assumed to be independent draws from a Fréchet-distribution with shape parameter θ. Migration costs between two locations i and j are assumed to be time-invariant, and given by μ_{ij}. The utility of a young individual moving from location i to j is therefore given by the following expression,

$$V_{ijt} = \frac{V_{jt}}{\mu_{ij}} \times \epsilon_{ijt}. \tag{16}$$

Each agent chooses the location that maximizes utility when young, hence $V_{it} = \max_{k \in R}\{V_{ikt}\}$. Using the properties of the Fréchet-distribution and the fact that the ϵ_{ijt} are independent draws, the expected utility of a young person before he knows the realization of the shock is given by,

$$\mathbb{E}\left[V_{it}\right] = \left(\sum_{i \in R}\left(\frac{V_{jt}}{\mu_{ij}}\right)^{\theta}\right)^{\frac{1}{\theta}}. \tag{17}$$

This gives the following gravity relationship of migration flows between i and j,

$$L_{ijt} = \mu_{ij}^{-\theta}\Pi_{it}^{-\theta}L_{it-1}V_{jt}^{\theta}, \tag{18}$$

where Π_{it} is the expected utility if for people born in region i. This equation gives the law of motion of population flows in the model.

General equilibrium and steady-State. A geography is made up of local fundamentals ($\bar{A}_i$ and $\bar{u}_i$), trade costs ($\boldsymbol{\tau}_{it}$), migration costs ($\boldsymbol{\mu}_i$), allocation of land H_i, and past population distribution L_{i0} for all locations R. Given a geography, an equilibrium is defined as a sequence of the endogenous variables such that all markets clear in each period. In particular, an equilibrium is given by $E_t = \{L_{it}, w_{it}, V_{it}, \Pi_{it}\}_{i \in R}$ such that in each region total sales equals the total income ($w_{it}L_{it}/\mu = \sum_{j \in R} X_{ijt}$), trade is balanced ($w_{it}L_{it}/\mu = \sum_{j \in R} X_{jit}$), the total population equals the population arriving at a location ($L_{it} = \sum_{j \in R} L_{jit}$), and the total population in the last period equals the number of people exiting a location between $t-1$ and t and ($L_{it-1} = \sum_{j \in R} L_{ijt}$). As shown in the Appendix, this corresponds to the equation system in Definition 1.

Definition 1 *(Equilibrium) An equilibrium given a geography G_t, is a sequence $E_t = \{L_{it}, w_{it}, V_{it}, \Pi_{it}\}_{i \in R}$ such that,*

1. $w_{it}^{\sigma}L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j \in R} \tau_{ijt}^{1-\sigma}\left(\frac{1}{\bar{A}_i L_{it-1}^{\alpha_2}\bar{u}_j L_{jt-1}^{\beta_2} H_i^{1-\mu}}\right)^{1-\sigma} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}^{1+\beta_1(\sigma-1)}$,

[53] I assumed that $\tau_{ijt} = \tau_{jit} = \frac{\tau_{ijt}+\tau_{jit}}{2}$ throughout the quantitative analysis.

2. $w_{it}^{1-\sigma} L_{it}^{\beta_1(1-\sigma)} V_{it}^{1-\sigma} = \sum_{j\in R} \tau_{jit}^{1-\sigma} \left(\frac{1}{\bar{A}_j L_{jt-1}^{\alpha_2} H_j^{1-\mu} \bar{u}_i L_{it-1}^{\beta_2}} \right)^{1-\sigma} w_{jt}^{1-\sigma} L_{jt}^{\tilde{\alpha}_1(\sigma-1)}$,

3. $L_{it} V_{it}^{-\theta} = \sum_{i\in R} \mu_{ji} \Pi_{jt}^{-\theta} L_{jt-1}$,

4. $L_{it-1} = \sum_{i\in R} \mu_{ij}^{-\theta} \Pi^{-\theta} L_{it-1} V_{jt}^{\theta}$,

where $\tilde{\alpha}_1 = \alpha_1 + \mu - 1$.

In this economy, one can define the steady-state given a geography as the allocation that the economy converges to in the long-run. Moreover, the economy exhibits path dependence, if the long-run steady state of the economy depends on initial conditions. In terms of the notation used in the model, this can be defined in the following manner.

Definition 2 *(Steady-state and Path Dependence) A steady state given a geography* $\{G_t\}_{t\in K}$*, is a sequence* $\{E_t\}_{t\in K}$ *such that* $\{E_t\} = E^*$ *for all t. The economy exhibits path dependence if there exist geographies* $\{G_0\}$ *and* $\{G_0'\}$ *such that* $E^*(G_0) \neq E^*(G_0')$.

Using results in Allen and Donaldson (2020) and Allen, Arkolakis and Li (2020), I provide proofs of existence and uniqueness of the equilibrium and steady-state in the Appendix.[54] The next section provides details on how the model is calibrated and shows that the conditions for the uniqueness of the equilibrium are satisfied.

6.2 Parameter Estimation and Identification

To facilitate estimating and solving the model, the model is derived on a smaller grid of 543 cells of $1.7°\times1.7°$.[55] There are six parameters, $\{\sigma, \theta, \alpha_1, \alpha_2, \beta_1, \beta_2\}$, as well as $|R|$ geographical fundamentals and local amenities, $\{\bar{A}_{it}, \bar{u}_{it}\}_{i\in R}$ which are backed out from the data. The estimation proceeds in three steps. First, the trade costs and migration costs are calculated by estimating the gravity equations for trade and migration respectively. Second, the equilibrium conditions are inverted in order to back out $\{p_{it}^{\sigma-1}, P_{it}^{\sigma-1}, V_{it}^{\theta}, \Pi_{it}^{\theta}\}_{i\in R}$. Third, I take the logarithm of the endogenous productivity and amenity values, $A_{it} = \bar{A}_i L_{it}^{\alpha_1} L_{it}^{\alpha_2}$ and $u_{it} = \bar{u}_{it} L_{it}^{\beta_1} L_{it}^{\beta_2}$, and take first differences to arrive at the estimating equations. Finally, the local amenities and productivities are calculated as the residuals of the estimated model. I further elaborate on the steps of this procedure as well as the underlying assumptions for identifying the parameters below.

Step 1: Gravity Equations. To estimate trade and migration costs, it is assumed that the costs of shipping or migrating between two locations i and j is a function of the bilateral travel time, T_{ijt}. The cost of shipping is assumed to be given by $\tau_{ijt} = T_{ijt}^{\kappa}$ while the cost of migrating is $\mu_{ij} = T_{ij}^{\lambda}$ where $\kappa > 0$ and

[54] In particular, the existence and uniqueness are guaranteed by the spectral norm of **A** being less than one. With the parameters of the baseline model, the spectral norm equals 0.97, where **A** is given by the following expression,

$$\mathbf{A} = \frac{1}{(b_{11}\theta + \tilde{\sigma}\sigma)\theta} \begin{bmatrix} \gamma_{11}\theta^2 + \gamma_{12}\theta & \gamma_{11}\tilde{\sigma}\sigma\theta - \gamma_{12}b_{11}\theta \\ \theta^2 & -b_{11}\theta^2 \end{bmatrix}, \tag{19}$$

where $\gamma_{11} = \tilde{\sigma}(1 + \beta_1(\sigma-1) + \alpha_1\sigma))$, $\gamma_{12} = \tilde{\sigma}(1-\sigma)$, and $b_{11} = \tilde{\sigma}(1 - \alpha_1(\sigma-1) - \beta_1\sigma) - (1-\mu)(1-\sigma)$.

[55] Approximately 180km.

$\lambda > 0$. Taking the natural logarithm of the gravity equation for trade and the migration (Equations 20 and 21) and inserting τ_{ij} and μ_{ij} gives the following relationships,

$$\ln X_{ijt} = \kappa(1-\sigma)\ln T_{ijt} + \ln\left(\frac{w_{it}}{\mu A_{it} L_{it}^{\mu-1} H_i^{1-\mu}}\right)^{1-\sigma} + \ln P_{jt}^{\sigma-1} w_{jt} L_{jt}, \tag{20}$$

$$\ln L_{ijt} = -\theta\lambda \ln T_{ijt} + \ln \Pi_{it}^{-\theta} L_{it-1} + \ln V_{jt}^{\theta}, \tag{21}$$

where the last two terms in each regression are interpreted as origin and destination fixed effects respectively. The equations are estimated using OLS with standard errors clustered at the origin and destination pair. The results are given in Table 19. The table shows there is a strong relationship between travel time and trade volumes as well as migration. A one percent increase in the travel time reduces trade flows by 1 percent and migration by 2.5 percent. Using these estimates, a matrix of trade as well as migration costs is calculated. I use these matrices in the quantitative exercises as well as to estimate the agglomeration spillovers.

Step 2: Model Inversion. The equilibrium conditions in Definition 1 are used to invert the model to solve for the endogenous variables given the data. Imputing data on the population size and wages as proxied by potential agricultural yield, all the parameters as well as the exogenous amenity and productivity values are identified. To proxy wages, I use data on the maximum attainable yield (measured in calories) that can be achieved across a large variety of crops. The model is inverted in the following manner,

$$p_{it}^{\sigma-1} - \sum_{j\in R} Y_{it} T_{ijt} \left(\frac{Y_{jt}}{Y_{it}}\right) P_{jt}^{\sigma-1} = 0, \tag{22}$$

$$P_{it}^{\sigma-1} - \sum_{j\in R} T_{jit} \left(p_{jt}^{\sigma-1}\right)^{-1} = 0, \tag{23}$$

$$V_{it}^{-\theta} - \sum_{j\in R} M_{jit} \left(\frac{L_{jt-1}}{L_{it}}\right) \Pi^{-\theta} = 0, \tag{24}$$

$$\Pi^{-\theta} - \sum_{j\in R} M_{ijt} V_{jt}^{\theta} = 0, \tag{25}$$

where $Y_{it} = L_{it} w_{it}/\mu$. Given $\{L_{it}, L_{it-1}, w_{it}\}_{i\in R}$, this system uniquely solves for the endogenous variables $\{p_{it}^{\sigma-1}, P_{it}^{\sigma-1}, V_{it}^{\theta}, \Pi_{it}^{\theta}\}_{i\in R}$.

Step 3: Parameter Estimation. The functional form of the productivity spillovers and the first-order condition of the firms, is used to identify the parameters of the productivity spillover parameters. Combining these expressions, taking the logarithm, and first differencing gives the following expression,

$$\Delta \ln p_{it}^{\sigma-1} = (\sigma-1)\Delta \ln w_{it} + \tilde{\alpha}_1(1-\sigma)\Delta \ln L_{it} + \alpha_2(1-\sigma)\Delta \ln L_{it-1} + (1-\sigma)\Delta \ln \bar{A}_i. \tag{26}$$

I substitute w_{it} with $\tilde{w}_i$ which is a proxy for the real wage of locality i based on the potential yield in the locality. The identification assumption is that $\bar{A}_i$ is time-invariant in the short run such that $(1-\sigma)\Delta \ln \bar{A}_i = 0$. This assumption is crucial since geographical fundamentals are unobserved. Therefore, without this assumption $\bar{A}_i$ enters the error term and generates a correlation between $\Delta \ln L_{it}$ and the error term (high ΔA_{it} increases the real wage which makes i a more attractive location for migrants). While the assumption is untestable in practice, the reduced form results support this assumption. To circumvent bias from the mismeasurement of population growth, I instrument $\Delta \ln L_{it}$ with the change in shipping time to Europe in a robustness check. This gives the following estimable equation,

$$\Delta \ln p_{it}^{\sigma-1} = (\sigma-1)\Delta \ln \tilde{w}_i + \tilde{\alpha}_1(1-\sigma)\Delta \ln L_{it} + \alpha_2(1-\sigma)\Delta \ln L_{it-1} + \epsilon_{it}, \tag{27}$$

where ϵ_{it} is clustered at the level of the closest port.

Next, using the indirect utility function, the amenity spillovers, taking the logarithm and first-differencing gives the following expression,

$$\Delta \ln V_{it}^{\theta} = \theta \Delta \ln w_{it} + \frac{\theta}{1-\sigma}\Delta \ln P_{it}^{\sigma-1} + \beta_1\theta\Delta \ln L_{it} + \beta_2\theta\Delta \ln L_{it-1} + \theta\Delta \ln \bar{u}_i. \tag{28}$$

Since $\bar{u}_i$ is unobserved it enters the error term. Therefore, estimating this equation in levels will lead to biased estimates. In particular, since localities with high values of $\bar{u}_i$ tend to attract migrants, the error term will be positively correlated with the error term of the regression. The key identification assumption is therefore that $\Delta\bar{u}_i = 0$. Since $\bar{u}_i$ is assumed to change only slowly, it remains constant during the reform period and thus the expression disappears when taking first-differences. This gives the following estimable equation,

$$\Delta \ln V_{it}^{\theta} = \theta \Delta \ln w_{it} + \frac{\theta}{1-\sigma}\Delta \ln P_{it}^{\sigma-1} + \beta_1\theta\Delta \ln L_{it} + \beta_2\theta\Delta \ln L_{it-1} + \psi_{it}, \tag{29}$$

where again ψ_{it} is clustered at the level of the closest port.

Finally, I use the estimated parameters to back out the location-specific amenity and productivity using the same equations in levels. In particular, the following equations identify the locality specific fundamentals,

$$\bar{A}_i = \exp\left\{\frac{1}{1-\sigma}\left(\ln p_{it}^{\sigma-1} - (\sigma-1)\ln w_{it} - \tilde{\alpha}_1(1-\sigma)\ln L_{it} - \alpha_2(1-\sigma)\ln L_{it-1} - \kappa ln H_i\right)\right\}, \tag{30}$$

$$\bar{u}_i = \exp\left\{\frac{1}{\theta}\left(\ln V_{it}^{\theta} - \frac{\theta}{1-\sigma}\ln P_{it}^{\sigma-1} - \beta_1\theta\ln L_{it} - \beta_2\theta\ln L_{it-1} - \theta\ln w_{it} + \theta\ln\mu\right)\right\}, \tag{31}$$

where $\kappa = (1-\mu)(1-\sigma)$. $\bar{A}_i$ and $\bar{u}_i$ are estimated as the residuals of Equation 27 and Equation 29.

Results. Table 20 contains the baseline estimates of Equation 26 and 28. Consistent with positive agglomeration externalities, the contemporaneous and lagged agglomeration spillovers, α_1, and α_2 are found to be positive. This is consistent with various forms of agglomeration externalities. The point estimate of the agglomeration externality is fairly large. This could potentially be explained by the model not incorporating variety gains from population Krugman (1991), as a result, these are potentially soaked up in the α_1 parameter. $\alpha_2 > 0$ could be driven by location-specific fixed capital such as infrastructure. The contemporaneous amenity spillover is negative, consistent with congestion forces making a location less attractive as more people locate there. The lagged amenity spillover is positive but significantly smaller. This could for example be driven by the quality of the housing stock or various forms of infrastructure that depreciate slowly. Since the amenity spillovers are less precise, I solve the model with alternative amenity spillovers as a robustness check.

The fifth parameter for which a value is needed is the elasticity of substitution between goods produced in different locations. A large literature provides various estimates of this parameter, however, there is no consensus on the value in the literature. Bajzik et al. (2020) find that most point estimates are between 1 and 5.1. Elasticities on goods produced in different locations within the same country are usually larger, typically ranging from 5 to 9 (Allen and Arkolakis, 2014). Allen and Donaldson (2020) find an elasticity of 13.6 which is among the few papers that provide the estimate in a historical context. In light of these findings, I set σ to 6 as a starting value and do robustness checks for values in the interval of $\sigma \in [5, 9]$. This gives a conservative starting point for the importance of trade in a within-country context.

There are much fewer estimates of the migration elasticity θ. Allen and Donaldson (2020) find a migration elasticity of around 11. However, this estimate in the context of developing countries typically ranges between 2 and 4 (Morten and Oliveira, 2018; Bryan and Morten, 2019; Tombe and Zhu, 2019). I therefore set $\theta = 3$ which is in the middle of this range as a starting point. I check for robustness to values in the range $\theta \in [2, 4]$. Finally, in the baseline case, the labor share is set to 0.6 following Caselli and Coleman (2001) who provide estimates of the farm labor share in the 19th-century US. I provide evidence that the results are robust to different labor shares. Given this calibration of the model there exists a unique equilibrium.[56] Table 21 displays the parameter estimates used in the baseline models of the counterfactual exercises.

Table 21: Model Parameters

Parameter	Description
Panel A: Preferences and Technology	
$\sigma = 6$	Elasticity of substitution
$\theta = 3$	Migration Elasticity
$\mu = 0.6$	Labor share of income (Caselli and Coleman, 2001)
Panel B: Trade and Migration Costs	
$\kappa(1-\sigma) = -1.06^{***}$	Elasticity of trade flow wrt. travel time
$-\lambda\theta = -2.8^{***}$	Elasticity of migration flow wrt. travel time
Panel C: Spillovers	
$\alpha_1 = 0.214^{***}$	Productivity spillover
$\alpha_2 = 0.011^{**}$	Lagged productivity spillover
$\beta_1 = -0.411^{*}$	Amenity spillover
$\beta_2 = 0.115$	Lagged amenity spillover

Note: The table shows the parameters used for the baseline simulation exercises. α_1, α_2 β_1, and β_2 are estimated directly from the data on 543 grid-cells. σ, μ, and θ are taken from the literature in the baseline case. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

[56]Uniqueness is guaranteed by $\rho(\mathbf{B}) = 0.997$.

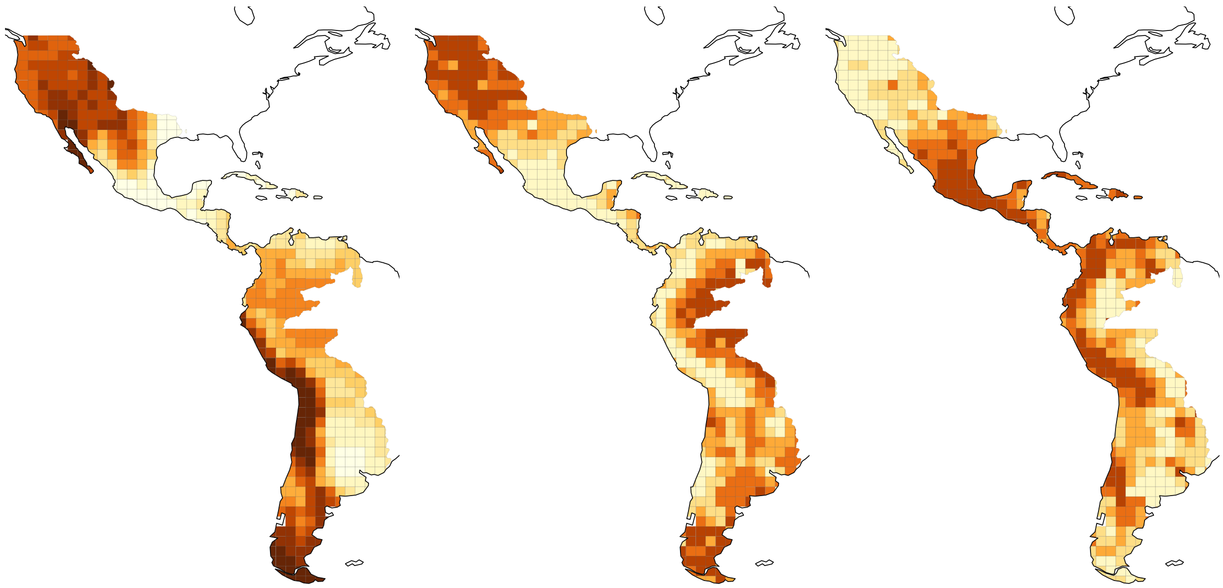

Figure 8: The figures show the results from the structural estimation. The left map shows the geographical fundamental productivity by grid-cell ($\bar{A}_i$), which is the residual from Equation 30. The center map shows the amenity value for each grid-cell ($\bar{u}_i$), which is the residual from Equation 31. The right map shows the change in population induced by the change in trade costs according to the model with the estimated parameters ($\bar{L}_t$). In all the maps, darker colors indicate higher values.

6.3 Model Fit

This section assesses the performance of the theoretical framework by comparing the evolution of the spatial distribution of economic activity predicted by the model with the realized population growth. Since the population growth after 1810 is not targeted by in the calibration of the model, this serves as a test of the relevance of the mechanisms emphasized by the model. The model is solved for the initial population distribution in 1760 and solved forward several periods. The realized population distributions and the population distributions implied by the model are then compared. As the population is highly persistent over time, both levels and changes are compared.

Table 22 displays the results of this exercise. Panel A shows the relationship between the model implied population in 1810 and the realized population in 1810 conditional on the baseline control variables. The table shows there is a robust relationship between the model implied population distribution and the realized population distribution. Column (3)-(4) shows that this relationship also holds within *audiencia* and viceroyalty as well as conditioning on controls. For the population changes, there is also a robust relationship between the model implied and the realized values. Table 23 compares the raw correlations between the model implied and realized population distribution both in levels and changes. For the changes, I find a correlation between 0.3 and 0.57 over the different horizons. Taken together, these exercises show that the mechanisms emphasized by the model are empirically relevant in explaining population growth in the current context.

6.4 Counterfactuals

This section uses the model to conduct counterfactual exercises. Since there exists a unique general equilibrium, the counterfactuals yield determinate predictions for the impact of the changes in the trade costs. The key object of interest is the population distribution under the scenario of changing trade costs, relative to the counterfactual of trade costs remaining constant. Thus, unless stated otherwise the results are reported relative to the baseline of non-changing trade costs. Throughout the section, $L_t^{T_0}$ will denote the population allocation at time t assuming the trade costs T_0 remained constant after 1760. Moreover, $L_t^{T_1}$ denotes the model implied population distribution with changing trade costs. The object of interest is $\bar{L}_t = L_t^{T_1} - L_t^{T_0}$, which is the difference in population between the scenario where trade costs remain fixed to the 1760 level and the scenario of changing trade costs. The main outcome variable in this section is $\mathbb{1}(\bar{L}_t > 0)$, an indicator variable taking the value one if the population size of the grid-cell is higher in the counterfactual scenario than in the baseline scenario. I present several counterfactual exercises below. First, I show that the model replicates the three broad patterns of the reform documented in the reduced form analysis. Second, I consider a different timing of the reform. In particular, what would be the long-run impact in the case where the reform happened earlier. Finally, I consider the role of initial conditions in determining the effect of the reform.

6.4.1 Quantifying the Effects of Opening Trade

The Impact of the Reform. Starting out, I simulate the impact of the reform. The model is solved for the population level in 1810, using the population in 1760 as a baseline. This gives the population size in the regime with changed trade costs relative to the baseline of unchanged trade costs, $\mathbb{1}(\bar{L}_t > 0)$. The results of this exercise are displayed on the left map in Figure 10. In the map, darker colors indicate a higher population density relative to what would have been achieved with constant trade-costs ($\bar{L}_{1810}$). Hence, it shows the regions that grow more as a result of the reform lowering trade costs. The figure shows that the results mirror the reduced form. First, the lower trade costs increase the coastal population density. Increasing the distance to the coastline by 100 percent reduces the average number of cells with higher density under lower trade costs by around four percentage points. Second, areas with larger reductions in trade costs to Europe grow relative to the baseline as a result of the reform. In particular, increasing the change in trade costs induced by the reform by 100 percent increases $\mathbb{1}(\bar{L}_t > 0)$ 14 percentage points. Finally, the effects are much smaller in the core. While the fraction of grid-cells with higher population density under the lower trade costs is 0.307, the average in the core is 0.11.

Long-run Effects. Next, I solve the model 250 years forward in time to 2010 comparing the population distribution under the new trade costs to the scenario in which the trade costs would have remained constant. Figure 9 displays the effects from this exercise. Point estimates are similar to the effect in 1810. The effect is larger closer to the coast, in areas with larger reductions in trade costs, and outside the core region for all the years. For a 100 percent increase in the distance to the coastline the share of cells with higher density under lower trade costs declines by 0.104 percentage points. Moreover, increasing the shipping time to Europe by 100 percent increases the share of cells with higher density under lower trade costs by 0.104. Finally, the effect is again substantially smaller in the core area, 0.11 from an average

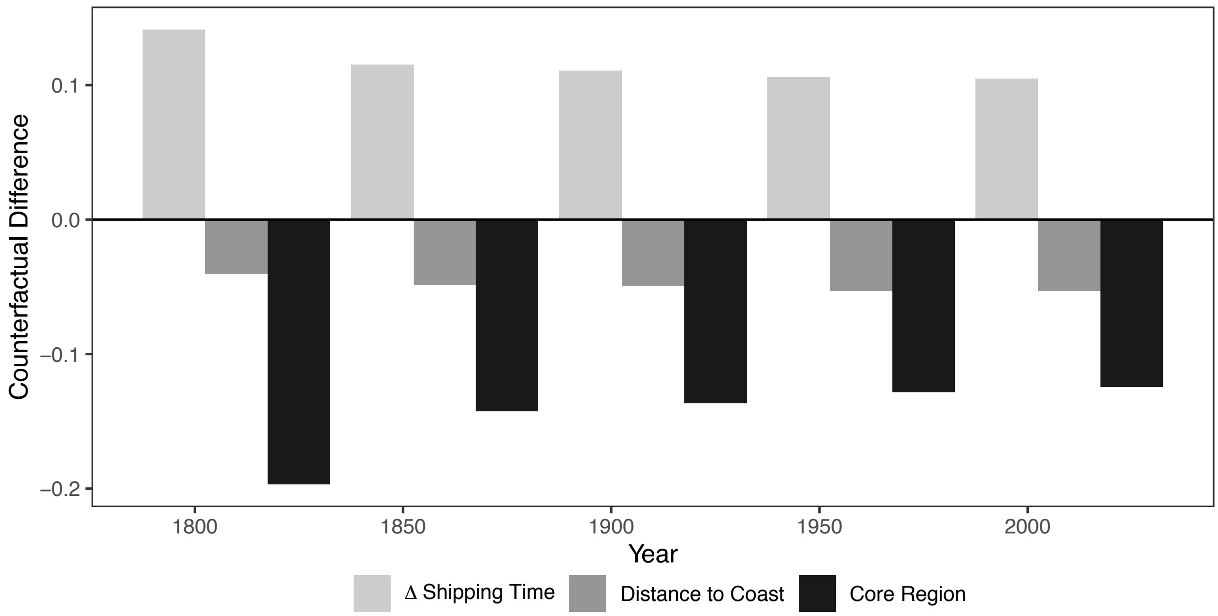

Figure 9: The figures show the results from the main counterfactual exercise. For each forward iteration of the model, the share of the number of grid-cells with higher population density under the new regime is compared. The Figure displays the difference in the counterfactual for places with more and less exposure to the reform, coastal versus interior regions, and the core versus the periphery.

of 0.235. As can be seen in Figure 9, this effect is highly persistent. The effect of the reform can still be seen after 250 years.

6.4.2 Other Counterfactuals

The Role of Initial Conditions. In this section I assess the impact of initial conditions on the impact of the reform. While lower transportation costs tend to make coastal localities more attractive, persistence driven by agglomeration economies in the hinterland will attenuate this effect. Furthermore, for the baseline parameters, the long-run steady state is not unique. As a result, changing initial conditions can have effects on the long-run steady-state.[57] To assess the quantitative significance of this mechanism, the long-run impact of the change in trade costs is calculated under different initial conditions. In particular, I solve the model forward using the population distribution in 1700 and 1600 as initial conditions.

Panel A of Table 24 displays the results from this exercise. The first column shows that direct trade with Europe increased population density in areas that increased their market access regardless of initial conditions, with effect sizes ranging from 0.141-0.137. The reform also increases the population in coastal areas regardless of the initial condition. This is also the case for the effect of the reform in the core. For all initial conditions, the reform reduced the tendency of the population to concentrate in the core areas. Taken together, the effects are slightly more muted for 1700 and 1600. Since the population distribution was more concentrated in the core in this period, this suggests that spatial persistence attenuates the effect of the trade cost shock.

[57] This follows from the fact that $\rho(\alpha_1 + \alpha_2, \beta_1 + \beta_2) > 1$.

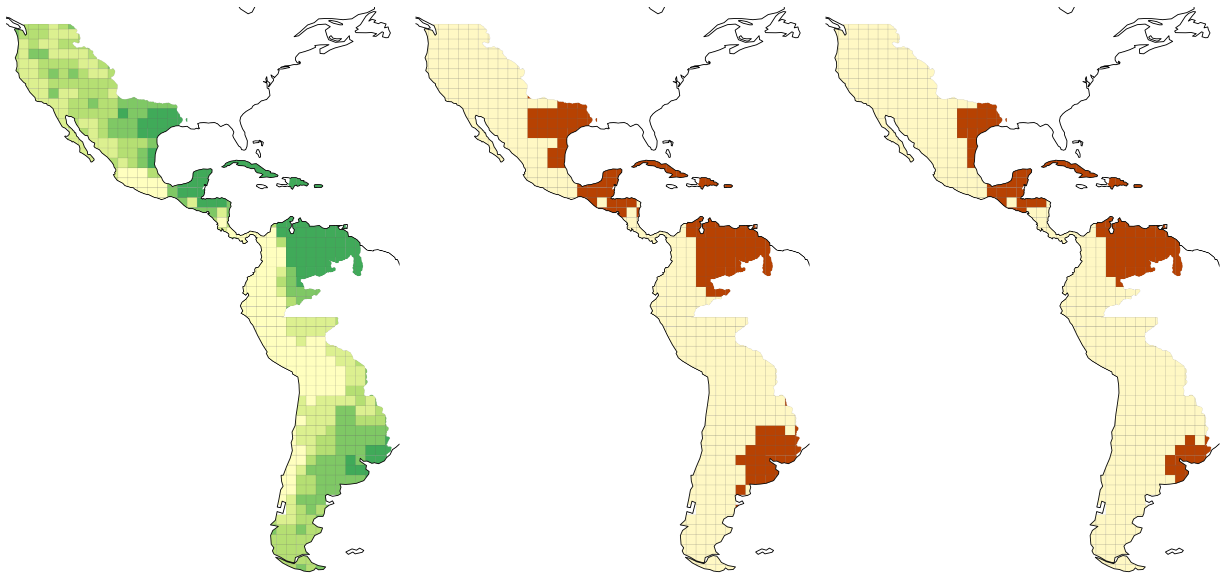

Figure 10: The figures show the results from the structural estimation. The maps show the change in population induced by the change in trade costs according to the model with the estimated parameters. In all the maps, darker colors indicate higher values. The left map displays the difference in population in 1810 under the two scenarios ($\bar{L}_{1810}$). The right hand side figures show the grid-cells with higher population under the new trade costs in 1810 and 2010 ($\mathbb{1}(\bar{L}_{1810} > 0)$ and $\mathbb{1}(\bar{L}_{2010} > 0)$).

Earlier Opening to Trans-Atlantic Trade. What would be the effect of opening direct trade with Europe earlier? To assess this in light of the model, I consider alternative opening years. The model is solved for opening at different points in time, and population levels of different grid-cells are again compared. The comparison is now made to the baseline case where the trade costs changed in 1765. The model implied population distribution in 1810 is then compared to the model implied distribution in 1810 had the reform been implemented earlier.

The results of this exercise can be seen in Panel B of Table 24 If direct trade had been opened earlier the difference between the places that reduced their shipping time to Europe more or less is smaller. This is consistent with Figure 9 which shows that the effect becomes more muted over time. Taken together, an earlier opening is consistent with less concentration in the core area by 1810 as well as a higher coastal gradient. In sum, these results support the view that low coastal population density partly is driven by the late opening of direct trade during the colonial era that has persisted until the present. Moreover, the findings are consistent with the restrictions on trade stunting economic development in the periphery and that the lifting of these being responsible for the growth in the periphery starting in the second half of the 18th century.

Changing migration costs. So far, migration costs have been assumed to remain fixed throughout the reform period. This section considers the effect in the counterfactual scenario where international migration costs change in accordance with the changes in trade costs. This would be the case if the reduction in travel times was induced by for example technological change or if increased maritime trade induced by the reform made it cheaper to migrate. This exercise can therefore be informative about the estimated effects when changes in trade costs are confounded by changes in migration costs.

The results from this exercise can be found in Table 25. Each column gradually adds more controls

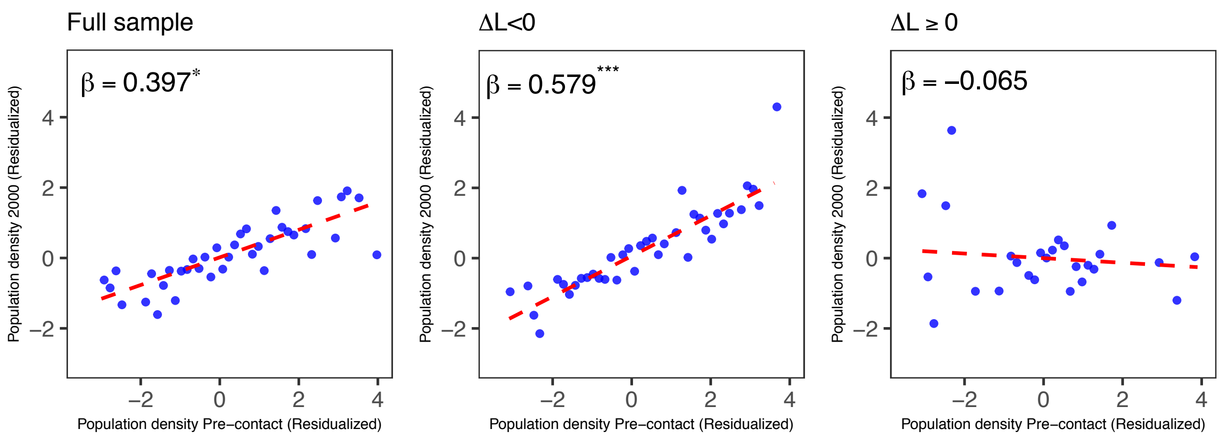

Figure 11: The figure shows the relationship between pre-colonial population density and the population density in year 2000 at the level of the province. The left figure shows the relationship for the full sample. The middle figure shows the relationship for provinces where the trade reform did not induce growth. The right figure shows the relationship for the sample where the reform did induce growth. Pre-colonial population density is the number of indigenous people per square kilometre before the arrival of Columbus from Maloney and Valencia (2016). The dependent variable is the log of people per square km in 2000. The full sample contains 258 observations. **Geographical controls:** Altitude, ruggedness, rainfall, and inverse distance to the coast (see Maloney and Valencia (2016) for details). **Standard errors** are clustered at the country-level.

and is therefore a stricter test of the hypothesis. Panel A considers the baseline case where migration costs remained unchanged over the study period while Panel B displays the result if migration costs had changed in accordance with the change in trade costs. For all specifications and outcomes, there is a positive relationship between lower trade costs and population density. As can be seen in Table 25, this pattern is significantly more pronounced in the case where migration costs also changed. Taken together, this shows that to the extent migration costs also changed as a result of the reform, the effects would have been larger. Moreover, this shows that approaches in the literature that do not explicitly account for migration costs are run the risk of overestimating the effect of trade costs.

6.5 Persistence

Finally, I revisit the impact of the reform on persistence. Is spatial persistence lower in the locations that grew as a result of the reform? To investigate this question I again match the areas where the model shows the reform induced large growth. I look at spatial persistence (the relationship between pre-colonial population density and population density in 2000) in areas within the same country that grew as a result of the reform. Key to this exercise is that the geographic incidence of the reform is uncorrelated with pre-colonial population density, which is the case.

Figure 11 shows the result from this exercise. The left-hand scatter plot again shows the relationship for the full sample, which is positive and significant, consistent with results in Maloney and Valencia (2016). The relationship is completely driven by areas that were less intensively affected by the reform. This shows that within-country, the areas with high spatial persistence are the areas that were not affected by the trade reform. Moreover, this shows that the large change in trade costs disrupted spatial persistence. The areas that were sensitive to the reform were coastal areas and less densely settled areas. Taken together, the findings point towards the timing of access to trade to play an important role in determining variation in spatial persistence. The spatial distribution of economic activity in places that reached higher levels of density early were not sensitive and thus pre-colonial settlement patterns persisted. Places that were less densely settled reached were more responsive to the reform and thus ended up with geographies that reflected trading opportunities.

6.6 Robustness Checks

Alternative Spillover Parameters. While the agglomeration parameters are precisely estimated from the data, I take the elasticity of substitution (σ) as well as the shape parameter (θ) on the Fréchet-distribution as given. To assess the robustness of the model predictions, I rerun the main simulation exercises using different parameter values. For all the parameters I solve the model using alternative plausible values for these parameters that preserve the uniqueness properties of the equilibrium as well as the steady-state. Taken together, I find little evidence that this exercise changes the qualitative impact of the reform.

Changes in coastal amenity values. While the baseline estimates account for fixed differences in amenity values across localities, it remains a possibility that there were changes in coastal amenity values during this period that can rationalize the above findings. To assess this, I change the double all amenity values within 100km of the coastline. This naturally increases the tendency of growth in coastal areas during the reform period. However, it does little to change the impact of changing trade costs. Taken together, the patterns uncovered in the reduced form are still replicated using the model.

Secular change in productivities. The assumption in the baseline simulations that all variables other than trade costs are constant after the reform is unlikely to be realistic. This is likely to be less of a concern for the short-run effect. To assess this, I assume a five percent reduction in productivity over the reform period. The estimates from the model remain largely unchanged. For the long-run results, this is more of a concern. Assuming a five percent increase in productivity each generation, the model is solved forward. Again, there is little to suggest the results are vulnerable to these assumptions.

Secular change in trade costs. Another quantity which we might expect to undergo secular change over the simulation period is trade-costs. I assess this by assuming a five percent reduction in trade costs over the reform period. The estimates from the model remain largely unchanged. For the long-run results, this is more of a concern. Assuming a five percent reduction in trade costs each generation, the model is solved forward. Again, there is little to suggest the results are vulnerable to assumptions about trade costs.

Changes in migration costs. Finally, we might expect migration costs to equally undergo secular change over the simulation period. Therefore, I simulate the model under two assumptions about migration costs. First, I let migration costs decline five percent each generation. Second, I assume migration across borders is infinitely costly. Finally, I assume migration across the Atlantic is infinitely costly. In all cases, the model replicated the qualitative results from the reduced form.

The role of national borders. In the baseline case, I assume throughout that movement across national borders are costless in the long-run. In this section, I therefore add national borders to the cost raster to assess the importance of this assumption. I assume that national borders, as pertaining to sovereign states in 2020 are infinitely costly to cross from 1820 onwards. I thus ignore border changes between these two periods for simplicity. I then rerun the main analysis. Taken together, I find similar effects with this extension. While, including costly international migration across tends to attenuate the long-run effect of the reform, the effects remain quantitatively and qualitatively similar.

7 Conclusion

This paper uses the abrupt opening of direct trade with Europe within the Spanish Empire to study the role of trade in breaking spatial persistence. I calculate the changes in travel times to Europe induced by a reorganization of the maritime communication in the wake of the Bourbon reforms in the second half of the 18th century. Using a difference-in-differences research design that relies on comparing areas within the same region that differentially reduced its shipping time to Europe, I estimate the impact of lower trade costs on the location of cities and population growth. I find a statistically and economically significant positive effect on population density associated with reduced shipping times to Europe. Moreover, the opening of direct trade is associated with a change in the role of economic fundamentals, in particular the increased importance of coastal proximity. I present evidence consistent with the increased importance of Trans-Atlantic trade and specialization in high-value agricultural commodities being an important mechanism explaining the effect. To assess the mechanisms, account for general equilibrium effects, and conduct counterfactual simulations, I develop a spatial general equilibrium model that I take to the data. Consistent with the reduced-form evidence, the model shows that the opening of direct trade with Europe increased population density. Lower levels of population density in the periphery facilitated the geographical reorientation towards coastal areas. Taken together, the findings provide evidence that large changes in trade costs can overcome spatial persistence and have a substantial impact on the spatial distribution of economic activity under the right conditions. The combination of low density and large changes in trade costs initiated a dispersal of economic activity and growth in the periphery of the Spanish Empire. The results therefore highlight that in addition to differences in local institutions, trade played an important role in initiating the reversal of fortune.

Both the quantitative and reduced-form evidence shows that changes in trade costs can overcome spatial persistence and have large effects on the spatial distribution of economic activity, especially when the trade cost shock is large or the initial population density is low. More broadly, the findings point towards that what determines the relative weight of history versus market access in the location of cities is the sequencing with which a country achieves high population density versus low trade costs. History will tend to explain the population distribution in places that attain high population density before reduced trade costs, while market access will explain the population distribution in places that had low density prior to opening up to trade. Thus, the findings highlight the role of history in shaping the population distribution in places that attained population density early, such as Europe, China, and India, and show that market access is more important in places that attained population density after the large reductions in trade costs in the 19th century, such as the United States and Argentina. Seen in light of the literature that has documented the importance of access to water for European urbanization (Acemoglu, Johnson and Robinson, 2005; Bosker and Buringh, 2017; Bosker, Buringh and van Zanden, 2012; Michaels and Rauch, 2018), the findings in this paper suggest having geography which poorly reflects access to maritime trade to being a potential cost of developing early.

Beyond the economic mechanisms emphasized in this paper, a potentially important mechanism through which the Bourbon commercial reforms disrupted long-run persistence was by accelerating independence movements. Alesina and Spolaore (2003) (p. 191) argues that increased reliance on international trade was an important impetus for the independence movements in Latin America.[58] Lower trade costs increased the reliance on international trade in the colonial periphery, making economic independence more attractive for political elites and in turn promoting political fragmentation. As such, an important issue that this paper does not address is how broader participation in international trade lead to political fragmentation and ultimately the emergence of stable national borders. Future research should quantitatively examine the role of trade costs in causing political fragmentation and the emergence of national borders, which remain important impediments to economic integration to this day.

[58] See Bonfatti (2017) and Arteaga (2016) for formal models embedding this mechanism.

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8 Tables

Table 1: Summary Statistics - Main Variables

Statistic	N	Mean	St. Dev.	Min	Median	Max
#Cities 1710-1810	73,282	0.10	0.30	0	0	1
City 2000 (Nightlights)	73,282	0.36	0.48	0	0	1
Nightlights	73,282	1.92	4.80	0	0.2	62
Population 1760	73,282	2,002.55	5,828.75	0	151.8	146,218
Population 1800	73,282	2,333.26	7,101.08	0	179.0	195,808
Shipping time 1760 (days)	73,282	121.57	24.04	69.02	124.16	179.54
Shipping time 1800 (days)	73,282	107.38	22.69	55.15	108.30	160.91
Market Access 1760	73,282	12,596.00	35,240.23	110.08	2,599.49	690,939.90
Market Access 1800	73,282	14,884.00	43,115.06	139.22	2,958.78	868,755.70
Elevation	73,282	0.23	0.42	0	0	1
Terrain ruggednes	73,282	188.81	214.16	0.48	100.95	1,286.09
Average crop suitability	73,282	−0.00	1.00	−1.93	−0.16	3.65
Mining center	73,282	0.03	0.17	0	0	1
Average Temp. (Celsius)	73,282	17.27	7.49	−2.18	18.12	28.73
Precipitation (mm.)	73,282	1,113.99	939.50	0.01	831.36	8,186.80
Coffee	73,282	7.13	1.32	2	8	9
Tobacco	73,282	6.70	1.35	2	6.9	9
Cotton	73,282	6.60	1.66	1	7.2	9
Wheat	73,282	6.59	1.63	1	7.2	9
Maize	73,282	6.24	1.69	1	6.3	9
Sugar cane	73,282	6.86	1.43	1	8	9
Dist. Coast (km)	73,282	444.77	364.29	0.03	354.71	1,600.06
Dist. River (km)	73,282	509.22	514.62	0.06	328.44	2,516.99
Dist. Port 1750 (km)	73,282	1,002.53	844.78	14.59	742.32	3,686.54
Decade	73,282	1,760.00	31.62	1,710	1,760	1,810

Notes: The table shows the main key variables in the main dataset used in the analysis. The unit of analysis is at the grid-cell level. The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. *Elevation* is an indicator variable equal one if the elevation is above 1500m. *Crop suitability* is the average suitability for tobacco, cotton, sugar cane, cacao, coffee (standardized). *City 2000* is an indicator equal one if the grid cell has one pixel with more than 30 in luminosity. The dataset hence contains $11 \times 6{,}662 = 73{,}282$ observations.

Table 2: Travel Speeds, Historical, and Contemporary Wind Conditons

Dependent variable:	Travel speed, wind speed, and wind direction			
	(1)	(2)	(3)	(4)
Panel A: Knots (daily average)				
θ_{ij}	0.036***	0.085***	0.085***	0.071***
	(0.012)	(0.015)	(0.015)	(0.011)
Wind speed$_i$	0.346***	0.315***	0.315***	0.424***
	(0.009)	(0.011)	(0.011)	(0.007)
Panel B: Wind Speed 1750-1850				
Wind speed (Beaufort)	0.357***	0.343***	0.343***	0.331***
	(0.018)	(0.035)	(0.035)	(0.016)
Panel C: Wind Direction 1750-1850				
Wind direction (Degrees)	0.226***	0.247***	0.246***	0.173***
	(0.013)	(0.016)	(0.016)	(0.014)
Year + Month FE	✓	✓	✓	✓
Ship Type FE		✓	✓	
Nationality FE			✓	
Voyage FE				✓

Note: The unit of analysis is at a logbook entry. **Dependent variable Panel A:** Average speed per day measured in knots. **Dependent variable Panel B:** Wind speed as reported in the logbooks measured in Beaufort. **Dependent variable Panel C:** The wind direction measured in degrees. θ_{ij} denotes the angle between the wind and the direction of travel. **Observations Panel A:** 225,211. **Observations Panel B:** 40,158. **Observations Panel C:** 17,221. **Standard errors:** Clustered at the voyage-level. **Data source:** NOAA and CLIWOC. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 4: Shipping Time to Europe and Market Access

Dependent variable:	Market Access (log)			
	(1)	(2)	(3)	(4)
Shipping Time (log)	-4.473^{***}	-5.090^{***}	-5.001^{***}	-5.061^{***}
	(0.389)	(0.438)	(0.365)	(0.343)
Viceroyalty FE × Decade FE	✓	✓		
Audiencia FE × Decade FE			✓	✓
Geographic Controls		✓		✓
Mean dep. var.	8.09	8.09	8.09	8.09
Observations	73,282	73,282	73,282	73,282
Adjusted R-squared	0.686	0.697	0.698	0.742

Notes: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **The dependent:** Market access (log). **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain audiencia fixed-effects. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The full dataset contains **11** × **6,662 = 73,282 observations**. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 5: Shipping Time, Market Access, and Population

Dependent variable:	Population (asinh)			
	(1)	(2)	(3)	(4)
Panel A: IV				
Market Access	0.406*	0.369	0.392*	0.245*
	(0.222)	(0.233)	(0.214)	(0.131)
Panel B: Reduced Form				
Shipping Time	−1.337*	−1.349	−1.436*	−0.936*
	(0.792)	(0.885)	(0.814)	(0.548)
Panel C: OLS				
Market Access	0.257*	0.234*	0.237*	0.254**
	(0.135)	(0.131)	(0.131)	(0.102)
First stage F	121.51	126.13	172.06	35.06
Viceroyalty FE × Year		✓		
Audiencia FE × Year			✓	✓
Controls				✓
Observations	73,282	73,282	73,282	73,282

Note: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **The dependent variable:** Population size of the grid-cell. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The full dataset contains **11 × 6,662 = 73,282 observations**. **Controls:** Elevation, crop suitability, the location of active mines, population size in 1710 and distance to the coastline, and terrain ruggedness. All specification contain *audiencia* fixed-effects. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}\ p < .1$

Table 6: Event-study Specification

Dependent variable:	Indicator variable for grid-cell containing a settlement				
	(1)	(2)	(3)	(4)	(5)
Δ T $\times$ $\mathbb{1}$ ($year = 1710$)	0.002	0.002	0.014	0.015	0.015
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Δ T $\times$ $\mathbb{1}$ ($year = 1720$)	0.005	0.005	0.016	0.016	0.016
	(0.013)	(0.013)	(0.015)	(0.016)	(0.016)
Δ T $\times$ $\mathbb{1}$ ($year = 1730$)	0.005	0.005	0.015	0.017	0.017
	(0.011)	(0.011)	(0.014)	(0.015)	(0.015)
Δ T $\times$ $\mathbb{1}$ ($year = 1740$)	−0.003	−0.003	0.001	0.002	0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Δ T $\times$ $\mathbb{1}$ ($year = 1750$)	−0.001	−0.001	−0.002	−0.003	−0.003
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Δ T $\times$ $\mathbb{1}$ ($year = 1770$)	0.002	0.002	−0.003	−0.003	−0.003
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Δ T $\times$ $\mathbb{1}$ ($year = 1780$)	−0.001	−0.001	−0.004	−0.002	−0.002
	(0.011)	(0.011)	(0.008)	(0.006)	(0.006)
Δ T $\times$ $\mathbb{1}$ ($year = 1790$)	0.001	0.001	0.002	0.004	0.004
	(0.013)	(0.013)	(0.008)	(0.007)	(0.007)
Δ T $\times$ $\mathbb{1}$ ($year = 1800$)	0.0003	0.0003	0.0003	0.002	0.002
	(0.014)	(0.014)	(0.009)	(0.008)	(0.008)
Audiencia FE		✓	✓	✓	✓
Audiencia × Decade FE			✓	✓	✓
Controls				✓	✓
Controls × Decade FE					✓
Mean dep. var.	0.1	0.1	0.1	0.1	0.1
Observations	66,620	66,620	66,620	66,620	66,620
Adjusted R-squared	0.014	0.173	0.179	0.197	0.197

Notes: The unit of analysis is at a 0.5°×0.5° grid-cell. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The full dataset contains 11 × 6,662 = 73,282 observations. The omitted year is the year prior to the treatment, therefore **N = 73,282 - 6,662 = 66,620**. **Controls:** Distance to the coast (log), elevation, presence of an active mine, terrain ruggedness, and crop suitability. **Standard errors:** Clustered at the level of the closest port. ***p $<$ .01, **p $<$ .05, * p $<$ .1

Table 7: Heterogeneity

Dependent variable:	Indicator for grid-cell containing a settlement			
	(1)	(2)	(3)	(4)
Panel A: Core				
Market Access	0.038**	0.037*	0.035*	0.019
	(0.019)	(0.021)	(0.019)	(0.041)
Panel B: Semiperiphery				
Market Access	0.090***	0.086***	0.085***	0.072***
	(0.017)	(0.018)	(0.017)	(0.017)
Panel C: Periphery				
Market Access	0.152***	0.153***	0.153***	0.130***
	(0.026)	(0.023)	(0.023)	(0.016)
Panel D: Coast				
Market Access	0.111***	0.110***	0.101***	0.090**
	(0.027)	(0.028)	(0.028)	(0.038)
Panel E: Hinterland				
Market Access	0.037***	0.036***	0.031***	0.030***
	(0.013)	(0.013)	(0.011)	(0.008)
Viceroyalty FE × Year		✓		
Audiencia FE × Year			✓	✓
Controls				✓
Observations	59,147	59,147	59,147	59,147
Adjusted R-squared	0.169	0.169	0.175	0.193

Note: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **Dependent variable:** Indicator taking the value one if the grid-cell contains a settlement. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. All specifications include grid-cell fixed-effects. **The core** denotes the audiencias of Charcas, Lima, and Mexico (1,009 cells $\times 11 = 11,099$ observations), **the periphery** the audiencias of Buenos Aires, Santiago, Caracas, (1,284 cells $\times 11 = 14,124$ observations) and the **semiperiphery** Quito, Santa Fe, Confines, Santo Domingo, Guadalajara, Cuzco (1,534 cells $\times 11 = 16,874$ observations). 2,835 cells do not pertain to an audiencia. **Coastal** denotes the grid cell being less than 100km from the coast. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. **Standard errors:** Clustered at the level of the closest port. ***$p < .01$, **$p < .05$, * $p < .1$

Table 8: Heterogeneity

Dependent variable:	Population size of grid-cell			
	(1)	(2)	(3)	(4)
Panel A: Core				
Market Access	1.542***	1.499***	1.566***	1.899***
	(0.181)	(0.190)	(0.205)	(0.332)
Panel B: Semiperiphery				
Market Access	1.266***	1.239***	1.246***	1.303***
	(0.181)	(0.174)	(0.179)	(0.097)
Panel C: Periphery				
Market Access	1.657***	1.707***	1.685***	1.528***
	(0.245)	(0.220)	(0.231)	(0.139)
Panel D: Coast				
Market Access	1.138***	1.141***	1.139***	1.062***
	(0.101)	(0.115)	(0.117)	(0.155)
Panel E: Hinterland				
Market Access	1.196***	1.220***	1.202***	1.143***
	(0.076)	(0.063)	(0.071)	(0.109)
Viceroyalty FE × Year		✓		
Audiencia FE × Year			✓	✓
Controls				✓
Observations	59,147	59,147	59,147	59,147
Adjusted R-squared	0.603	0.606	0.604	0.606

Note: The unit of analysis is at a 0.5°×0.5° grid-cell. **Dependent variable:** Population size of grid-cell (ihs) **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. All specifications include grid-cell fixed-effects. **The core** denotes the audiencias of Charcas, Lima, and Mexico (1,009 cells $\times 11 = 11,099$ observations), **the periphery** the audiencias of Buenos Aires, Santiago, Caracas, (1,284 cells $\times 11 = 14,124$ observations) and the **semiperiphery** Quito, Santa Fe, Confines, Santo Domingo, Guadalajara, Cuzco (1,534 cells $\times 11 = 16,874$ observations). 2,835 cells do not pertain to an audiencia. **Coastal** denotes the grid cell being less than 100km from the coast. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. **Standard errors:** Clustered at the level of the closest port. ***p $< .01$, **p $< .05$, * p $< .1$

Table 9: Spatial persistence in high and low exposure areas

Dependent variable:	Population density 2000 (log)			
	(1)	(2)	(3)	(4)
Panel A: Full sample				
Population density 1500	0.348^{***}	0.279^{***}	0.397^{**}	0.397^{**}
	(0.113)	(0.097)	(0.143)	(0.143)
Panel B: ΔT <Median				
Population density 1500	0.572^{***}	0.554^{***}	0.541^{***}	0.541^{***}
	(0.078)	(0.093)	(0.099)	(0.099)
Panel C: $\Delta T \geq$Median				
Population density 1500	0.264^{*}	0.179^{**}	0.120	0.120
	(0.135)	(0.074)	(0.174)	(0.174)
Country FE			✓	✓
Controls		✓		✓
Observations	125	125	125	125
Adjusted R-squared	0.132	0.353	0.509	0.509

Note: Market access is standardized. The unit of analysis is at the province-level. Pre-colonial population density is the number of indigenous people per square kilometre before the arrival of Columbus from Maloney and Valencia (2016). The dependent variable is the log of people per square km in 2000. The full sample contains 258 observations. **Geographical controls:** Altitude, ruggedness, rainfall, and inverse distance to the coast (see Maloney and Valencia (2016) for details). **Standard errors** are clustered at the country-level. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 10: Coastal consentration in high and low exposure areas

Dependent variable:	Population density 2000 (log)			
	(1)	(2)	(3)	(4)
Panel A: Full sample				
Distance to coast	-4.542^{***}	-3.947^{***}	-6.316^{***}	-6.316^{***}
	(1.402)	(1.432)	(1.895)	(1.895)
Panel B: ΔT <Median				
Distance to coast	-5.849^{***}	-5.742^{***}	-4.430^{*}	-4.430^{*}
	(1.485)	(1.069)	(2.115)	(2.115)
Panel C: ΔT ≥Median				
Distance to coast	-5.081^{***}	-4.595^{***}	-9.021^{***}	-9.021^{***}
	(1.560)	(1.602)	(1.708)	(1.708)
Country FE			✓	✓
Controls		✓		✓
Observations	125	125	125	125
Adjusted R-squared	0.252	0.296	0.495	0.495

Note: Market access is standardized. The unit of analysis is at the province-level. Pre-colonial population density is the number of indigenous people per square kilometre before the arrival of Columbus from Maloney and Valencia (2016). The dependent variable is the log of people per square km in 2000. The full sample contains 258 observations. **Geographical controls:** Altitude, ruggedness, rainfall, and inverse distance to the coast (see Maloney and Valencia (2016) for details). **Standard errors** are clustered at the country-level. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 11: Coastal Population Density in the Long-Run

	log(Population)		log(Nightlights)		Nightlights City		Nightlights City	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Full Sample								
Dist. coast (log)	-0.272^{*}	-0.348^{**}	-0.373^{***}	-0.405^{***}	-0.170^{***}	-0.179^{***}	-0.057^{***}	-0.061^{***}
	(0.159)	(0.158)	(0.076)	(0.077)	(0.041)	(0.041)	(0.015)	(0.015)
Panel B: High Exposure								
Coast dist. (log)	-0.243	-0.159	-0.449^{***}	-0.384^{***}	-0.245^{***}	-0.194^{***}	-0.078^{***}	-0.059^{***}
	(0.207)	(0.159)	(0.103)	(0.090)	(0.059)	(0.049)	(0.022)	(0.018)
Panel C: Low Exposure								
Coast dist. (log)	-0.288^{*}	-0.268^{**}	-0.296^{***}	-0.328^{***}	-0.102^{***}	-0.117^{***}	-0.032^{**}	-0.035^{**}
	(0.149)	(0.115)	(0.060)	(0.060)	(0.038)	(0.042)	(0.013)	(0.014)
Geographic FE	✓	✓	✓	✓	✓	✓	✓	✓
Controls		✓		✓		✓		✓
Observations	3,331	3,331	3,330	3,330	3,331	3,331	3,331	3,331
Adjusted R-squared	0.640	0.659	0.544	0.566	0.390	0.404	0.214	0.222

Notes: The unit of analysis is at a 1°×1° grid-cell. ***Population*** denotes the average population density of the grid-cell in 2000, ***Nightlights*** denotes the average nighlight luminosity, and ***Nightlight City*** is a dummy variable for if the the average nighlight luminosity exceeds 30. ***High Exposure*** denotes above median reduction in remoteness. ***High Exposure*** denotes below median reduction in remoteness. **Observations** The full sample contains 6,662 observations. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specifications contain country, *audiencia*, and *viceroyalty* fixed-effects. **Standard errors:** Clustered at the port-level. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 12: Changes in Shipping Times and Exports to Spanish America

Dependent variable:	Exports from Spain			
	(1)	(2)	(3)	(4)
Panel A: Export Share (asinh)				
ΔT	0.336**	0.488***	0.515	0.589**
	(0.126)	(0.129)	(0.309)	(0.250)
Panel B: Export Value (asinh)				
ΔT (asinh)	0.454**	0.472***	0.585	0.401*
	(0.202)	(0.135)	(0.398)	(0.236)
Geo. distance		✓	✓	✓
Viceroyalty FE			✓	✓
Lon+Lat				✓

Notes: The table shows the relationship between changes in shipping times and exports from Cadiz and Barcelona between 1797 and 1820 which made up 86 percent of exports to Spanish America. **Dependent Panel A:** Share of total exports for 23 ports in Spanish America. **Dependent Panel B:** The value (reales de vellon) for Spanish American ports. ΔT equals the change in shipping times between 1760 and 1810 at the level of the port. All variables are transformed with the inverse hyperbole sine function. ***Geo. distance*** denotes the geodesic distance of the port from Europe (Cádiz). **Observations Panel A:** 23 observations. **Observations Panel B:** 246. **Standard errors:** Clustered at the level of the port. Source: Fisher(1993). ***p $< .01$, **p $< .05$, * p $< .1$

Table 13: The Reform and Commodity Prices

Dependent variable:	Commodity prices (guilders)				
	(1)	(2)	(3)	(4)	(5)
Post	0.271^{***}				
	(0.040)				
America	-2.733^{***}	-2.733^{***}			
	(0.040)				
America × Post	-0.201^{***}	-0.201^{***}	-0.201^{***}	-0.203^{***}	-0.065
	(0.074)	(0.074)	(0.074)	(0.074)	(0.086)
War × America				0.016	
				(0.019)	
Year Fe		✓	✓	✓	✓
Commodity FE			✓	✓	✓
War × Treat				✓	✓
Commodity × Time trend					✓
Observations	29,988	29,988	29,988	29,988	29,988
Adjusted R-squared	0.164	0.165	0.986	0.986	0.991

Notes: The table shows the relationship between the timing of the reform and the prices of commodities produced in the Americas. The average price is 58.76. ***America*** denotes if the commodity is either tobacco, sugar, or cocoa. ***Post*** is an indicator variable for the period after 1778. ***War*** equals one for years in which Atlantic maritime powers were among the belligerents (Seven Years' War and the American Revolutionary War). **Standard errors:** Clustered at the commodity-level. $^{***}p < .01$, $^{**}p < .05$, $^{*}\ p < .1$

Table 14: Heterogeneity by Crop Suitability

Dependent variable:	Indicator for grid-cell containing a settlement			
	(1)	(2)	(3)	(4)
T	-0.099^{*}	-0.129^{***}	-0.048	-0.068
	(0.053)	(0.041)	(0.044)	(0.042)
T × Crop suitability	-0.119^{***}	-0.107^{***}	-0.079^{**}	-0.080^{**}
	(0.035)	(0.035)	(0.033)	(0.037)
Viceroyalty FE × Year	✓	✓		
Audiencia FE × Year			✓	✓
Geographic Controls		✓		✓
Mean dep. var.	0.1	0.1	0.1	0.1
Observations	73,282	73,282	73,282	73,282
Adjusted R-squared	0.839	0.841	0.846	0.846

Notes: The unit of analysis is at a 0.5°×0.5° grid-cell. **Crop suitability** is measured as the average suitability for cocoa, coffee, cacao, cotton, tobacco, and sugar cane. **Dependent variable:** Indicator variable taking the value 1 if the grid-cell contains a settlement. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The full dataset contains **11 × 6,662 = 73,282 observations**. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 15: Shipping Times to Europe and the Slave Trade

Dependent variable:	# ships arriving per year (log)		
	(1)	(2)	(3)
Panel A: Trans-Atlantic Slave Trade			
Shipping Time	−0.001	−0.092**	0.021
	(0.007)	(0.036)	(0.028)
Panel B: Intra-American Slave Trade			
Shipping Time	−0.010	−0.079**	−0.066**
	(0.007)	(0.031)	(0.027)
Year FE	✓	✓	✓
Port FE		✓	✓
Port × Trend			✓

Notes: The unit of analysis is the port. **Dependent variable:** Number of ships arriving at a port in a given year (log). **Observations Panel A:** 149 observations. **Observations Panel B:** 314. **Standard errors:** Clustered at the port-level. Source: Eltis (2018). $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 16: Population, Urbanization, Density, and Shipping Times

Dependent variable:	Urban population and density		
	(1)	(2)	(3)
Panel A: Population density			
Market Access	0.671^{***}	0.635^{***}	0.618^{***}
	(0.061)	(0.073)	(0.056)
Panel B: Urban population			
Market Access	0.159^{**}	0.160^{**}	0.110
	(0.074)	(0.072)	(0.076)
Panel C: City size			
Shipping Time	-1.302^{*}	-1.076	-0.882
	(0.755)	(1.154)	(0.682)
Viceroyalty FE × Year	✓		
Audiencia FE × Year		✓	✓
Controls			✓

Notes: The unit of analysis is at a 1°×1° grid-cell. All specifications include *audiencia* fixed effects. The variables are transformed using the inverse hyperbolic sine function. Panel A and Panel B contain **11 × 6,662 = 73,282 observations**. Panel C contains 2 × 211 = 422 observations. **The geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. **Standard errors** are clustered at the port-level. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 17: Rerouting and Transshipment

Dependent variable:	Indicator for grid-cell containing a settlement			
	(1)	(2)	(3)	(4)
Panel A: Rerouting: City formation				
Market Access	0.071*	0.065*	0.063	0.065***
	(0.041)	(0.039)	(0.038)	(0.024)
Panel B: Rerouting: Population				
Market Access	1.382***	1.435***	1.429***	1.172***
	(0.195)	(0.185)	(0.186)	(0.142)
Panel C: Transshipment: City formation				
Market Access	0.112***	0.111***	0.111***	0.126***
	(0.017)	(0.019)	(0.019)	(0.032)
Panel D: Transshipment: Population				
Market Access	1.018***	1.017***	1.011***	1.092***
	(0.093)	(0.112)	(0.099)	(0.115)
Audiencia FE × Year		✓	✓	✓
Controls				✓
Adjusted R-squared	0.235	0.235	0.239	0.254

Notes: The unit of analysis is at a 1°×1° grid-cell. **Observations Panel A:** 44,825 observations. **Observations Panel B:** 44,825 observations. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specifications include *audiencia* fixed effects. **Standard errors:** Clustered at the port-level. $^{***}p < .01$, $^{**}p < .05$, $^{*}\ p < .1$

Table 18: Effects in the frontier

Dependent variable:	Indicator for cell containing a settlement			
	(1)	(2)	(3)	(4)
Panel A: Frontier: Post Office				
Market Access	0.010**	0.009**	0.006**	0.006
	(0.004)	(0.004)	(0.003)	(0.005)
Panel B: Frontier: Audiencia				
Market Access	0.003**	0.002	0.003**	0.002
	(0.001)	(0.001)	(0.001)	(0.002)
Panel C: Not frontier: Post Office				
Market Access	0.108**	0.113**	0.097**	0.079**
	(0.046)	(0.050)	(0.042)	(0.037)
Panel D: Not frontier: Audiencia				
Market Access	0.103***	0.103***	0.094***	0.087***
	(0.018)	(0.018)	(0.016)	(0.017)
Viceroyalty FE × Year		✓		
Audiencia FE × Year		✓	✓	✓
Controls				✓

Notes: The unit of analysis is at a 1°×1° grid-cell. **Sample Panel A:** Observations below median distance to the closest post-office. 36,641 observations. **Sample Panel C:** Observations below median distance to the closest post-office. 36,641 observations. **Sample Panel B:** Places outside an *audiencia*. 31,185 observations. **Sample Panel D:** Places inside an *audiencia*. 42,097 observations. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specifications include *audiencia* fixed effects. **Standard errors:** Clustered at the port-level. ***$p < .01$, **$p < .05$, * $p < .1$

Table 19: Gravity Equations

Dependent variable:	Trade		Migration	
	(1)	(2)	(3)	(4)
Shipping Time	-0.633^{***}	-1.060^{***}	-2.398^{***}	-2.800^{***}
	(0.152)	(0.156)	(0.064)	(0.046)
Origin + Destination FE		✓		✓
Mean dep. var.	10.46	10.46	4.55	4.55
Observations	753	753	1,096	1,096
Adjusted R-squared	0.021	0.578	0.563	0.848

Notes: Trade measures the bilateral trade flow between Spanish America and Spain from 1820-1870 at the country level. Migration measures the population by state of birth in 1865 for Argentina and 1895 for Mexico. All specifications controls for time fixed-effects. ***p $< .01$, **p $< .05$, * p $< .1$

Table 20: Estimating model parameters

	Model inversion	
	(1)	(2)
Panel A: OLS		
Population$_t$	1.239^{***}	1.054^{***}
	(0.019)	(0.050)
Population$_{t-1}$	-0.116^{***}	-0.324^{***}
	(0.012)	(0.042)
Panel B: IV		
Population$_t$	-0.130^{***}	-0.152
	(0.020)	(0.104)
Population$_{t-1}$	1.289^{***}	0.402
	(0.063)	(0.330)
Origin + Destination FE	✓	✓
F-statistic (effective)	36.58	25.19
Observations	542	542
Adjusted R-squared	0.956	0.799

Notes: The table provides estimates of the contemporaneous and lagged agglomeration and amenity parameters of the model. Equation (26) provides estimates of the agglomeration spillovers while Equation (27) provides the amenity spillovers. Trade and migration costs are estimated using origin and destination fixed effect. **The first-stage F-statistic:** Accounts for clustering following Olea and Pflueger (2013). **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 22: Assessing the Model Performance

Dependent variable:	Population size of grid-cell			
	(1)	(2)	(3)	(4)
Panel A: Levels				
Population$_M$	5.224***	5.479***	5.549***	5.526***
	(0.165)	(0.173)	(0.261)	(0.277)
Panel B: Changes				
Population$_M$	0.078***	0.087***	0.110***	0.117***
	(0.023)	(0.025)	(0.032)	(0.033)
Viceroyalty FE		✓	✓	✓
Audiencia FE			✓	✓
Controls				✓
Adjusted R-squared	0.732	0.779	0.827	0.834

Notes: The table compares the population levels and growth by the grid-cell level implied by the model with the realized population level and growth. **Population$_M$** refers to the model implied population. **The dependent variable** in Panel A is the population level in 1810. **The dependent variable** in Panel B is the change in population between 1760 and 1810. **Controls** include longitude, latitude as well as the distance to the coast. **Standard errors** are clustered at the level of the port. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 23: Correlation of population between the model and the data

Year	Changes	Levels
Population_{1810}	0.306	0.878
Population_{1860}	0.572	0.689
Population_{1910}	0.573	0.457
Population_{1960}	0.537	0.206
Population_{2010}	0.523	0.145

Note: The table shows the correlation between the model implied and realized population both in levels and changes.

Table 24: Main Counterfactual Exercises

Dep. variable: $\tilde{L}$	Δ Shipping Time	Distance to Coast	Core Region
Panel A: Initial Population			
1760:	0.141	-0.04	-0.197
1700:	0.135	-0.041	-0.193
1600:	0.137	-0.038	-0.179
Panel B: Opening year			
1700:	-0.039	0.002	-0.033
1600:	-0.039	-0.024	0.3
1500:	-0.014	0.008	-0.143

Note: The unit of analysis is at a $1° \times 1°$ grid-cell. All variables are standardized. ΔT denotes the change in shipping time during the reform period. ***Coast*** measures the distance to the coastline. ***Core*** is an indicator variable taking the value one if the grid-cell is in the core. ***Pop.*** denotes the population size of the grid-cell at the time of the change in transportation costs. ***Initial Pop.*** denotes the initial distribution of population as the transportation cost change. ***Opening year*** denotes the counterfactual of implementing the policy in a given year. ***Long-run*** denotes the effect 150 years in the future with different initial population distributions.

Table 25: Effects of the Reform with Changing Migration Costs

Dependent variable:	Model implied population			
	(1)	(2)	(3)	(4)
Panel A: Migration costs fixed				
Δ T	0.141***	0.178***	0.190***	0.143***
	(0.031)	(0.036)	(0.054)	(0.051)
Panel B: Migration costs changing				
Δ T	0.286***	0.263***	0.251***	0.274***
	(0.019)	(0.020)	(0.042)	(0.035)
Viceroyalty FE		✓	✓	✓
Audiencia FE			✓	✓
Controls				✓
Adjusted R-squared	0.204	0.318	0.516	0.627

Notes: The table compares the population levels and growth by the grid-cell level implied by the model with the realized population level and growth. **Population**$_M$ refers to the model implied population. **The dependent variable Panel A:** An indicator variable taking the value one if the grid-cell has higher density under the new trade costs with fixed migration costs. **The dependent variable Panel B:** An indicator variable taking the value one if the grid-cell has higher density under the new trade costs when migration costs change in accordance with the trade costs. **Controls:** Longitude, latitude as well as the distance to the coast. **Standard errors:** Clustered at the level of the port. ***p $<$ .01, **p $<$ .05, * p $<$ .1

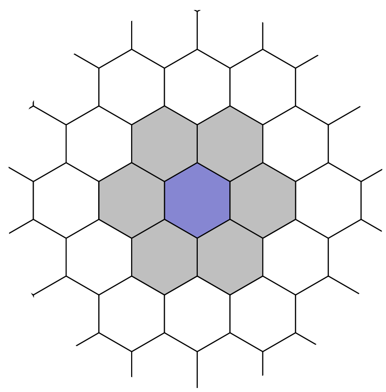

Figure 12: This figure shows a grid-cell and its six adjacent cells that constitute the unit of analysis. The final dataset consists of 6,662 grid-cells of $0.5° \times 0.5°$.

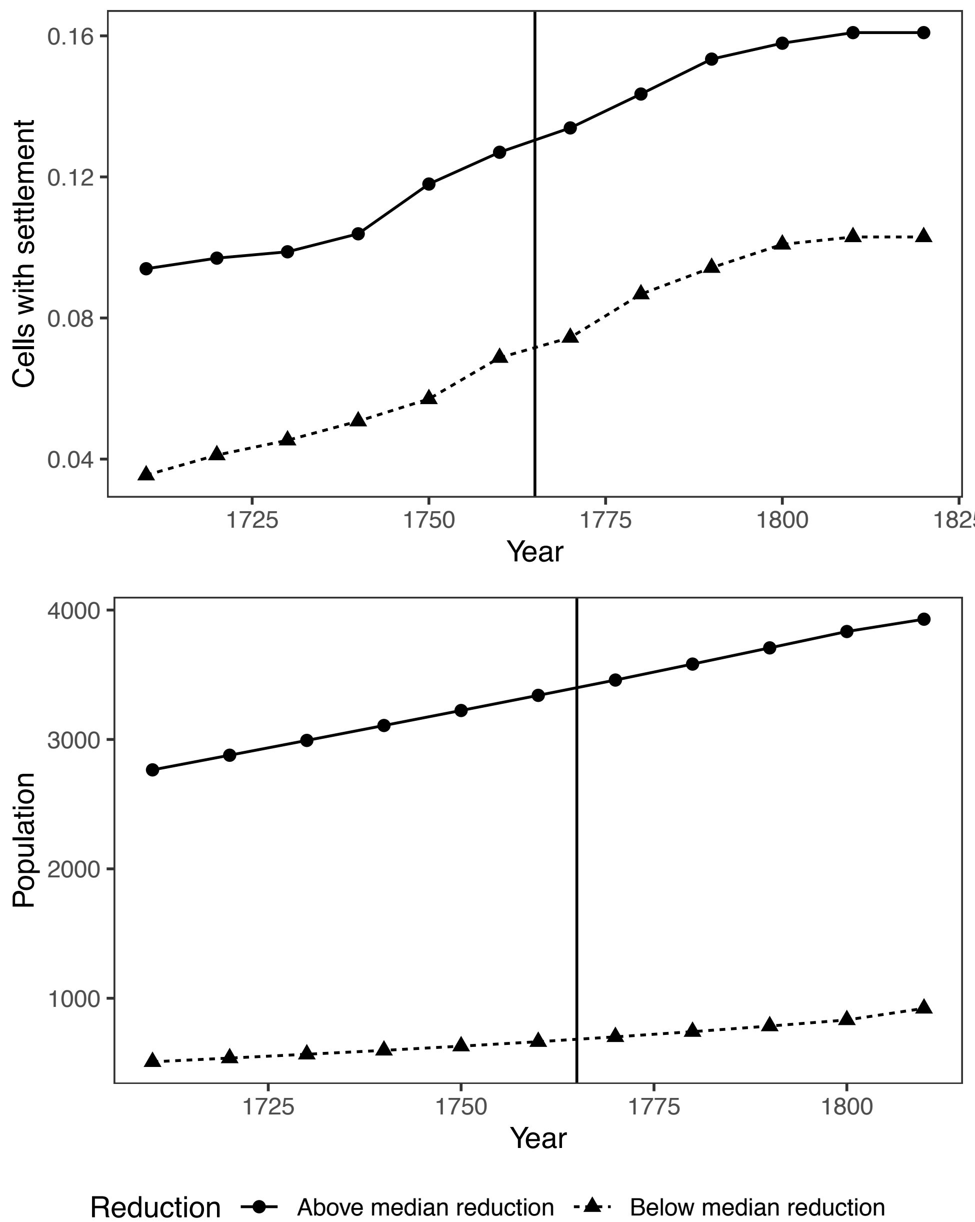

Figure 13: The figures show the average population and settlements by grid-cell for each decade. The solid line is the average for grid-cells above median reduction in shipping times. The dashed line is the average for cells with below average reduction in shipping times.

Figure 14: The figures show the viceroyalty and audiencia borders in 1790 used in the main part of the analysis. Light gray areas show all the areas claimed by the Spanish Empire in 1790. The full lines denote the borders of the viceroyalties while lighter lines denote the borders of the audiencias. The lightest lines denote the coastlines.

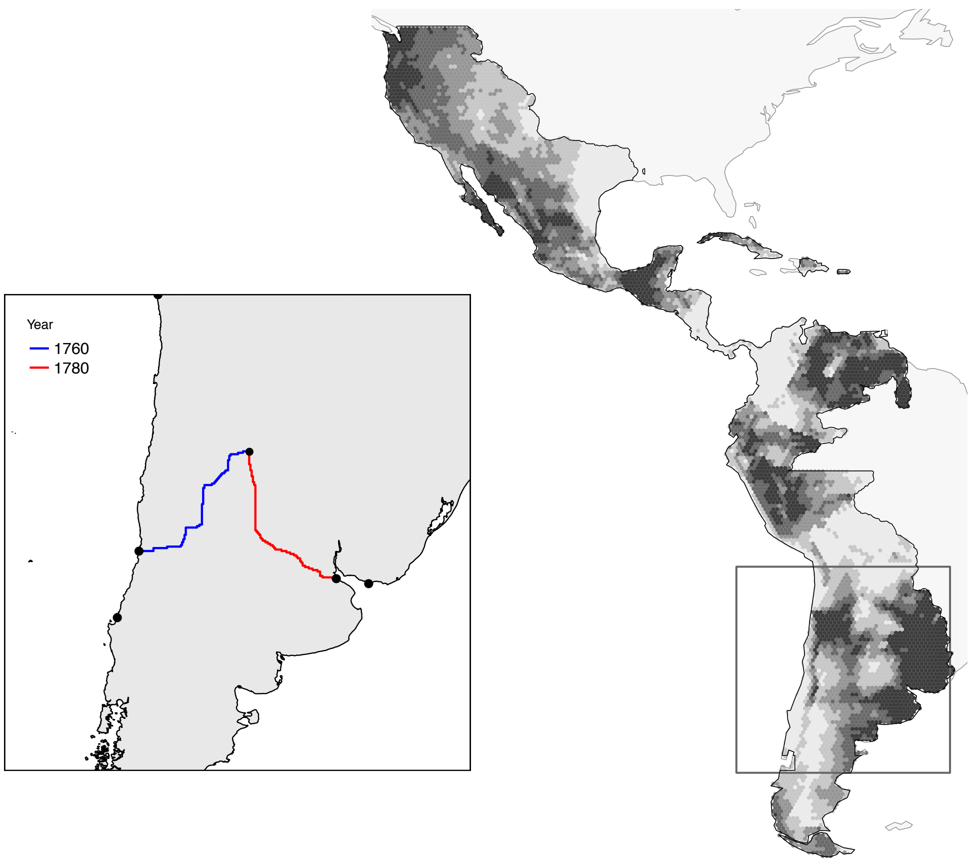

Figure 15: The figure on the left shows the least-cost paths for a grid-cell in 1760 and 1780. The figure on the right shows residualized change in shipping times by grid-cell between 1760 and 1810.

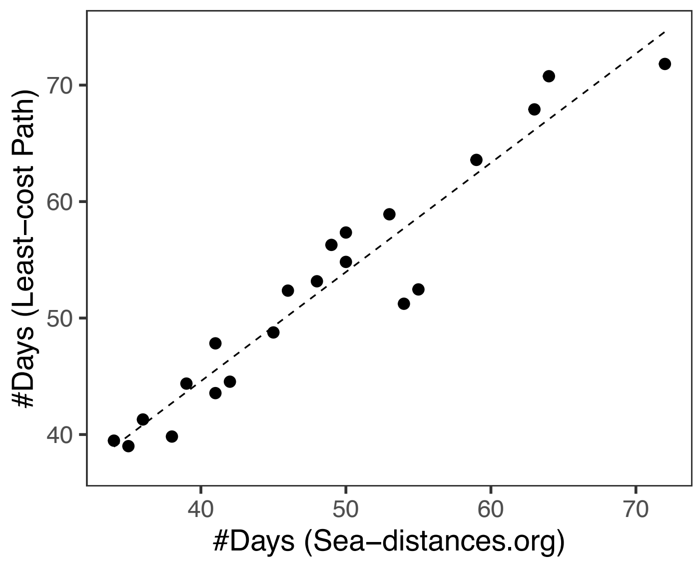

Figure 16: The figures shows the relationship between sailing times produced by the least-cost path on the constructed cost-surface and and sailing times from sea-distances.org for voyages between Cadiz and 21 ports in Spanish America. The travel times are set to 4 knots which is the average speed attained over the cost-surface.

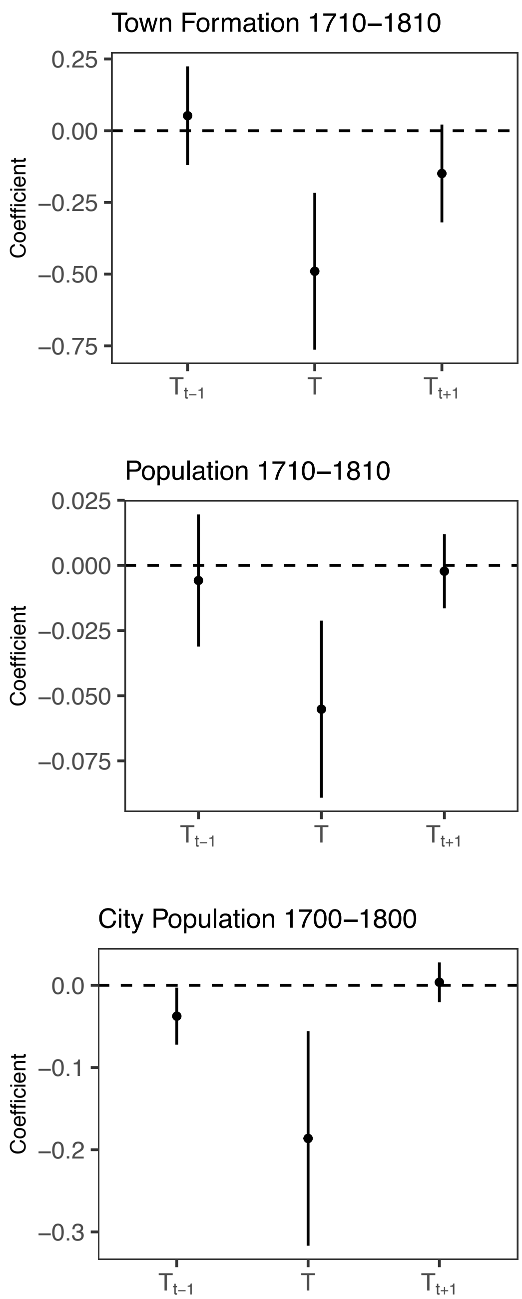

Figure 17: The figures show the estimated leads and lags of the baseline specification for the main outcomes. The specification controls for port catchment area as well as port catchment area times decade fixed effects.

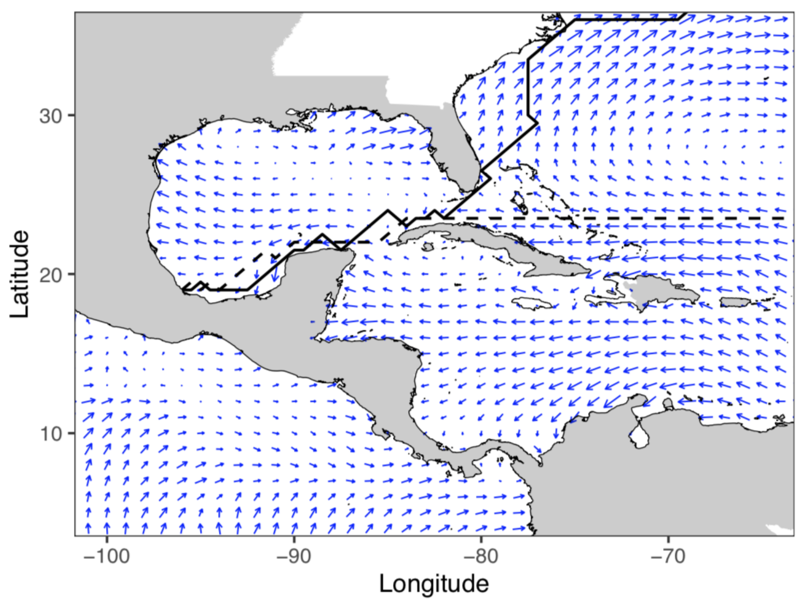

Figure 18: The figure shows the average wind speed and direction for the Caribbean over 2011-2017. The length of each arrow is proportional to the wind speed. The dashed line shows the shortest path from Cádiz to the port of Veracruz while the full line shows the shortest path from Veracruz to Europe (as proxied by the port of Cádiz). The grey areas indicate territory claimed by the Spanish Empire as of 1790. Source: NOAA.

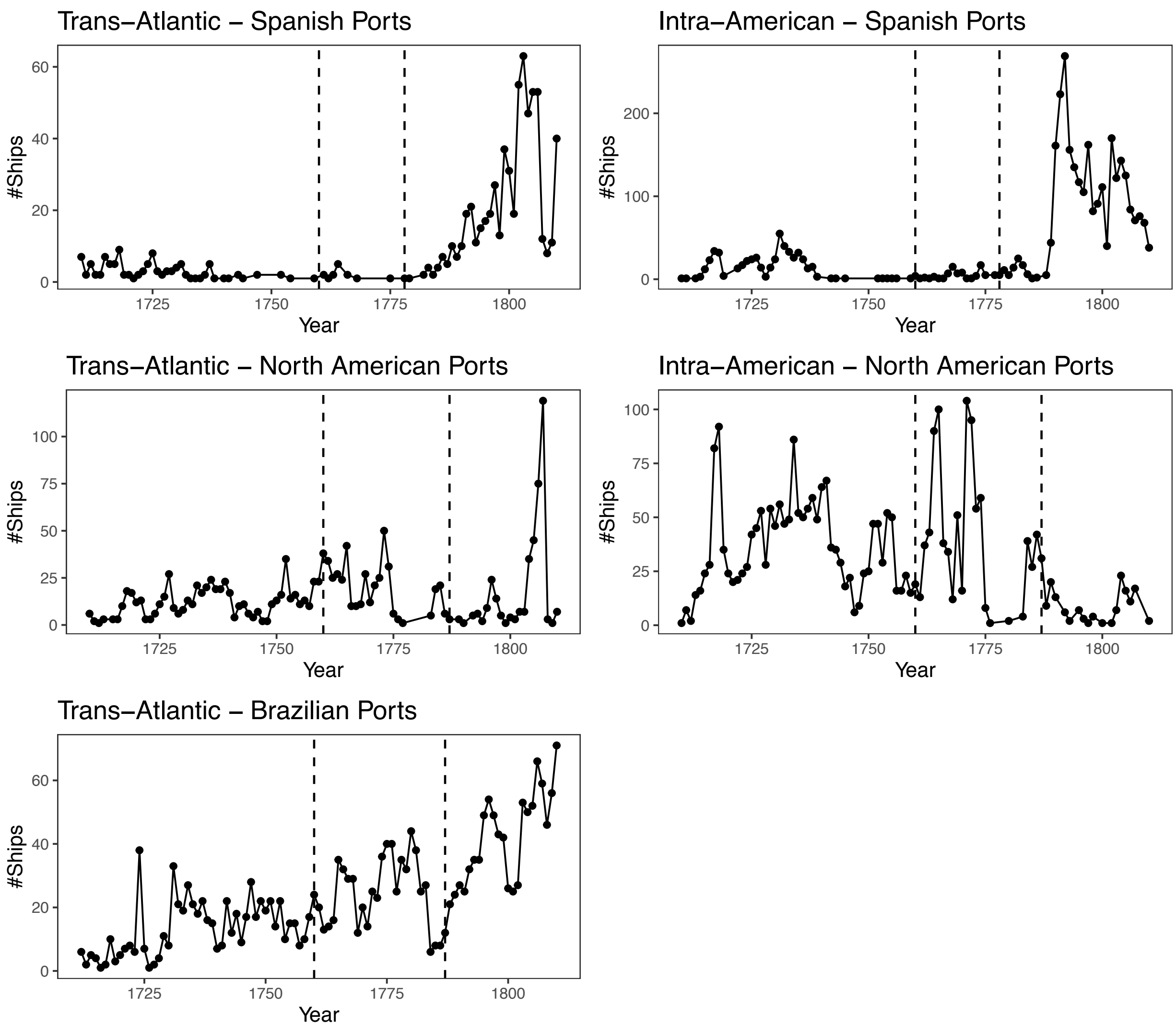

Figure 19: The figures show the number of ships participating in the intra-american and trans-atlantic slave trades arriving at Spanish, North American, and Brazilian ports between 1710 and 1810. The vertical lines denote the years between which most Spanish ports in were opened for long-distance trade. A ship is assigned to a port if the port is the first destination of a particular ship. Source: Eltis (2018).

Online Appendix

A Model Derivation

This section shows the main steps of the derivation of the model, the equilibrium conditions, and the estimation of the parameters.

Consumers problem. The consumers problem is standard and I outline the main steps in this section. The utility function is assumes every locality produces a unique good and takes the following form,

$$M_{it} = u_{it} \sum_{j \in R} \left(q_{jit}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \tag{A.1}$$

which gives rise the standard price index, $P_i = \left(\sum_{j \in R} p_{jit}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$. To find the compensated demand function for each variety the household solves the following problem,

$$\max_{\{q_{ijt}\}_{j=R}^{R}} \sum_{j \in R} \left(q_{ijt}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \text{ s.t.} \sum_{j \in R} q_{ijt} p_{ijt} \leq \frac{w_{it}}{\mu}, \tag{A.2}$$

which gives the following compensated demand function $q_{ijt} = \frac{w_{it}}{\mu P_{it}} \left(\frac{p_{it}}{P_{it}} \right)^{-\sigma}$. Using the definition of the price index gives the deterministc part of the utility function as presented in the paper,

$$V_{it} = \frac{u_{it} w_{it}}{P_{it} \mu}. \tag{A.3}$$

Production. Production is undertaken by a continum of firms from the set Ω operating under constant returns to scale technologies, $q_{it}(\omega) = A_{it} l_{it}(\omega)^{\mu} h_{it}(\omega)^{1-\mu}$ using land ($h_{it}(\omega)$) and labor as ($l_{it}(\omega)$) as inputs where μ is the constant labor share. Firms maximize profits which gives the demand for labor of firm ω as $p_{it} = w_{it} / A_{it} \mu l_{it}(\omega)^{\mu-1} h_{it}(\omega)^{1-\mu}$. In each region and at each time labor market clear $\int_{\Omega} l_{it}(\omega) = L_{it}$ and $\int_{\Omega} h_{it}(\omega) = H_{it}$.

Gravity equations. The total value of trade from i to j at time t is given by $X_{ijt} = q_{ijt} p_{ijt} = p_{ijt}^{1-\sigma} X_{jt} P_{jt}$, where X_{jt} denotes the total income in location j $X_{jt} = w_{jt} L_{jt} / \mu$. This gives the gravity equation for trade,

$$X_{ijt} = \frac{1}{\mu} \tau_{ijt}^{1-\sigma} p_{it}^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.4}$$

Since $p_{it} = w_{it} / A_{it} \mu l_{it}(\omega)^{\mu-1} h_{it}(\omega)^{1-\mu}$, $\int_{\Omega} h_{it}(\omega) = H_{it}$, and $\int_{\Omega} l_{it}(\omega) = L_{it}$ this gives the gravity equation in the text,

$$X_{ijt} = \frac{1}{\mu} \tau_{ijt}^{1-\sigma} \left(\frac{w_{it}}{\mu A_{it} L_{it}^{\mu-1} H_i^{1-\mu}} \right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.5}$$

The utility of an individual moving from region i to region j at time t is given by

$$V_{ijt} = \frac{V_{jt}}{\mu_{ij}}\epsilon_j, \tag{A.6}$$

where ϵ_j follows the Fréchet-distribution. π_{ijt} is the fraction of young individuals in region i with a large enough shock to move from i to j. This happens if $Pr\left(V_{ijt} \geq \{V_{ikt}\}_{\forall k\in R}\right)$. The number of young leaving i for j is then given by $L_{ijt} = \pi_{ijt}L_{it-1}$. Using that the shocks are iid. and properties of the Fréchet-distribution it follows that,

$$Pr\left(V_{ijt} \geq \{V_{ikt}\}_{\forall k\in R}\right) = \tag{A.7}$$

$$\int_{\mathbb{R}} Pr\left(u \geq \max_{k\in R}\{u_{ik}\}\right) dG(u) = \tag{A.8}$$

$$\int_{\mathbb{R}} \prod_{n=1}^{R} \exp\left\{-\left(\frac{V_{ik}}{\mu_{ik}}\right)^{\theta}\right\} dG(u) = \tag{A.9}$$

$$\frac{\left(V_{ij}/\mu_{ij}\right)^{\theta}}{\left(\sum_{j\in R} V_{ij}/\mu_{ij}\right)^{\theta}}. \tag{A.10}$$

The expression can be further simplified by defining the expected value of a young person in location i prior to the realization of the shock, $\mathbb{E}[\max_{k\in R}\{V_{ik}\}]$. To find this expression one needs to derive the cdf of $\max_{k\in R}\{V_{ik}\}$ which can be done in closed form using the properties of the Frechet distribution. In particular, it follows that,

$$Pr\left(\max_{k\in R}\{V_{ik}\} \leq v\right) = \tag{A.11}$$

$$\prod_{n=k}^{R} Pr\left(V_{ik} \leq v\right) = \tag{A.12}$$

$$\exp\left\{-v^{-\theta}\Phi\right\}, \tag{A.13}$$

where $\Phi = \sum_{k\in R}\left(V_{ik}/\mu_{ik}\right)^{\theta}$. From this it follows that the expected utility of a young individual in i before knowing the realization of the shock is given by,

$$\Gamma\left(1 - \frac{1}{\theta}\right)\Phi^{\frac{1}{\theta}}, \tag{A.14}$$

where $\Gamma(\cdot)$ is the gamma function. Using this, the expression in Equation (17) of the text follows.

Equilibrium Conditions. The equilibrium of the model is a sequence of the endogenous variables such that all goods markets clear in every period. These expressions are rewritten in order to solve the model numerically and provide proofs. The first condition determines that total sales are equal to the total income of the region in each period. This is guaranteed by $w_{it}L_{it}/\mu = \sum_{j\in R} X_{ijt}$. Using the gravity-equation for trade it follows that,

$$\frac{w_{it}L_{it}}{\mu} = \frac{1}{\mu}\sum_{j\in R}\tau_{ijt}^{1-\sigma}p_{it}^{1-\sigma}P_{jt}^{\sigma-1}w_{jt}L_{jt} \tag{A.15}$$

$$w_{it}^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{A_{it} \mu L_{it}^{\mu-1} H_i^{1-\mu}} \right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.16}$$

Next, using that $A_{it} = \bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2}$ it follows that,

$$w_{it}^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu \bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2} L_{it}^{\mu-1} H_i^{1-\mu}} \right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.17}$$

$$w_{it}^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu \bar{A}_i L_{it}^{\alpha_1+\mu-1} L_{it-1}^{\alpha_2} H_i^{1-\mu}} \right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.18}$$

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu \bar{A}_i L_{it-1}^{\alpha_2} H_i^{1-\mu}} \right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}, \tag{A.19}$$

where $\tilde{\alpha}_1 = \alpha_1 + \mu - 1$. Next, using that $V_{jt} = \frac{u_{jt} w_{jt}}{\mu P_{jt}}$ it follows that $P_{jt}^{\sigma-1} = \left(\frac{u_{jt} w_{jt}}{\mu V_{jt}} \right)^{\sigma-1}$. Substituting the price index gives and the amenity spillovers gives,

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} H_i^{1-\mu}} \right)^{1-\sigma} \left(\bar{u}_j L_{jt}^{\beta_1} L_{jt-1}^{\beta_2} \right)^{\sigma-1} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}, \tag{A.20}$$

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} H_i^{1-\mu}} \right)^{1-\sigma} \left(\bar{u}_j L_{jt-1}^{\beta_2} \right)^{\sigma-1} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}^{1+\beta_1(\sigma-1)}, \tag{A.21}$$

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} \bar{u}_j L_{jt-1}^{\beta_2} H_i^{1-\mu}} \right)^{1-\sigma} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}^{1+\beta_1(\sigma-1)}, \tag{A.22}$$

which equals the first equilibrium condition. The second condition ensures that all income in location i is spent on imports to location i in each period which is guaranteed by $\frac{w_{it} L_{it}}{\mu} = \sum_{j \in R} X_{jit}$. Again using the gravity equation for trade combined with the price index, productivity and amenity spillovers gives the following expression,

$$\frac{w_{it} L_{it}}{\mu} = \frac{1}{\mu} \sum_{j \in R} \tau_{jit}^{1-\sigma} p_{jt}^{1-\sigma} P_{it}^{\sigma-1} w_{it} L_{it}, \tag{A.23}$$

$$1 = \sum_{j \in R} \tau_{jit}^{1-\sigma} \left(\frac{w_{jt}}{\bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2} L_{it}^{\mu-1} H_i^{1-\mu}} \right)^{1-\sigma} \left(\frac{u_{it} w_{it}}{V_{it}} \right)^{\sigma-1}, \tag{A.24}$$

$$1 = \sum_{j \in R} \tau_{jit}^{1-\sigma} \left(\frac{w_{jt}}{\bar{A}_j L_{jt}^{\tilde{\alpha}_1} L_{jt-1}^{\alpha_2} H_j^{1-\mu}} \right)^{1-\sigma} \left(\frac{\bar{u}_j L_{jt}^{\beta_1} L_{jt-1}^{\beta_2} w_{it}}{V_{it}} \right)^{\sigma-1}, \tag{A.25}$$

$$w_{it}^{1-\sigma} L_{it}^{\beta_1(1-\sigma)} V_{it}^{1-\sigma} = \sum_{j \in R} \tau_{jit}^{1-\sigma} \left(\frac{1}{\bar{A}_j L_{jt-1}^{\alpha_2} H_j^{1-\mu} \bar{u}_i L_{it-1}^{\beta_2}} \right)^{1-\sigma} w_{jt}^{1-\sigma} L_{jt}^{\tilde{\alpha}_1(\sigma-1)}. \tag{A.26}$$

The third equilibrium condition ensures that the number of workers in the locality equals the number of workers exiting all other localities for i. This gives $L_{it} = \sum_{j \in R} L_{jit}$. Using the gravity equation which incorporates the migration decisions of the young directly gives the expression in the text.

$$L_{it} V_{it}^{-\theta} = \sum_{i \in \Omega} \mu_{jit}^{-\theta} \Pi_{jt}^{-\theta} L_{jt-1}. \tag{A.27}$$

The final equilibrium condition denotes that the number of people in the location in the last period equals the number of people who exited that location between t and $t+1$. This is guaranteed by $L_{it-1} = \sum_{j \in R} L_{ijt}$. Again using the gravity equation for migration it follows that,

$$L_{it-1} = \sum_{i \in \Omega} \mu_{ijt}^{-\theta} \Pi^{-\theta} L_{it-1} V_{jt}^{\theta}. \tag{A.28}$$

Uniqueness of the Equilibrium. The results that guarantee uniqueness of the equilibrium are found in Allen and Donaldson (2018) and **?**. Here I show how to calculate the conditions for uniqueness in the presence of land relying on the same techniques as in Allen and Donaldson (2018). First,

$$w_{it}^{1-\sigma} A_{it}^{\sigma-1} \propto P_{it}^{\sigma-1} w_{it} L_{it} \tag{A.29}$$

$$w_{it} \propto u_{it}^{\frac{\sigma-1}{1-2\sigma}} V_{it}^{\frac{1-\sigma}{1-2\sigma}} L_{it}^{\frac{1}{1-2\sigma}} A_{it}^{\frac{1-\sigma}{1-2\sigma}} \tag{A.30}$$

$$w_{it} \propto u_{it}^{-\tilde{\sigma}} V_{it}^{\tilde{\sigma}} L_{it}^{\frac{1}{1-2\sigma}} A_{it}^{\tilde{\sigma}} \tag{A.31}$$

which is then inserted in the first equilibrium condition in Definition (1) to yield,

$$\left(u_{it}^{-\tilde{\sigma}} V_{it}^{\tilde{\sigma}} L_{it}^{\frac{1}{1-2\sigma}} A_{it}^{\tilde{\sigma}} \right)^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{L_{it}^{\mu-1} H_i^{1-\mu}} \right)^{1-\sigma} A_{it}^{\sigma-1} u_{jt}^{\sigma-1} \left(u_{jt}^{-\tilde{\sigma}} V_{jt}^{\tilde{\sigma}} L_{jt}^{\frac{1}{1-2\sigma}} A_{jt}^{\tilde{\sigma}} \right)^{\sigma} V_{jt}^{1-\sigma} L_{jt}, \tag{A.32}$$

$$V_{it}^{\tilde{\sigma}\sigma} L_{it}^{\frac{\sigma}{1-\sigma}\tilde{\sigma}+1} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu H_i^{1-\mu}} \right)^{1-\sigma} L_{it}^{(1-\mu)(1-\sigma)} A_{it}^{\sigma-1-\tilde{\sigma}\sigma} u_{it}^{\tilde{\sigma}\sigma} u_{jt}^{\sigma-1-\tilde{\sigma}\sigma} L_{jt}^{\frac{\sigma}{1-\sigma}\tilde{\sigma}+1} A_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{1-\sigma+\tilde{\sigma}\sigma}. \tag{A.33}$$

Inserting the agglomeration spillovers gives the following three equilibrium conditions,

$$\begin{aligned} V_{it}^{\tilde{\sigma}\sigma} L_{it}^{\sigma(1-\alpha_1-\beta_1\sigma\tilde{\sigma})-(1-\mu)(1-\sigma)} = {} & \textstyle\sum_{j \in R} \left(\frac{\tau_{ijt}}{\mu H_i^{1-\mu}} \right)^{1-\sigma} \bar{A}_i^{(\sigma-1)\tilde{\sigma}} \bar{u}_{it}^{\tilde{\sigma}\sigma} \bar{u}_{jt}^{\tilde{\sigma}(\sigma-1)} \bar{A}_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{\tilde{\sigma}(1-\sigma)} \\ & L_{it-1}^{\tilde{\sigma}(\alpha_2(\sigma-1)+\sigma\beta_2)} L_{jt-1}^{\tilde{\sigma}(\beta_2(\sigma-1)+\alpha_2\sigma)} L_{jt}^{\tilde{\sigma}(1+\beta_1(\sigma-1)+\alpha_1\sigma))}. \end{aligned} \tag{A.34}$$

The following equations therefore pin down the equilibrium of the model,

$$\begin{aligned} V_{it}^{\tilde{\sigma}\sigma} L_{it}^{\tilde{\sigma}(1-\alpha_1(\sigma-1)-\beta_1\sigma)-(1-\mu)(1-\sigma)} = {} & \textstyle\sum_{j \in R} \left(\frac{\tau_{ijt}}{\mu H_i^{1-\mu}} \right)^{1-\sigma} \bar{A}_i^{(\sigma-1)\tilde{\sigma}} \bar{u}_{it}^{\tilde{\sigma}\sigma} \bar{u}_{jt}^{\tilde{\sigma}(\sigma-1)} \bar{A}_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{\tilde{\sigma}(1-\sigma)} \\ & \times L_{it-1}^{\tilde{\sigma}(\alpha_2(\sigma-1)+\sigma\beta_2)} L_{jt-1}^{\tilde{\sigma}(\beta_2(\sigma-1)+\alpha_2\sigma)} L_{jt}^{\tilde{\sigma}(1+\beta_1(\sigma-1)+\alpha_1\sigma))}. \end{aligned} \tag{A.35}$$

$$\Pi_{it}^{\theta} = \sum_{i \in R} \mu_{ij}^{-\theta} V_{jt}^{\theta}. \tag{A.36}$$

$$L_{it}V_{it}^{-\theta} = \sum_{i\in R} \mu_{ji}\Pi_{jt}^{-\theta}L_{jt-1}, \tag{A.37}$$

Ordering the endogenous variables as L, V, Π gives the following matrices of coefficients,

$$\mathbf{B} = \begin{bmatrix} \tilde{\sigma}(1-\alpha_1(\sigma-1)-\beta_1\sigma)-(1-\mu)(1-\sigma) & \tilde{\sigma}\sigma & 0 \\ 0 & 0 & \theta \\ 1 & -\theta & 0 \end{bmatrix}, \tag{A.38}$$

$$\mathbf{\Gamma} = \begin{bmatrix} \tilde{\sigma}(1+\beta_1(\sigma-1)+\alpha_1\sigma)) & \tilde{\sigma}(1-\sigma) & 0 \\ 0 & \theta & 0 \\ 0 & 0 & -\theta \end{bmatrix}. \tag{A.39}$$

Taking the inverse of $\mathbf{B}$ gives,

$$\mathbf{B}^{-1} = \frac{1}{(b_{11}\theta+\tilde{\sigma}\sigma)\theta}\begin{bmatrix} \theta^2 & 0 & \tilde{\sigma}\sigma\theta \\ \theta & 0 & -b_{11}\theta \\ 0 & b_{11}\theta+\tilde{\sigma}\sigma & 0 \end{bmatrix} \tag{A.40}$$

Therefore,

$$\mathbf{A} = \mathbf{\Gamma}\mathbf{B}^{-1} = \frac{1}{(b_{11}\theta+\tilde{\sigma}\sigma)\theta}\begin{bmatrix} \gamma_{11}\theta^2+\gamma_{12}\theta & 0 & \gamma_{11}\tilde{\sigma}\sigma\theta-\gamma_{12}b_{11}\theta \\ \theta^2 & 0 & -b_{11}\theta^2 \\ 0 & -\theta(b_1 1\theta+\tilde{\sigma}\sigma) & 0 \end{bmatrix} \tag{A.41}$$

Then, using Proposition 1 in Allen and Donaldson (2018), the equilibrium is unique if,

$$\rho(\mathbf{A}) \leq 1, \tag{A.42}$$

where,

$$\mathbf{A} = \frac{1}{(b_{11}\theta+\tilde{\sigma}\sigma)\theta}\begin{bmatrix} \gamma_{11}\theta^2+\gamma_{12}\theta & \gamma_{11}\tilde{\sigma}\sigma\theta-\gamma_{12}b_{11}\theta \\ \theta^2 & -b_{11}\theta^2 \end{bmatrix}. \tag{A.43}$$

Under the baseline calibration $\rho(A) = 0.972$. Therefore there exists a unique equilibrium.

Steady-state Multiplicity. Here I derive the conditions for the uniqueness/multiplicity of the steady-state of the model again relying on the results in **?** and Allen and Donaldson (2018). In the steady state $L_{it} = L_{it-1}$ for all $i \in R$ and all t. In order to ensure this, the number of people exiting a location must equal the number of people entering it, $\sum_{i\in R} L_{ijt} = \sum_{j\in R} L_{jit}$. Again, the destination and origin fixed effects must be proprtional which implies there exists a real numer Ω such that $V_i\Pi_i L_i^{\frac{1}{\theta}} = \Omega$ for all $i \in R$. This gives the following conditions in the steady,

$$\begin{aligned} V_{it}^{\tilde{\sigma}\sigma}L_i^{\tilde{\sigma}(1-(\alpha_1+\alpha_2)(\sigma-1)-(\beta_1+\beta_2)\sigma)-(1-\mu)(1-\sigma)} = \textstyle\sum_{j\in R}\left(\frac{\tau_{ijt}}{\mu H_i^{1-\mu}}\right)^{1-\sigma} \bar{A}_i^{(\sigma-1)\tilde{\sigma}}\bar{u}_{it}^{\tilde{\sigma}\sigma}\bar{u}_{jt}^{\tilde{\sigma}(\sigma-1)} \\ \times \bar{A}_{jt}^{\tilde{\sigma}\sigma}V_{jt}^{\tilde{\sigma}(1-\sigma)}L_{jt}^{\tilde{\sigma}(1+(\beta_1+\beta_2)(\sigma-1)+(\alpha_1+\alpha_2)\sigma))}, \end{aligned} \tag{A.44}$$

$$V_i^{-\theta} L_i = \sum_{i \in R} \mu_{ij}^{-\theta} V_j^{\theta}, \tag{A.45}$$

Writing out the system gives the following matrices of coefficients,

$$\mathbf{B} = \begin{bmatrix} \tilde{\sigma}(1 - (\alpha_1 + \alpha_2)(\sigma - 1) - (\beta_1 + \beta_2)\sigma) - (1-\mu)(1-\sigma) & \tilde{\sigma}\sigma \\ 1 & \theta \end{bmatrix}, \tag{A.46}$$

$$\mathbf{\Gamma} = \begin{bmatrix} \tilde{\sigma}(1 + (\beta_1 + \beta_2)(\sigma - 1) + (\alpha_1 + \alpha_2)\sigma)) & \tilde{\sigma}(1-\sigma) \\ 0 & \theta \end{bmatrix}. \tag{A.47}$$

Which again gives the following conditions for uniqueness,

$$\rho(\mathbf{A}) \leq 1, \tag{A.48}$$

where $\mathbf{B} = \mathbf{\Gamma}\mathbf{B}^{-1}$ and given by,

$$\mathbf{A} = \frac{1}{(b_{11}\theta + \tilde{\sigma}\sigma)\theta} \begin{bmatrix} \gamma_{11}\theta^2 + \gamma_{12}\theta & \gamma_{11}\tilde{\sigma}\sigma\theta - \gamma_{12}b_{11}\theta \\ \theta^2 & -b_{11}\theta^2 \end{bmatrix}. \tag{A.49}$$

In the baseline calibration of the model $\rho(A) = 3.35$.

Model Inversion. To back out the relationships between the endogenous variables and the the following variables are defined, $p_{it} = w_{it}/A_{it}\mu l_{it}(\omega)^{\mu-1}h_i(\omega)^{1-\mu}$, $\int_\Omega h_i(\omega) = H_i$, $\int_\Omega l_{it}(\omega) = L_{it}$ and $Y_{it} = L_{it}w_{it}/\mu$. The first equilibrium condition then becomes,

$$p_{it}^{\sigma-1} - \sum_{j \in R} T_{ijt} P_{jt}^{\sigma-1} \frac{Y_{jt}}{Y_{it}} = 0, \tag{A.50}$$

$$P_{it}^{\sigma-1} - \sum_{j \in R} T_{jit} \left(p_{jt}^{\sigma-1}\right)^{-1} = 0, \tag{A.51}$$

$$V_{it}^{-\theta} - \sum_{j \in R} M_{jit} \left(\frac{L_{jt-1}}{L_{it}}\right) \Pi^{-\theta} = 0, \tag{A.52}$$

$$\Pi^{-\theta} - \sum_{j \in R} M_{ijt} V_{jt}^{\theta} = 0. \tag{A.53}$$

Estimating equations. To arrive at the estimating equations (Equations 26 and 27) the definition of the agglomeration externality and indirect utility is used. Taking logs of $p_{it}^{\sigma-1} = \frac{w_{it}}{\mu \bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2} L_{it}^{\mu-1} H_i^{1-\mu}}$ and then taking the first difference gives,

$$\Delta \ln p_{it}^{\sigma-1} = (\sigma - 1)\Delta \ln w_{it} + \tilde{\alpha}_1(1-\sigma)\Delta \ln L_{it} + \alpha_2(1-\sigma)\Delta \ln L_{it-1} + (1-\sigma)\Delta \ln \bar{A}_i. \tag{A.54}$$

Using $V_{it} = \bar{u}_i L_{it}^{\beta_1} L_{it-1}^{\beta_1} w_{it} / P_{it} \mu$, taking logs and first-differences gives,

$$\Delta \ln V_{it}^{\theta} = \theta \Delta \ln w_{it} + \frac{\theta}{1-\sigma} \Delta \ln P_{it}^{\sigma-1} + \beta_1 \theta \Delta \ln L_{it} + \beta_2 \theta \Delta \ln L_{it-1} + \theta \Delta \ln \bar{u}_i. \tag{A.55}$$

A.1 Further Robustness Checks

Table A1: Correcting for spatial correlation

	(1)	(2)	(3)	(4)
Panel A: Town Formation				
Shipping Time (log)	-0.466***	-0.215***	-0.520***	-0.179***
	[0.024]	[0.022]	[0.035]	[0.023]
	(0.038)	(0.030)	(0.039)	(0.033)
Panel B: Population				
Shipping Time (log)	-0.909***	-1.336***	-1.198***	-1.02***
	[0.291]	[0.332]	[0.359]	[0.278]
	(0.032)	(0.033)	(0.404)	(0.311)
Panel C: Market Access (log)				
Shipping Time (log)	-6.411***	-4.495***	-7.201***	-0.545***
	[0.204]	[0.173]	[0.297]	[0.115]
	(0.210)	(0.176)	(0.353)	(0.093)
Viceroyalty FE	✓			
Audiencia FE		✓		
Port catchement FE			✓	
Grid-cell FE				✓
Observations	73,282	73,282	73,282	73,282

Note: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **Dependent variable Panel A:** An indicator variable taking the value 1 if the grid-cell contains a town. **Dependent variable Panel B:** Logarithm of grid-cell population size. **Dependent variable Panel C:** Logarithm of of market access. **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The full dataset contains **11 × 6,662 = 73,282 observations**. **Standard errors:** Conley standard errors with cutoff set to 5,000km in brackets. Robust standard errors in parenthesis. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table A2: Heterogeneity

Dependent variable:	Urban population			
	(1)	(2)	(3)	(4)
Panel A: Core				
Market Access	0.483***	0.497***	0.591***	0.797**
	(0.151)	(0.130)	(0.205)	(0.331)
Panel B: Semiperiphery				
Market Access	0.181	0.225*	0.227*	0.125
	(0.122)	(0.123)	(0.126)	(0.092)
Panel C: Periphery				
Market Access	0.455***	0.412**	0.402**	0.185
	(0.175)	(0.185)	(0.189)	(0.213)
Panel D: Coast				
Market Access	0.228**	0.247**	0.247**	0.161
	(0.106)	(0.112)	(0.113)	(0.177)
Panel E: Hinterland				
Market Access	0.128*	0.130	0.131*	0.098*
	(0.078)	(0.079)	(0.077)	(0.057)
Viceroyalty FE × Year		✓		
Audiencia FE × Year			✓	✓
Controls				✓
Observations	59,147	59,147	59,147	59,147
Adjusted R-squared	0.096	0.098	0.101	0.102

Note: The unit of analysis is at a 0.5°×0.5° grid-cell. **Dependent variable:** Urban population of the grid-cell (ihs) **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. All specifications include grid-cell fixed-effects. **The core** denotes the audiencias of Charcas, Lima, and Mexico (1,009 cells $\times 11 = 11,099$ observations), **the periphery** the audiencias of Buenos Aires, Santiago, Caracas, (1,284 cells $\times 11 = 14,124$ observations) and the **semiperiphery** Quito, Santa Fe, Confines, Santo Domingo, Guadalajara, Cuzco (1,534 cells $\times 11 = 16,874$ observations). 2,835 cells do not pertain to an audiencia. **Coastal** denotes the grid cell being less than 100km from the coast. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

A3: Heterogeneity

Dependent variable:	Population density			
	(1)	(2)	(3)	(4)
Panel A: Core				
Market Access	1.118***	1.163***	1.182***	1.314***
	(0.069)	(0.113)	(0.122)	(0.209)
Panel B: Semiperiphery				
Market Access	0.836***	0.879***	0.894***	0.884***
	(0.088)	(0.091)	(0.096)	(0.066)
Panel C: Periphery				
Market Access	0.897***	0.903***	0.897***	0.744***
	(0.148)	(0.148)	(0.151)	(0.095)
Panel D: Coast				
Market Access	0.683***	0.721***	0.752***	0.652***
	(0.107)	(0.100)	(0.098)	(0.134)
Panel E: Hinterland				
Market Access	0.622***	0.664***	0.643***	0.624***
	(0.046)	(0.047)	(0.048)	(0.066)
Viceroyalty FE × Year		✓		
Audiencia FE × Year			✓	✓
Controls				✓
Observations	59,147	59,147	59,147	59,147
Adjusted R-squared	0.706	0.718	0.714	0.716

Note: The unit of analysis is at a 0.5°×0.5° grid-cell. **Dependent variable:** Population density of grid-cell (ihs). **Observations:** The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. All specifications include grid-cell fixed-effects. **The core** denotes the audiencias of Charcas, Lima, and Mexico (1,009 cells $\times 11 = 11,099$ observations), **the periphery** the audiencias of Buenos Aires, Santiago, Caracas, (1,284 cells $\times 11 = 14,124$ observations) and the **semiperiphery** Quito, Santa Fe, Confines, Santo Domingo, Guadalajara, Cuzco (1,534 cells $\times 11 = 16,874$ observations). 2,835 cells do not pertain to an audiencia. **Coastal** denotes the grid cell being less than 100km from the coast. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

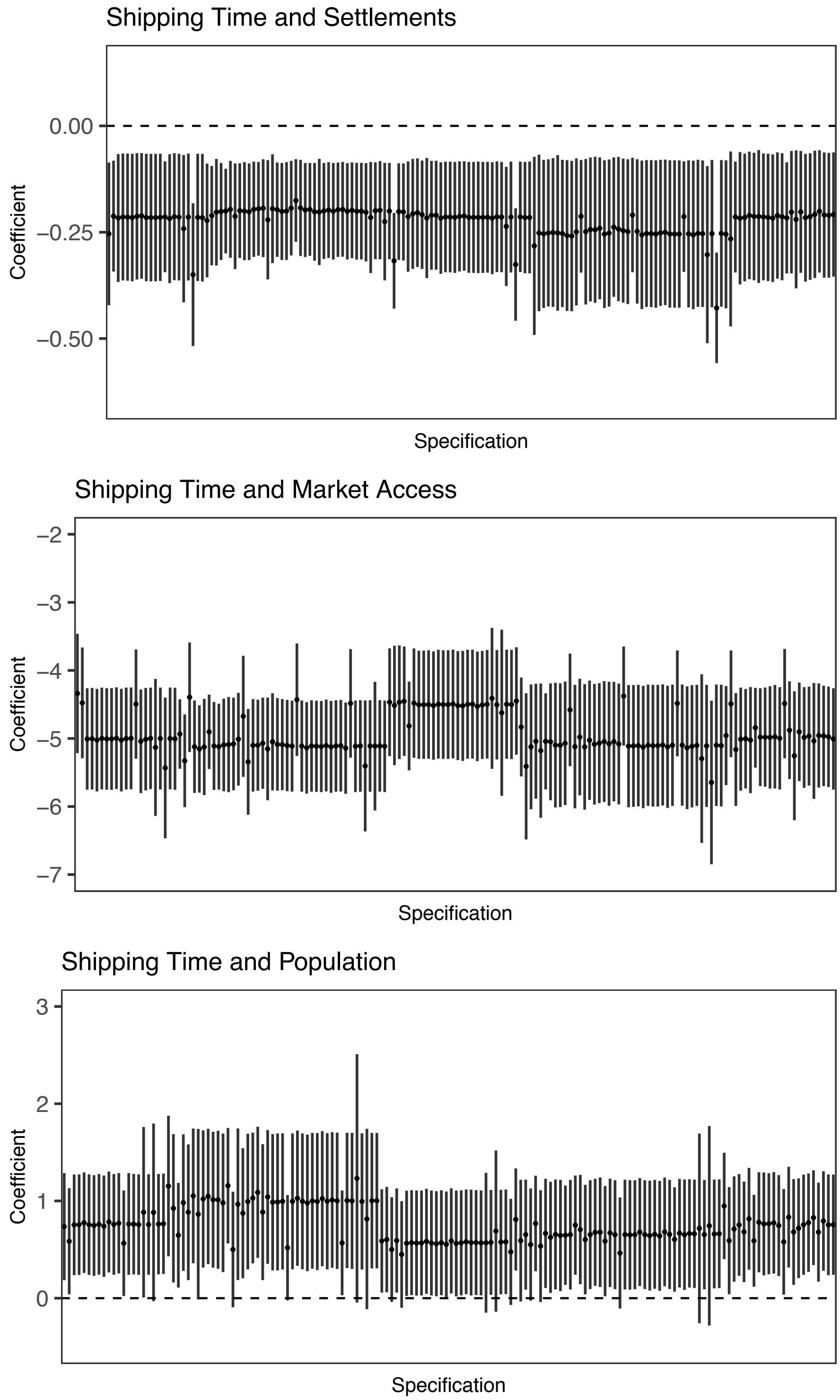

Figure A1: The figure shows the estimated coefficients from the different specifications reported in the paper. The top figure shows the estimated coefficient of the probability of a grid-cell containing a town on shipping time. The middle figure shows the coefficients from regressions where the population size of the grid-cell is regressed on shipping time. The bottom figure shows market access regressed on shipping time. For each specification, the catchment area of one is removed from the sample.

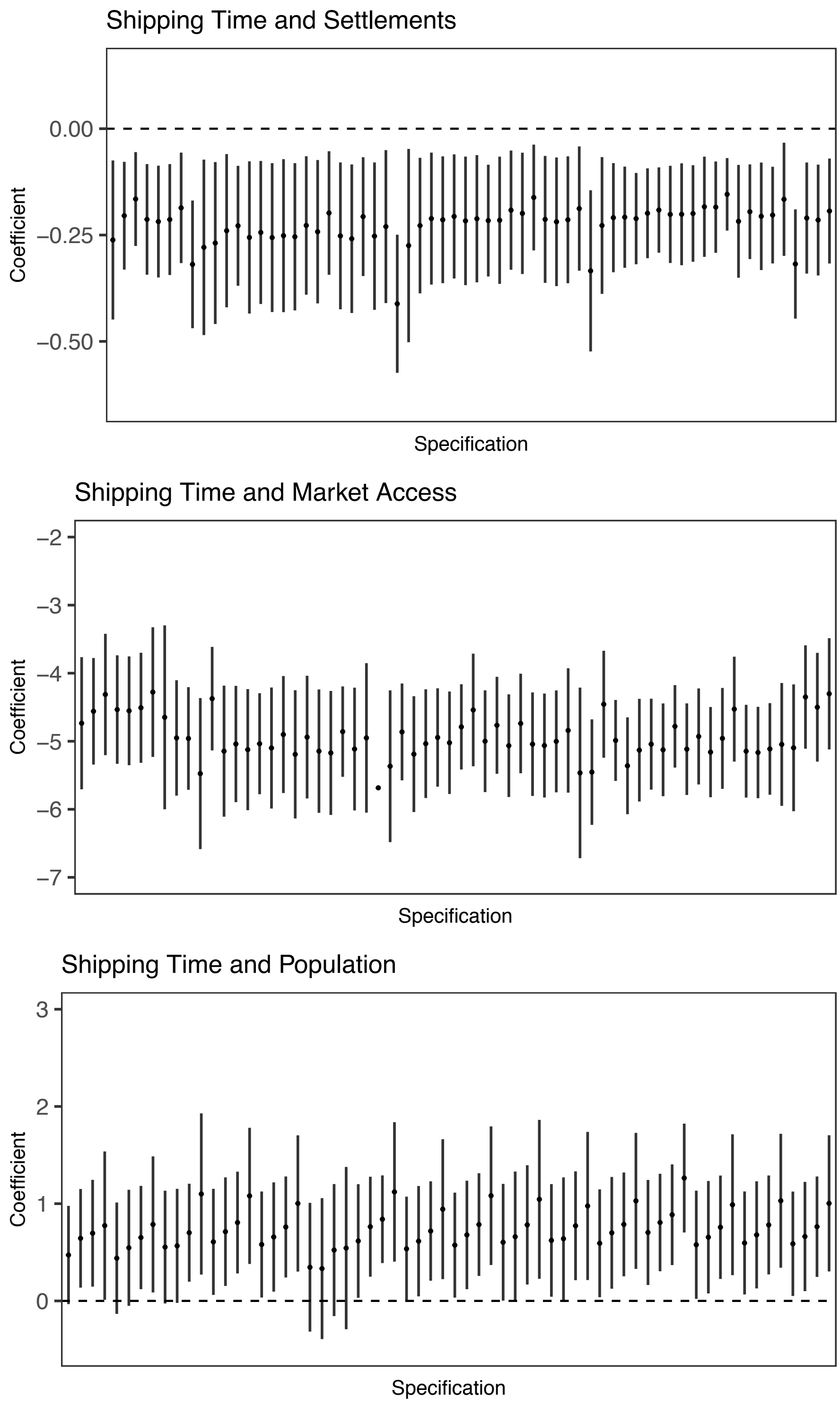

Figure A2: The figure shows the estimated coefficients from the different specifications reported in the paper. The top figure shows the estimated coefficient of the probability of a grid-cell containing a town on shipping time. The middle figure shows the coefficients from regressions where the population size of the grid-cell is regressed on shipping time. The bottom figure shows market access regressed on shipping time. For each specification, an audiencia is removed from the sample.

Figure A3: The left map shows study region partitioned in 0.5°×0.5° grid-cells which is used as the baseline. The right map shows the resoultion used as a robustness check with larger grid cells (1°×1°).

A.2 Changes in Gradients in Distance to the Coast

Did the reform promote the formation of settlements in coastal areas? This section presents evidence on the changing role of coastal proximity in determining the location of new settlements. In particular, the change of the effect of coastal proximity is compared between places in which the reform substantially lowered shipping times to Europe to places where the changes were minor. Consider the following triple difference-in-differences specification,

$$\begin{aligned} y_{i(t,a)} &= \alpha_a + \beta_1 \text{Coast}_i + \beta_3 \text{Free}_i + \beta_2 \text{Post}_t + \\ &\quad \phi_1(\text{Free}_i \times \text{Post}_t) + \phi_2(\text{Coast}_i \times \text{Post}_t) + \phi_3(\text{Free}_t \times \text{Coast}_i) + \\ &\quad \theta(\text{Free}_i \times \text{Coast}_i \times \text{Post}_t) + \epsilon_{i(t,a)} \end{aligned} \tag{A.56}$$

where $Coast_i$ denotes the (log) distance to the coastline, $Free_i$ denotes a measure of the reduction in shipping times (either the difference in shipping times between 1760 and 1810 or higher than median difference),[1] and $Post_t$ is an indicator variable taking the value one after 1765. Estimating $\theta > 0$ is consistent with the trade reform accelerating the formation of new settlements in coastal areas.

The results are found in Table 4. All specifications control for grid-cell as well as *audiencia* $\times$ decade fixed-effects. Column (1) shows the average increase in the coastal gradient after the reform. It shows there is a larger reduction in the probability of a grid-cell containing a city away from the coastline. A ten percent reduction in coastal proximity has an 8 percentage point larger negative effect on the probability of a city after the reform. Column (2) and Column (3) considers the differential increase in the coastal gradient depending on the size of the reduction in time. The interaction shows that areas that were affected by the trade reform experienced an even larger increase in the importance of coastal proximity after the reform. While the probability of a settlement declines by 0.7 percentage points after the reform on average, for places with higher exposure to the reform it decreases by almost twice that amount, 0.15 percentage points. Column (3) shows this result is robust to controlling the main control variables. This effect is both economically and statistically significant (the joint significance of the coefficients having a p-value of 0.059). Is this effect also more pronounced in the periphery? Column (4) and Column (5) addresses this question. The interaction between the differential change in the effect of coastal proximity is larger in the periphery. This shows that the importance of coastal proximity increases more for treated areas in the periphery. Taken together, the effects in Table 4 show that the reform accelerated city formation in coastal areas. This effect is especially pronounced in the periphery.

[1] This definition of the variable is used in the baseline specification to facilitate interpretation of the coefficients. The results are robust to using the continuous measure of shipping times directly.

Table 9: Market Access and Coastal Cities

Dependent variable:	Indicator variable for grid-cell containing a town				
	(1)	(2)	(3)	(4)	(5)
Free × Post		0.006	−0.025	−0.158***	−0.182***
		(0.042)	(0.034)	(0.056)	(0.045)
Coast × Post	−0.017***	−0.016***	−0.019***	−0.020***	−0.020***
	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)
Periphery × Post				−0.072	−0.027
				(0.047)	(0.045)
Free × Coast × Post		−0.001	0.005	0.038***	0.042***
		(0.006)	(0.005)	(0.011)	(0.009)
Free × Periphery × Post				0.246***	0.227***
				(0.060)	(0.058)
Coast × Periphery × Post				0.008	0.002
				(0.007)	(0.008)
Free × Coast × Periphery × Post				−0.050***	−0.049***
				(0.011)	(0.010)
Controls × Decade FE			✓		✓
Observations	73,282	73,282	73,282	73,282	73,282
Adjusted R-squared	0.851	0.851	0.852	0.853	0.853

Note: Specifications contain grid-cell and viceroyalty × year fixed-effects. **The dependent variable** is a dummy taking the value one if the grid-cell contains a city. The dataset is a balanced panel at a 10 year frequency for the period 1720-1820 of 6,662 grid cells (**11 × 6,662 = 73,282 observations**). ***Periphery*** is indicator taking the value one if the grid-cell falls within the audiencias of Buenos Aires, Caracas, Santiago or outside areas pertaining to an audiencia, ***Free*** takes the value one if the grid-cell has above median reduction in shipping time, ***Post*** is one for observations after 1765. ***Coastdist*** is the log distance to the coastline. **Controls** include elevation, average slope, the terrain ruggedness index, longitude and latitude. **Standard errors** are clustered at the level of the closest port. $^{***}p < .01$, $^{***}p < .05$, **

B Data Sources

B.1 Settlements

Figure A4: The left map shows the location of settlements in 1710 and 1810 for the settlement types *Poblacion*, *Villa*, and *Ciudad*. The black cells are cells which overlap a settlement. The dark lines denote the viceroyalty borders of 1790. Source: HGIS Indias.

The city *cidudad* was the highest legal category given a settlement in the Spanish Empire. The founding of cities were typically conscious efforts by the crown to ensure territorial control, rather than naturally occurring through population growth. Several were founded in localities where large population centers already were located. Moreover, towns were in some cases upgraded to receive city status. Few settlements with the status of city were founded during the study period, however, several settlements were founded that later would evolve into large population centers. The town *villa* was a legal status granted a settlement in the Spanish Empire. Also the founding of cities were typically conscious efforts by the crown to ensure territorial control, rather than naturally occurring through population growth. The formation of new towns was frequent throughout the study period.

B.2 Potential Vegetation

Global potential vegetation data is from the Center for Sustainability and the Global Environment (SAGE). The data is representative of the world's "potential" vegetation, that is vegetation that would most likely exist now in the absence of human activities. The data consists of a global map of natural vegetation at a 5 min resolution classified into 15 vegetation types. These are:

- Tropical evergreen forest/woodland
- Tropical deciduous forest/woodland
- Temperate nroadleaf evergreen forest/woodland
- Temperate needleleaf evergreen forest/woodland
- Temperate deciduous forest/woodland
- Boreal evergreen forest/woodland
- Boreal deciduous forest/woodland
- Evergreen/deciduous mixed forest/woodland
- Savanna
- Grassland/steppe
- Dense shrubland
- Open shrubland
- Tundra
- Desert
- Polar desert/rock/ice

The data is available at https://nelson.wisc.edu/sage/data-and-models/global-potential-vegetation/index.php. Details about the construction of the data can be found in Ramankutty and Foley (1999).

B.3 Agricultural Yield

I use a measure of agricultural potential constructed by Galor and Özak (2015, 2016). The data measure the maximum attainable yield measured in calories that can be achieved for a variety of crops. Agricultural productivity is the maximum potential production capacity in tons per hectare over the seventeen crops

- buckwheat
- barley
- chickpea
- foxtail millet
- groundnut
- maize
- oat
- pearl millet
- wetland rice
- rape
- rye
- sunflower
- soybean
- sweet potato
- sorghum
- wheat
- white potato

B.4 Climate and Temperature

Data on climate and temperature are from the WorldClim global climate database. The data spans (1960-1990) at 5 minute resolution. See https://www.worldclim.org/data/bioclim.html for the data source. The following variables are included in the analysis:

- Annual Mean Temperature
- Mean Diurnal Range (Mean of monthly (max temp - min temp))
- Isothermality
- Temperature Seasonality (standard deviation ×100)
- Max Temperature of Warmest Month
- Min Temperature of Coldest Month
- Temperature Annual Range
- Mean Temperature of Wettest Quarter
- Mean Temperature of Driest Quarter
- Mean Temperature of Warmest Quarter
- Mean Temperature of Coldest Quarter
- Annual Precipitation
- Precipitation of Wettest Month
- Precipitation of Driest Month
- Precipitation Seasonality (Coefficient of Variation)
- Precipitation of Wettest Quarter
- Precipitation of Driest Quarter
- Precipitation of Warmest Quarter
- Precipitation of Coldest Quarter

B.5 Ruggedness, Slope, and Elevation.

The Terrain Ruggedness Index was developed in Elliot, DeGloria and Riley (1999). Follows the the classification:

- 0-80 - level terrain surface.
- 81-116 - nearly level surface.
- 117-161 - slightly rugged surface.
- 162-239 - intermediately rugged surface.
- 240-497 - moderately rugged surface.
- 498-958 - highly rugged surface.
- $>$ 959 - extremely rugged surface.

I measure ruggedness by the average standard deviation of elevation. Plains will score low in this measure, while mountains and valleys will score high. Elevation, terrain ruggedness, and the slope of the main study area are displayed in the following maps which shows they are all highly correlated.

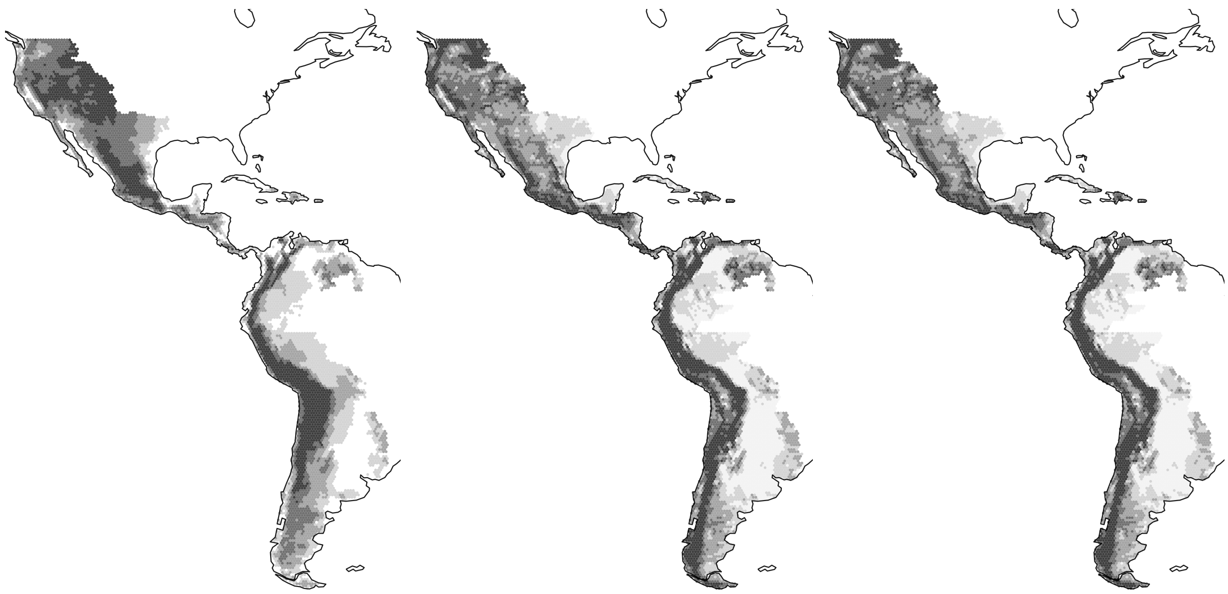

Figure A5: The left figure shows the average movement cost for each grid cell. Darker areas indicate less time consuming travel. The figure in the centre shows the residualized change in remoteness between 1750 and 1800 at the level of 6,662 0.5°×0.5° grid-cells. Brighter colors indicate larger reductions. The figure on the left shows the residualized change in market access 1750 and 1800 at the level of 6,662 0.5°×0.5° grid-cells. Brighter colors indicate larger increases

B.6 Measures of State Presence

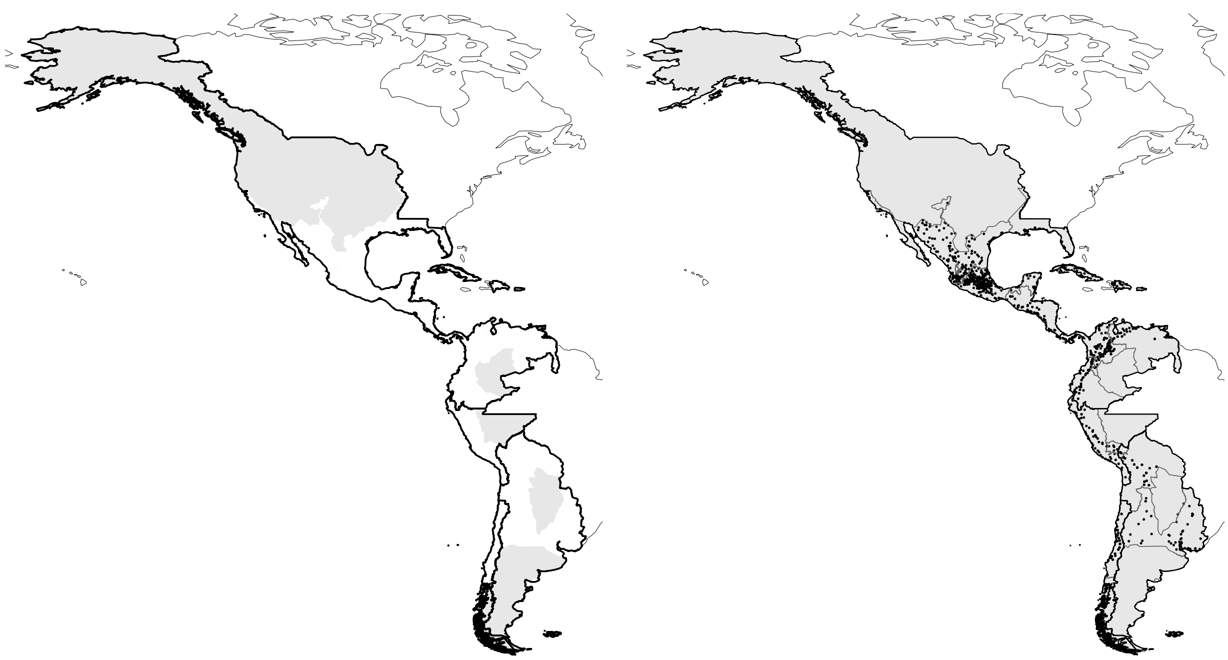

Figure A6: The left map shows the areas pertaining to an *audiencia* in 1790 in white. Areas outside and *audiencia* are colored in grey. The right map shows 897 post offices in Spanish America between 1710 and 1810.

Two measures of state capacity are used in the paper. First, territorial organization is informative about the de-facto territorial reach of the state. This is more apparent in the context of the *audiencia* which tended to cover areas more firmly in Spanish control in the 18th century. Second, I consider the role of post offices which has been extensively used in the literature to proxy for historical state capacity. To this end, I use a datasets of around 900 post-offices that were in operation in the 18th century.

C Further Robustness Checks

C.1 Cross-validating Hyde 3.1 and Census Data

Demographic data consisting of historical census data. It contains demographic data for various administrative entities between 1700 and 1820. The data is not complete, but nevertheless contains 900 observations for the period 1701-1810 for various administrative units. It is worth noting that the historical census data clearly also imperfectly reflect the true population counts, reflecting the bias that is inherent in historical data of this nature. The following administrative units are included in the dataset.

- Provincia
- Provincia menor
- Provincia mayor
- Partido
- Obispado
- Jurisdiccion
- Intendencia

The dataset comes with shapefiles delineating the territory of each administrative unit. These shapefiles are used to aggregate the population data implied by Hyde 3.1. This dataset is a raster file of population density spanning the whole study region at 10-year intervals. It extrapolates of various historical population statistics to create granular population data. Here I assess the quality of this extrapolation by cross-validating against historical census data. A scatter plot of the observations in the two datasets can be seen in the figure below. Moreover, I consider the overall distribution of the two datasets. Overall, the two datasets match fairly well. I find that the raw correlation between the two datasets is 0.77. From the scatter plot it is apparent that the two datasets line up more poorly for smaller administrative units, while they match better for larger ones. The distributions of the two variables overlap to high extent.

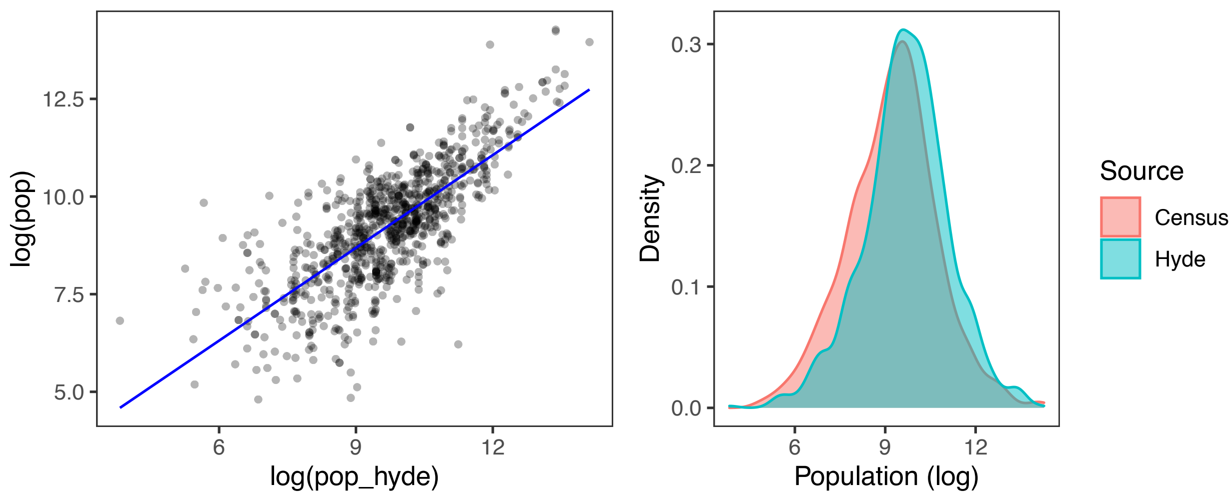

Figure A7: The figure shows the relationship between population counts in census data and in Hyde 3.1. The left figure is a scatter plot of the logarithm of the two variables. The righ figure shows the density plots of the two variables.

References

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