# Long-Distance Trade and Long-Term Persistence*

Sebastian Ellingsen

**Abstract**

The spatial distribution of economic activity depends largely on market access and history, but countries differ greatly in the extent to which their geographies reflect 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 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 provide evidence that a key determinant of persistence in the location of economic activity is the level of development of a country as it opens up to trade.

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

*This version: September 27, 2021. Click here for the latest version. I thank Maria Petrova and Giacomo Ponzetto for their support and supervision on this project. I thank Dávid Nagy, Luigi Pascali, Jaume Ventura, Treb Allen, Stephan Maurer, Jenny Chan, Alessandro Tarozzi, Mohamed Saleh, Gino Gancia, and Felipe Valencia, as well as seminar participants at Pompeu Fabra, Bristol, Nottingham, UBC Sauder, Oxford, Stockholm School of Economics, the University of Oslo, USC, the UEA PhD Student Workshop in Urban Economics, NBER Summer Institute, the Frisch Center, the Econometric Society World Congress, DEVPEC, YES, the 42nd Annual Meeting of the Norwegian Association of Economists, Ridge, and SAEe, the BGSE Jamboree, and the International Lunch and Applied Seminar at Pompeu Fabra. for their valuable comments and suggestions, which substantially improved this paper. Department of Economics, Dartmouth. Email: sebatke@gmail.com. Website: sebastianellingsen.github.io.

# 1 Introduction

The spatial distribution of economic activity is shaped by market access and history. However, the economic geographies of different countries differ significantly in the extent to which they reflect each of these two determinants. Market access is particularly important for city location in the United States; this is evident when one considers that the two largest cities are also the two largest international ports (New York and Los Angeles). Other urban systems, with large cities centered around former imperial capitals (e.g., Rome, Beijing, and Delhi), reflect historical precedent to a much larger extent. What determines the relative importance of market access versus history in determining the spatial distribution of economic activity in different places? Do urban systems adapt to changes in the trading environment? 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. Early Spanish commercial policy 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, this number had increased to 45 by the beginning of the 19th century. By this time, no major ports in the empire were subjected to restrictions on the direct trade of goods with Europe (see Figure 1). The reform reduced trade costs in different years and different locations. This variation is 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.[1] Second, the geographic scope of the reform allows us 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 is compelling in terms of external validity.

I study the long-run impact of the reform 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 various geographic features that determined mobility, such as elevation and landcover, as well as infrastructures, such as roads and ports. I validate the resulting shipping times with various historical and contemporary sources, confirming the accuracy of my 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 that were in place in a given decade. This results in bilateral shipping time matrices for each decade between 1710 and 1810. These time-varying measures of bilateral shipping times are then matched with data on geographical characteristics, agricultural productivity, and the locations of settlements to construct a balanced panel covering Spanish America between 1710 and 1810.

[1] This contrasts with standard approaches relying on changes in the effective distance for identification, which typically alter numerous aspects of long-distance communication. Examples in the literature are technological innovations in 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), and disruptions in transportation networks induced by conflict (Feyrer, 2009; Juhász, 2018).

I use this dataset to study the reduced form effect of lower international trade costs on the formation of new settlements and 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 settlements 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 find that the reform had large and heterogeneous effects on trade costs between Europe and America. While the shipping time was 6 days lower on average, the decrease ranges from 27 days to no changes for several locations. These reductions are relative to a pre-reform average of around 83 days.[2] These changes in trade costs in turn affected population growth and the formation of new settlements. In the preferred specification, a one standard deviation reduction in the shipping time (25 days) increases the probability of a cell containing a settlement by 4 percentage points. Next, I look at the heterogeneity of these effects. First, these effects were larger in macroregions with lower population density, showing that the economic geography was much more sensitive to changing trade costs in areas that were less densely populated. Consistent with these patterns, I show that the correlation between pre-colonial density and population density in the year 2000 is lower in areas more intensively treated by the reform. Taken together, these findings provide evidence that the opening of trade restructured the economic geographies of places that were initially less densely settled. In the long run, the location of economic activity came to reflect the location of trading opportunities. In places that adjusted less, the location of economic activity remained reflective of pre-colonial settlement patterns.

To assess the mechanisms and account for general equilibrium effects, I build a dynamic spatial general equilibrium model, building on the work of Allen and Arkolakis (2014) and Allen and Donaldson (2020).[3] I adapt this framework to the setting by incorporating land as a factor of production as well as time-varying trade costs. In this 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 frictions, and the utility derived from each location depends on locational fundamentals, agglomeration, and congestion forces. Agglomeration forces are a function of both contemporaneous and historical 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) were uncorrelated with changes in population during the reform period, conditional on a large set of controls. While this is an untestable assumption in practice, 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

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

[3] 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 and 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).

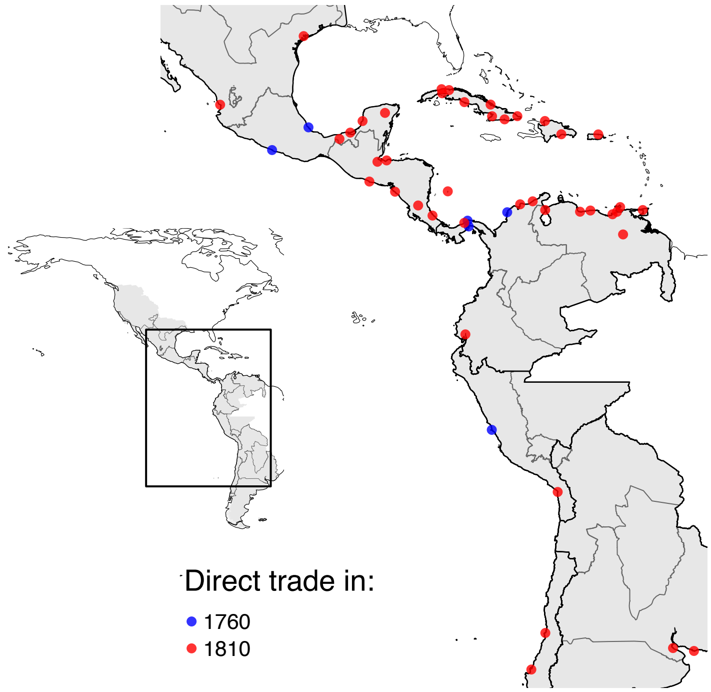


**Figure 1:** This map shows the extent of the territory claimed by the Spanish Empire in 1790 with its ports marked according to status. Ports marked in blue were licensed for long-distance trade prior to 1765 (Callao, Cartagena, Veracruz, Panama, and Acapulco), while those marked in red were licensed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

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 effects were larger in the periphery than in the core areas. Finally, it weakened the relationship between historical and contemporary population density. I then use the model to run a series of counterfactual simulations. In particular, I show that increased population concentration attenuated the impact of the reform. Taken together, 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 high. This provides further evidence that the initial conditions as a country opens up to trade shapes the importance of history relative to trade in determining the spatial distribution of economic activity. Locational fundamentals associated with maritime 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 the literature on the role of persistence in economic 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).[4] 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;

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

Miguel and Roland, 2011). These findings are consistent with the conclusion that location-specific factors, such as geographical fundamentals, fixed capital, and market access play an important role. However, Bleakley and Lin (2012) show population centers persist around historical portage sites after the technology has become obsolete; this points to an important role played by agglomeration economies. Indeed, Henderson et al. (2018) found that only 35 percent of the within-country variation in population density is explained by geographical fundamentals. While spatial persistence remains well-documented in various 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 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 locations of cities is the *sequencing* by which a location attains high population density and lower trade costs. History explains the location of economic activity 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 population density before opening up to trade. This paper therefore contributes to the literature by shedding light on when persistence matters in determining the spatial allocation of economic activity and the conditions under which it breaks down.

This paper also contributes to the literature exploring the long-term economic impacts 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). Furthermore, the results of this paper shed light on the findings of a seminal paper by Acemoglu, Johnson and Robinson (2002) in which they establish a negative relationship between population densities in 1500 and 2000 at the country level. They argue that the population density at the time of settlement shaped the incentives faced by early European settlers. In particular, lower initial population density necessitated that institutions enable broad participation in the economy to ensure subsistence. These institutions were more compatible with modern economic growth and therefore caused divergence between areas with different initial population densities starting in the second half of the 18th century. This paper complements these findings by highlighting the role of trade-related institutions in generating the increased growth in the periphery that Acemoglu, Johnson and Robinson (2002) document. The results are consistent with the view that the *reversal of fortune* is rooted in institutional change but also highlight the importance of the factors that shaped institutions governing trade, such as the transition from Habsburg to Bourbon rule in Spain, in addition to property rights, of which Acemoglu, Johnson and Robinson (2002) emphasize the importance. More broadly, this paper provides evidence of the impact of trade-related institutions on economic geography, which has received little attention in the literature (Acemoglu, Johnson and Robinson, 2005; Jha, 2013; Jia, 2014; Arteaga, 2016; Alvarez-Villa and Guardado, 2020).

Finally, this paper relates to the body of literature that considers the impact of trade on national income. Several papers have documented large, positive elasticities of national income with respect to trade (Frankel and Romer, 1999; Noguer and Siscart, 2005; Feyrer, 2009, 2019; Feyrer and Sacerdote, 2009; Pascali, 2017).[5] This is puzzling given that the gravity literature has documented more 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 the trade of 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 lower trade costs. In particular, changes in effective distance affect travel and migration costs. Moreover, within-country variation allows for the analysis of effect heterogeneity. This is difficult in cross-country studies partly due to sample size and the number of potential confounders. In sum, the results presented in this paper shed light on the mechanisms through which lower trade costs affect national income. Furthermore, I show that trade increased density and promoted the formation of settlements situated in locations with higher market access.

This 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 reform influenced long-term regional development patterns.

**The Spanish Commercial System.** A central aim of Spanish commercial policy was to promote state wealth acquisition through trade surpluses (Findlay and O'Rourke, 2007). To this end, several policies restricted Atlantic trade. First, points of entry and exit were restricted to four ports in the Americas (Cartagena de Indias, El Callao, Portobello/Nombre de Dios, and Veracruz) and only Seville/Cádiz in Europe. Further, the frequency of travel and the routes were restricted.[6] This facilitated naval defense of convoys and limited imports to the Americas, thus promoting a favorable trade balance. Moreover, it served to limit the flow of bullion to other places than the Iberian Peninsula and kept prices for Spanish exports artificially high (Baskes, 2013). Ships sailing under special permission of the crown (*registros*) supplied ports that were too remote relative to the large trade routes. However, this was never done at a sufficiently large scale (Walker, 1979) and increased the reliance on contraband trade which was sizeable (Christelow, 1942). Third, participation in Atlantic trade was restricted to Spanish merchants. Finally, there were high tax rates on imports and exports.[7] Mercantilist restrictions and high trade costs ensured that trade was limited to non-competing goods with a high value-to-weight

[5] There are several limitations to the earlier literature that has dealt 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).

[6] 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 (Walker, 1979). Moreover, the Manilla galleon would sail between Acapulco and Manilla. 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.

[7] The duties typically depended on the origin of the goods, with lower rates on goods originating from Spain.

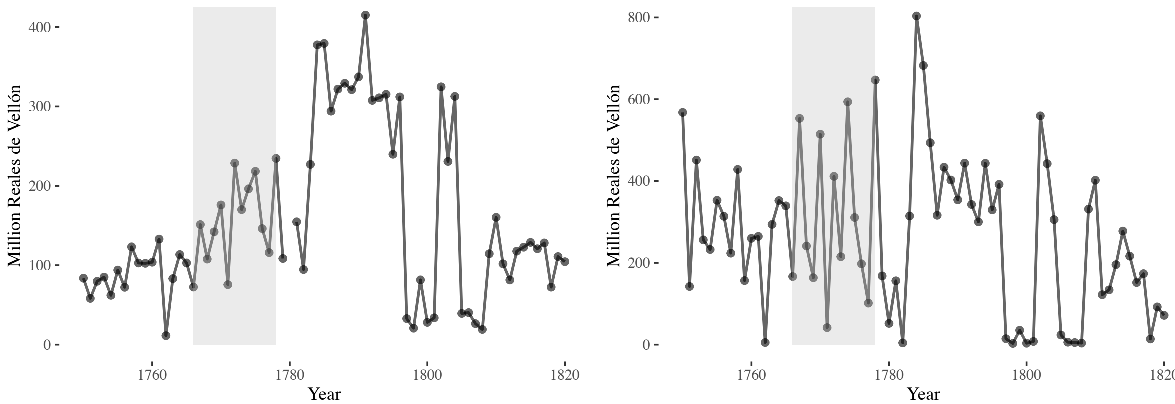


**Figure 2:** The left figure the value of non-bullion exports from Spain to American ports from 1750-1820. The right panel denotes bullion exports to Spain for a 1750-1820. The vertical lines denote the beginning and end of the main part of the liberalization. The large drop in 1797 is due to the British 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).

ratio.[8] Important exports beyond precious metals were hides, tallow, sugar, indigo, and cochineal (Rahn Phillips, 1990). While as a rule, there were no restrictions on inter-regional trade (Elliott, 2006, p. 111), a likely consequence of Spanish mercantilist policies before the liberalization in the late 18th century was the underdevelopment of peripheral areas in America (Fisher, 1997, p. 73).

**Reforming Trans-Atlantic Trade.** Beginning in the 18th century, Spanish policymakers were induced by geopolitical considerations, originating mainly in Europe, to overhaul the external trading system (Elliott, 2006). In the immediate aftermath of Spain's defeat in the Seven Years' War, a technical committee was appointed under Charles III to assess and reform the system. Drawing on ideas of reforming the system of government in America that had been circulating for a long time, 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).[9] Four ports in the Caribbean were opened already in 1765.[10] The liberalization measures culminated in the decree of free trade in 1778, which opened several of the remaining ports.[11] In the 1780s, the remaining ports followed. Spanish communication with the Americas was disrupted during the Napoleonic wars (O'Rourke, 2006). As a result, trade with neutral nations during the Napoleonic war was allowed. This marked the end of Spain's ability to enforce protected trade with the colonies. By the beginning of the 19th century, Spanish America enjoyed *de facto* although not *de jure* unrestricted

[8]The slave trade was subject to different 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).

[9]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).

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

[11]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 (Fisher, 1997). Even so, especially Veracruz was affected by the changes before the late 1780s due to the abolition of the convoy system and the increased prevalence of *registros*.

trade with foreigners (Fisher, 1998). As a result, direct trade with Britain, not mediated though Spain, grew in importance (Prados de la Escosura and Casares, 1983). Independence was laregly followed by high tariffs, mainly driven by the revenue needs of post independence governments (Coatsworth and Williamson, 2004).

The historical literature emphasizes the role of European interstate competition and the resulting increased need of a modernized imperial defense as motivating the reform. Thus, the drive to reform the Spanish commercial system can be understood as being motivated by the intense interstate competition between the European states of the 18th century (Kuethe and Andrien, 2014). Highlighted in the historical literature as an important impetus for the reform was the "humiliating" capture of Havana and Manila by the British during the Seven Years' war. This opened a window of opportunity for reform-minded policymakers in Spain who now could justify reforming the commercial system with 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 Development.** The reform affected economic growth in different regions. Formerly neglected regions such as *Rio de La Plata*, Venezuela, and Cuba became more important exporters of primary commodities. Lower trade costs induced by unrestricted sailing potentially allowed for specialization in a wider range of commodities, such as more perishable goods. 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 (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. Presumably, as a result of these developments, several 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, it has been argued that the population and economies of previously stagnant peripheral colonies in Spanish America grew rapidly (Bulmer-Thomas, 2003; Mahoney, 2010).[12] In summary, the historical

[12]Cadiz remained the dominant port for trade with Spanish America between 1778 and 1796 (76.4 percent of total exports

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.

# 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.[13] The dataset consists of 5,573 grid-cells of $0.5° \times 0.5°$.[14] It covers the 100 year-period 1710-1810, roughly corresponding to the Spanish Empire under the Bourbon dynasty. This results in a balanced panel of $5,573 \times 11 = 61,303$ observations. Summary statistics of the main variables can be found in Table 1.

## 3.1 Population and and Settlements

**Settlements.** I construct the main sample from a territorial gazetteer of around 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*).[15] 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 village in order to capture the location of population centers. This avoids common pitfalls associated with using population thresholds for defining a settlement. 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. The location of the place is determined by the functional center.[16] Altogether, the final dataset contains 2,125 places spanning 1710 and 1810, and 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 **??** 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

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).

[13]The contemporary countries partly or entirely contained in the sample 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.

[14]This constitutes around 55km at the equator. I also analyze different spatial resolutions and obtain similar results.

[15]"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 was mostly not written for giving geographic information but may touch one specific detail or incidentally exposes 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).

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

entities between 1710 and 1810. Unfortunately, this data is cross-sectional. 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.[17] It extrapolates from various historical population statistics to create granular population data spanning the whole globe. 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.[18] Further, I use city-level population data from Buringh (2013) which includes cities with more than 4,000 inhabitants. I restrict the dataset to cities for which there is data in 1750, which constitutes 211 cities that are observed in 1750 and 1800. Data on pre-colonial population density reflect consensus estimates from Denevan (1992). The estimates combine the most recent available geographical, anthropological, and archaeological findings (Maloney and Valencia, 2016). The data used in this paper have been made available by Bruhn and Gallego (2011) and Maloney and Valencia (2016). Finally, I include data on contemporary population density is from the Gridded Population of the World, which is distributed by the (CIESIN) at Columbia University.

## 3.2 Sailing and Trade

**Sailing data.** To estimate the sailing speeds, I combine information on maritime logbooks with data on wind patterns. In particular, I calculate average sailing speeds 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.[19] 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. Information on the average velocity and direction of the sea-surface winds by $0.5° \times 0.5°$ cells for each week between 2011 and 2017 is from the US National Oceanic and Atmospheric Administration (NOAA).[20].

**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 shipping times and the value of trade. Second, I use data on bilateral trade flows at the country level (Fouquin and Hugot, 2016). I restrict this dataset to be between 1820 and 1870 which roughly corresponds to the period before the diffusion of the steamship.

[17] 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). The years used in this analysis are 1500, 1600, 1700, 1710-1820 (by decade).

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

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

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

### 3.3 Geography and Infrastructure

**Geography.** I use high-resolution data on agricultural yields to proxy for agricultural land quality and suitability for important high-value export crops. Crop suitability for cotton, tobacco, sugarcane, and cacao is provided by FAO's Global Agro-Ecological 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 suitability under rain-fed, low-input agriculture. Second, I incorporate data on the potential agricultural output (measured in calories) to proxy income. I use a measure of the maximum attainable yield constructed by Galor and Özak (2015, 2016). 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 an indicator variable that takes the value one if the average elevation is below 1500m.[21] Finally, information on climatic variation is from Hijmans et al. (2005). Proxying 18th and 19th-century geographical characteristics with several of these data sources requires further assumptions. In particular, I assume that the values have remained fixed or only changed with the same factor across different locations.

**Infrastructure.** The trading status of each port is from the decree *Reglamento y aranceles reales para el comercio libre de España a Indias de 12. de octubre de 1778* (Ramíres Bibiano and Ortíz de la Tabla, 1978), as well as Fisher (1997). I validate these sources with various other secondary sources. Further, I include the location of the principal mining centers in the 18th century. These are in total 78 locations across the Spanish Empire 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 exports from Spanish America to Spain in the period. Finally, I use mail routes 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 from Natural Earth.

## 4 Shipping Times and Trade Costs

To estimate the impact of the reform, I compute trade costs between locations in the Spanish Empire in the 18th century. While trade costs in this context are a function of a range of factors, I exploit that trade costs have been widely documented to depend on distance both in contemporary and historical settings (Head and Mayer, 2014; Flückiger et al., 2019; Barjamovic et al., 2019). I leverage this by constructing a directed graph, where nodes denote localities and edges the shipping times

[21] 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 in a flexible manner.

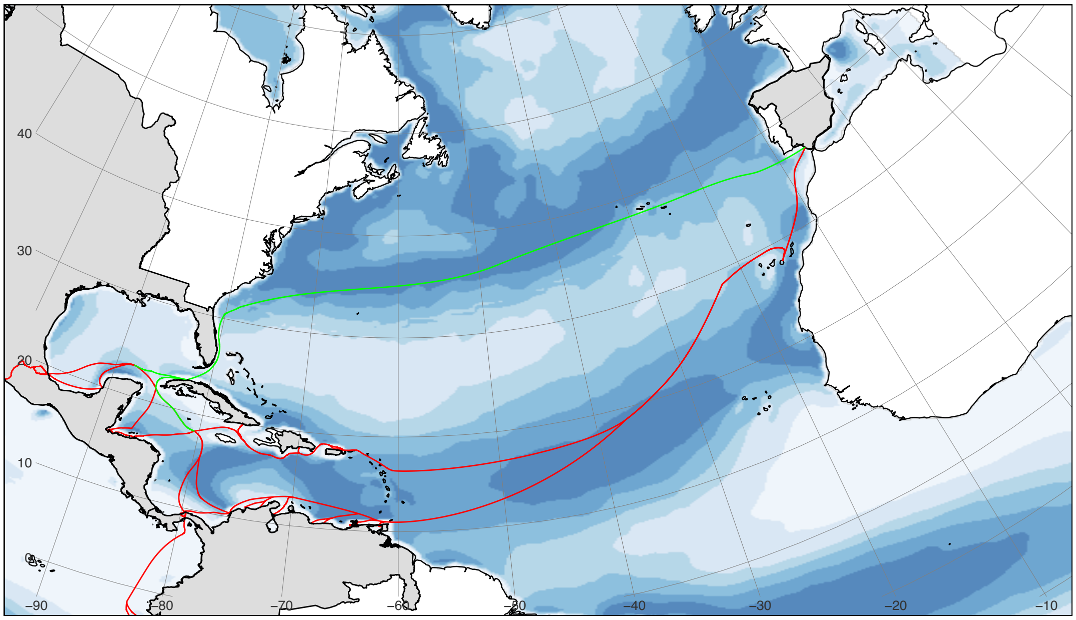


**Figure 3:** The figure shows the cost surface of maritime travel between 1750 and 1850. The map plots the average cost for each $1° \times 1°$ grid-cell where darker colors indicate that the cell can be crossed at higher speed. Grey areas denote territory claimed by the Spanish Empire in 1790. The 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.

to all adjacent localities (measured in days). Shipping times are calculated based on predetermined first-order determinants of mobility in the context, such as wind patterns, elevation, and infrastructure constructed before the reform. Using the graph, I calculate time minimizing trade routes, accounting for which ports were allowed to trade directly with Europe by decade. This section further elaborates on the procedure.

## 4.1 Estimating Trade Costs

**Maritime Transportation.** I estimate the sailing speed by using information from maritime logbooks in the 18th and early 19th centuries. From each logbook entry, I extract information on recorded wind speed, wind direction as well as travel direction. Figure 5 panel (a) shows the distribution of recorded wind directions and panel (b) travel speeds. The figure shows that the average sailing speed was around 5 knots and that most sailings took place in the direction of the wind or at 90 degrees where sails work most efficiently (Pascali, 2017; Kelly and Ó Gráda, 2019). To estimate the relationship between wind direction, wind speed, and sailing speed, I consider the following equation,

$$S_i = e^{f(\theta_i, s_i) + \epsilon_i}, \tag{1}$$

where $s_i$ measures the wind speed in grid-cell $i$, $\theta_i$ measures the deviation of the angle between the wind direction and direction of travel, and $S_i$ denotes the sailing speed. Given a large number of features, Equation 1 is estimated using an elastic net where tuning parameters are chosen optimally using 10-fold cross-validation (Zou and Hastie, 2005). The full sample ($N = 37,141$) is then split into a training sample (80 percent of the sample) and a validation sample. I fit the model on a training sample and then test its performance in a validation sample. The model predicts sailing speed accurately (with a mean absolute error of 1.48 in the preferred model). Next, I average high-resolution data on wind speed and wind direction from NOAA weekly over the period 2011-2017. For every node in the graph, I then calculate the wind speed and wind direction between all adjacent nodes and use $\hat{S}_i$ to calculate the predicted sailing time.[22]

**Overland Transportation.** Long-distance transportation on land relied on pack animals at least until the second half of the 19th century. I calculate the costs faced by shipping with pack animals using geographical features, drawing on least-cost analysis tools from archaeology (White, 2015). The pace will depend on whether travel occurs on the road, the slope of the terrain, the elevation, and the land cover. The predicted speed of travel between node $i$ and $j$ is given by $W_{ij}$ and based on the Tobler function (Tobler, 1993),

$$W_{ij} = \kappa_i \times 6.096 \times \mathrm{e}^{-3.5|\mathrm{slope}_{ij}+0.05|-\gamma \mathrm{elev}_i} \tag{2}$$

where $slope_{ij}$ measures the slope between cells $i$ and $j$, $\kappa_i$ is a coefficient determined by the landcover in cell $i$, and $\mathrm{elev}_i$ denotes the elevation in meters ($\gamma = -0.0001072$).[23] As a consequence, travel on flat terrain at sea level the predicted speed is around 5 kilometers per hour.[24] To adjust for differences in landcover, I rely on coefficients from Weiss et al. (2018). Five terrain types have a natural mapping between historical land cover data and the terrain coefficients.[25] I rely on data on official routes for mail in the Spanish Empire during the Bourbon period to proxy the location of roads. Travel on a path is affected by the slope and elevation, but not the landcover. The walking speed is then used to construct the time required to travel between all nodes. The left map in Figure 4 shows the resulting cost surface.[26]

**Least-Cost Path Problem.** Once the duration of passing between all adjacent cells is known, I calculate the bilateral travel time between all cells by searching for the cost-minimizing route of getting from a cell $i$ to any other cell $j$ along the graph. Since there will be many alternative routes to ship a good between localities $i$ and $j$, I assume goods shipping follows the time-minimizing route according to the Dijkstra algorithm (Dijkstra, 1959). Beyond sailing speed, the turnaround time in port shapes the total sailing time of a route. Since it is not clear whether turnaround times improved over time (Rönnbäck, 2012), I assume these are constant and zero as a starting point. Moreover, I model Europe as a point-like country centered on Cadiz containing the population mass of Spain,

[22] The graph is weighted again to account for the fact that the distance between the nodes of the graph varies due to their relative position as well as the curvature of the earth.

[23] While Equation 3 models walking speed, the use of pack-animals will not have affected the speed much since these were typically accompanied by humans on foot (Verhagen, Joyce and Groenhuijzen, 2019).

[24] 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.

[25] These are tropical forests, temperate forests, desert, savanna, and shrubland. The terrain factors are 0.324 in a tropical forest, 0.648 in a temperate forest, 0.97 in a savanna, 0.6 in shrubland, and 0.6 in deserts. Inland water can be crossed at half the speed (Herzog, 2014).

[26] Özak (2018) develops a *Human Mobility Index* to calculate pre-modern travel times. This measure is not appropriate in this context because I use context-specific features such as the location of paths and maritime technology available during the period.

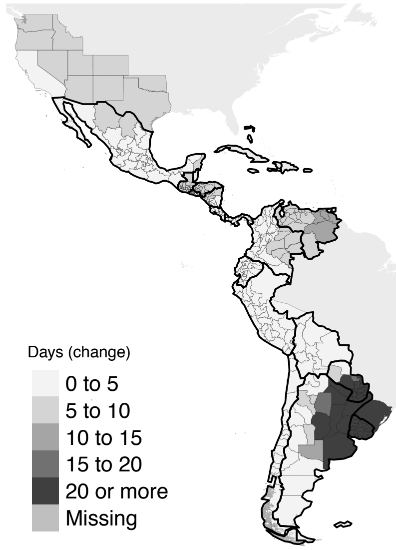


**Figure 4:** The figure shows the difference between shipping times in 1760 and 1810 by province. Darker colors indicate larger reductions in shipping times.

the United Kingdom, and France in 1700. I choose Cadiz because the majority of legal trade with Europe was channeled through this port throughout the period.[27] This approach results in a $R \times R$ dimensional matrix of bilateral trade costs between all the cells, $\mathbf{T}_t[\tau_{ij} \geq 1]$. I calculate one matrix for every decade, accounting for which ports were open to direct trade with Europe in a given decade, and I refer to $\mathbf{T}_t$ as the trade cost matrix in decade $t$.[28]

**Shipping time elasticity.** Next, I calculate the elasticity of the value of trade with respect to shipping time. I estimate the following equation,

$$\ln X_{jt} = \alpha_r + \gamma_t + \beta \mathrm{T}_j + \epsilon_{jt}, \tag{3}$$

where $X_{jt}$ is the value of exports from Spain and port $j$ in year $t$. $\alpha_r$ accounts for regional heterogeneity that is unlikely to be driven by shipping time, such as route-specific shocks such as risk caused by weather or the presence of privateering along the route.[29] Finally, $\gamma_t$ accounts for year-specific factors affecting trade during the period, such as interstate conflict. A challenge is that missing data on bilateral trade between American ports prevent me from fully accounting for multilateral resistance terms, which arise in a large class of trade models (Anderson and Wincoop, 2003). However, since trade in this context was a closed system, trade with third countries is less of a concern in the current context. I therefore estimate Equation 3 using ordinary least squares and poisson pseudo maximum likelihood for robustness (Silva and Tenreyro, 2006).

[27] 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 (Prados de la Escosura and Casares, 1983).

[28] In the baseline case R = 5,573.

[29] The decline in piracy and privateering has been highlighted as an important source of productivity growth in shipping in the first half of the 18th century (North, 1968). These factors had become less important towards the end of the 18th century (Hillmann and Gathmann, 2011).

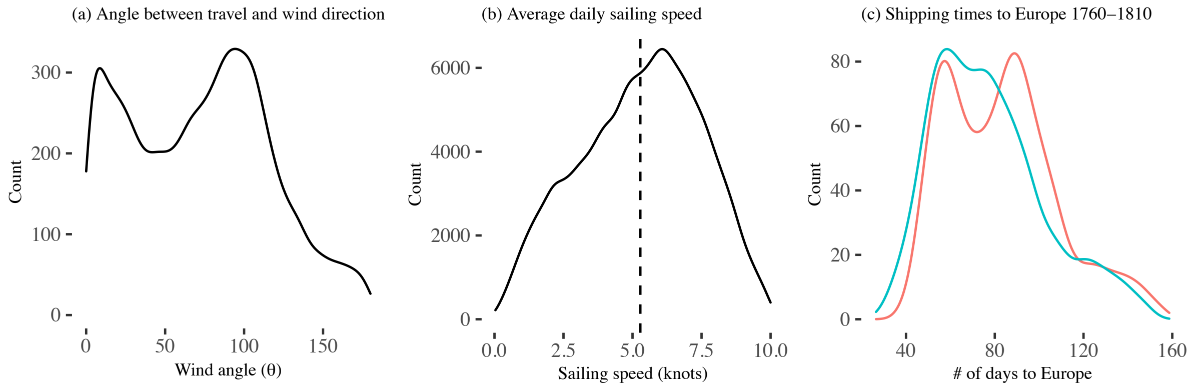


**Figure 5:** The left deviation of the sailing direction and wind direction for the logbook entries. The middle figure displays the average daily speed imputed from the logbook entries. The right panel displays the number of days' travel from a grid-cell to Europe in 1760 (red) and 1810 (green) for the grid cells in the sample.

## 4.2 Results

**Results.** Figure 5 presents the change in both shipping between 1760 and 1810. The red curve denotes the shipping times in 1760, while the green curve the distribution of shipping times in 1810. As can be seen from the figure, there is an overall shift to the left in the distribution of shipping times. The shipping time is 6 days lower on average. The reduction ranges from 27 days shorter shipping to no changes for several locations. These reductions are relative to a pre-reform average of around 83 days. As a result, the reductions in shipping time and trade costs induced by the reform are economically significant. Figure 4 shows the variation in the reduction of shipping time and shows that the reduction in shipping times is highly heterogeneous across the study region. Localities with the largest reductions are in the River Plate region, Venezuela, and Central America. Tables 3 shows the relationship between shipping times and the value of exports from Spain between 1797 and 1820. Across all the specifications, there is a negative relationship between the shipping time and the value of trade. A one percent increase in the shipping time reduced the value of trade between around 2 and 3 percent, depending on the vector of controls. As a baseline estimate, I consider Column (3) of Table 3 which controls for region and year fixed effects. In this specification, a one percent increase in the shipping time reduced the value of trade by 5.7 percent.[30]

**Assessing the Shipping Times.** How plausible are these estimates? First, I find a close correspondence between predicted trade routes and the location of known historical trade routes.[31] Next, I quantitatively assess the quality of the estimates in three ways. First, I compare the results to measures sailing times according to a database of bilateral sailing times.[32] 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 5 knots is used, the average speed of Spanish freight ships in 1750 (Kelly and Ó Gráda, 2019). For shipping on land, I compare the calculated shipping times with walking times using the Human Mobility Index Özak (2018) as well as google maps. Figure 11 shows

[30] I explore different elasticities as a robustness check.

[31] For example, Pacific and Atlantic ports are connected by the Panama isthmus, Mexico City is connected to maritime trade through Veracruz and Acapulco, and Potosi and Arica with Callao.

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

that these alternative shipping time measures are highly correlated with the measure developed in this paper. Next, I assess the correlation between predicted travel time and the duration of mail dispatches between major ports in Spanish America (Baskes, 2013). Finally, I assess the correlation between historical and contemporary wind patterns. There is a strong correlation between wind speed and direction in these two datasets. A remaining concern is that changes in maritime technology changed the relationship between distance and trade costs over the period. However, improvements in maritime technology were unlikely to be the most important determinant of productivity gains in shipping before the 19th-century (North, 1968; Harley, 1988; Menard, 1991).[33] Taken together, the exercises show that the determinants of trade costs emphasized in the estimation were important in the context.

# 5 Trade Costs and the Location of Economic Activity

In this section, I use the calculated changes in trade costs to examine the effects of trade on the location of economic activity. This section presents the empirical strategy, the reduced-form results, and robustness checks.

## 5.1 Baseline Empirical Strategy

**Difference-in-differences.** I begin by documenting the impact of the changes in shipping times on the formation of new settlements. Consider the following regression model,

$$y_{i(t)} = \alpha_i + \gamma_a \times \tau_t + \beta T_{i(t)} + \phi x_{i(t)} + \epsilon_{i(t)}, \tag{4}$$

where $y_{i(t)}$ 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, agroclimatic suitability, and whether the grid cell contains a mining center. While elevation and coastal access are fixed over time, the effect of these factors could have changed with for example the disease environment. The variables are therefore interacted with decade indicators, which allows each feature to vary in importance over time.[34] $\gamma_a \times \tau_t$ are *audiencia*-times-decade fixed effects and account for shocks affecting all localities within a given *audiencia* in a particular decade.[35] $\epsilon_{i(t)}$ is an error term potentially spatially correlated across nearby cells. In the baseline specification, standard errors are clustered at the level of the closest port, which constitutes the level of the treatment assignment

[33] This view has recently been challenged by (Kelly and Ó Gráda, 2019). However, they show that Spanish sailing speeds remained stagnant throughout the period of this study.

[34] Elevation is an indicator variable taking the value one if the average elevation is above 1,500m. Agroclimatic suitability is 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.

[35] The viceroyalty was subdivided into audiencias, which were political bodies in charge of various policies. The *audienca* was further divided into governorships or provinces and further into principal mayoralties *corregimientos* (Mahoney, 2010). The smallest administrative unit considered in this paper is the *audiencia*. Figure 1 shows the geographical extent of the *audiencia* and viceroyalties in 1790. In robustness checks, I consider borders in place for earlier periods and find similar results.

in this context (Abadie et al., 2017).[36] The coefficient $\beta$ captures the change in the probability of a cell containing a settlement for a one-unit change in shipping time to Europe. The 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.

**Cross-sectional design.** The long-run effects are estimated with a cross-sectional specification. The specification compares population density between localities with different treatment intensities, 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. I estimate the following equation,

$$D_{i(2000)} = \alpha_c + \beta D_{i(1500)} + \phi x_i + \epsilon_{i(c)}, \tag{5}$$

where $D_{i(2000)}$ denotes population density in the year 2000, $D_{i(1500)}$ the population density in 1500, and $x_i$ a vector of control variables. Standard errors are clustered at the country level in the main specifications.[37] The interpretation of the coefficient rests on changes in shipping times to be independent of counterfactual long-run outcomes. This is naturally a stronger assumption than required for the specifications relying on the timing being exogenous. I therefore explore several exercises that support the identifying assumptions.[38].

## 5.2 Results

The results are presented in two parts. First, I summarize the main results showing the impact of trade costs on the formation of new settlements. Second, I discuss several robustness checks.

**Fact 1.** *Lower shipping times led to the formation of new settlements.* Table 4 shows the relationship between shipping times and the formation of new settlements. Panel (a) presents the results estimated on the full sample. Across a wide range of specifications, there is a negative relationship between shipping time to Europe and the probability of a new settlement forming. In the preferred specification in Column (3), containing both year and decade fixed effects in addition to the full set of controls, I find that a one standard deviation increase in the shipping time to Europe (25 days) leads to an around 4 percentage point reduction in the probability of a new settlement forming ($\beta = -0.041$). The estimated coefficients range from $-0.03$ and $-0.08$. The sample average is 0.1, hence ten percent of grid cell decade pairs contain settlements. The estimates are therefore both statistically and economically significant. As a result, the estimates are consistent with cheaper access to goods produced in other locations and better export opportunities, increasing the attractiveness of settling

[36]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. 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 of 5,000km. This correction matters little for the size of the standard errors, as can be seen in the appendix.

[37]To address concerns about spatially correlated errors, I report Conley standard errors in the Appendix (Conley, 1999).

[38]In particular, 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.

in a new location. This increased the population pressure in locations that experienced improved access to trade. The effects on city population mirror these results.

*Table 4: Shipping time and settlements*

| *Dependent variable*: | Indicator for cell containing a settlement | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel (a): Full sample | | | | |
| Shipping Time | $-0.085^{***}$ | $-0.031^{**}$ | $-0.041^{***}$ | $-0.046^{***}$ |
| | (0.020) | (0.014) | (0.012) | (0.015) |
| *Observations* | 55,154 | 55,154 | 55,154 | 55,154 |
| Panel (b): High population density | | | | |
| Shipping Time | $-0.145^{***}$ | 0.019 | $-0.067$ | 0.053 |
| | (0.033) | (0.085) | (0.064) | (0.064) |
| *Observations* | 20,240 | 20,240 | 20,240 | 20,240 |
| Panel (c): Low population density | | | | |
| Shipping Time | $-0.064^{***}$ | $-0.052^{***}$ | $-0.032^{**}$ | $-0.035^{**}$ |
| | (0.021) | (0.011) | (0.013) | (0.015) |
| *Observations* | 34,914 | 34,914 | 34,914 | 34,914 |
| Cell FE | | ✓ | ✓ | ✓ |
| Year FE | | | ✓ | ✓ |
| Controls × Decade FE | | | ✓ | ✓ |
| Viceroyalty × Decade FE | | | | ✓ |

Note: Shipping time is standardized. The unit of analysis is at a 0.5°×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 5,014 grid cells. The full dataset contains 11 × 5,014 = 55,154 observations. Panel (b) contains cells in high density macroregions. (c) contains cells in low density macroregions. **Controls:** Elevation, crop suitability, the location of active mines, distance to the coastline, and a polynomial of longitude and latitude. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}\ p < .1$

**Fact 2:** *The effect is driven by areas that were less densely settled.* The change in trade costs induced by the reform affected regions that differed substantially in terms of population density. If city and town locations are path dependent, we should expect smaller effects to changes in economic fundamentals in areas with more population agglomeration. To explore this possibility, I study heterogeneity by the initial level of population density. I divide the study area into macro-regions constituting a core and a low population density fringe (Mahoney, 2010). These areas can be seen in Figure 12. I estimate the baseline specification in Equation 4 separately for these locations. The results are presented in Panel (b) and (c) in Table 4. Across all specifications, the marginal effects of changes in shipping times are significantly different in the two samples at conventional levels of significance. For the preferred specifications in Columns (2)-(4), the effect is driven by areas in the low-density fringe. For this sample, a one standard deviation increase in the shipping time to Europe reduced the probability of a settlement forming. For the remaining areas, the effect is indistinguishable from zero. In sum, these results show that the effect is mainly driven by the areas with lower initial density.

A possible interpretation of this pattern is that improved market access facilitated settlement in frontier areas or areas with low state presence. There were efforts during the 18th to increase state presence and population density in the frontier (Parry, 1990). I explore this by estimating the effects separately in locations with low and high state presence. I find that formation was more responsive to changes in shipping times in areas with more state presence.[39] Another interpretation could be that urban congestion costs are high in this context. If so, then areas with more agglomeration will react less to changes in market access. However, Mexico and Peru experienced fairly high rates of urbanization, surpassing that of Spain by the 18th century (Arroyo Abad and Zanden, 2016), which is inconsistent with high congestion costs constraining urban growth. 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, accounting for non-linearity and considering different subsamples gives 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 result is therefore consistent with the mediating factor being initial population density.

**Fact 3:** *Lower persistence of historical settlement patterns in areas opened to trade.* Did the changes in economic geography documented above result in lower persistence in the location of economic activity? To examine this question, I explore the relationship between pre-modern and contemporary settlement patterns in areas that experienced different changes in trade costs. I estimate the elasticity between pre-modern and contemporary population density at the province level for 18 countries in Spanish America. To examine the relationship between the reform and spatial persistence, I split the sample into whether the provinces have high or low exposure to the reform as measured by above or below change in shipping times to Europe between 1760 and 1810.

Figure 10 shows the relationship between pre-colonial population density and the current population for the different samples. The left figure shows the correlation for all regions in the study region. Consistent with Maloney and Valencia (2016), there is a strong positive relationship within country between pre-colonial population density and population density in 2000. 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 5 documents that this pattern is robust across several specifications. Consistent with the results in Section 5.2, I find that these areas are substantially more concentrated in coastal areas today. Table 6 uses the same approach to compare the differences in coastal access for areas more or less intensively treated by the reform. The table shows that the distribution of the population is more spatially clustered in coastal areas for places more intensively treated by the reform. In sum, the results from Table 6 support the interpretation that the reform increased the population in coastal areas.

[39] Two approaches are taken to proxy for state presence. First, 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 regions.

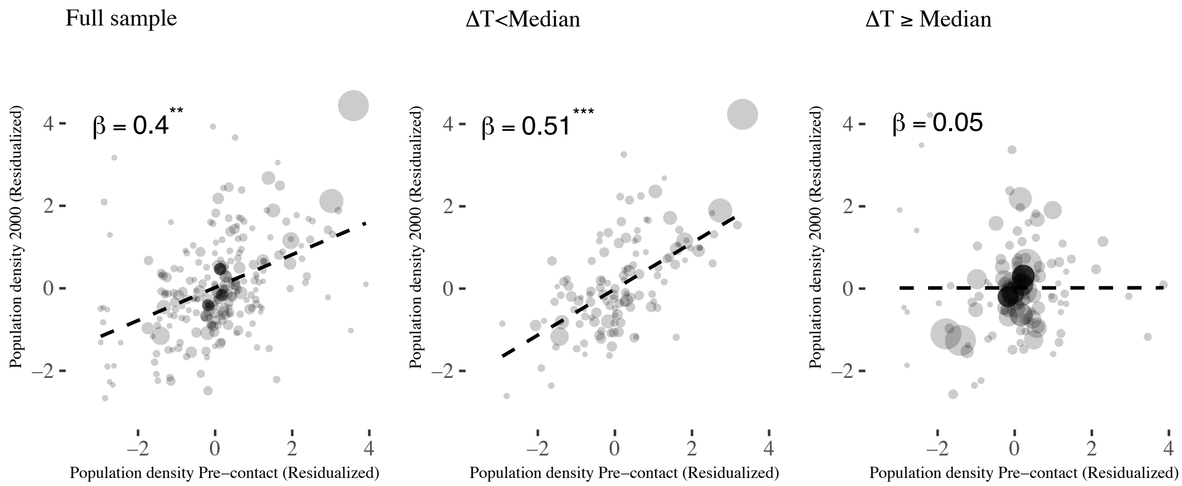


**Figure 6:** The figure shows the relationship between pre-contact population density and the population density in year 2000 at the level of the province. The left figure shows the relationship for the full sample. The middle figure shows the relationship for provinces with below median change in the 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 people per square kilometre pre-contact. The dependent variable is the log of people per square km in 2000. The full sample contains 337 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.

**Discussion.** The combination of large regional differences in population density, a strong degree of path dependence in the location of economic activity contribute to explain differences in the importance of trade and historical persistence across Spanish America. In locations that develop high levels of population density early, population agglomeration will form in places with important pre-modern locational fundamentals (such as natural defenses, a favorable disease environment, and high agricultural productivity). Due to path dependence, these agglomerations remain even though international trade becomes a relatively more important determinant for economic activity. For places with low initial population density, the forces generating path dependence in the location of economic activity are weaker, and population agglomerations emerge in places with increased market access. As a result, the sequence with which a country reaches high levels of population density and comes to rely more heavily on trade is an important factor in determining the importance of trade for the location of economic activity. Section 6 present a quantitative model showing these mechanisms are quantitatively important in explaining differences in spatial development across the Americas.

## 5.3 Assessing the Research Design

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. To assess the plausibility of this assumption, I consider the dynamic version of Equation 4 where the change in shipping time is interacted with decade indicators. In particular, I estimate the following model

$$y_{i(t)} = \alpha_i + \gamma_a \times \tau_t + \sum_{s=1710}^{1810} \mathbb{1}[t = s]\Delta T_i \times \tau_s + \phi x_{i(t)} + \epsilon_{i(a,t)}, \tag{6}$$

where $\Delta T_i = T_{i(1760)} - T_{i(1810)}$ and the other variable are defined as in Equation 4. Figure 10 shows the estimated coefficients using the baseline specification. The plotted coefficients give the estimated difference between differentially exposed localities in year $j$ relative to 1760, which is the last year prior to the reform. 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 before the reform.[40] Table 7 summarizes several alternative specifications.

Did other policies change at the same time that could explain the timing of the effect? In the second half of the 18th century, other administrative, ecclesiastical and military reforms were conducted in Spanish America. 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. However, when dropping cells in the Viceroyalty of *Rio de la Plata* the estimated coefficients are similar.[41] To further account for unobserved regional heterogeneity, I use viceroyalty and *audiencia* borders between 1710 and 1750 as additional controls as well as virtual country fixed effects. Next, I assess the robustness of the results of choosing different grid-cell sizes (Briant, Combes and Lafourcade, 2010). I construct two additional datasets with different resolutions and re-estimate the main effects in Table 4. Even though all large ports were eventually allowed to trade directly with Europe, it cannot be ruled out that the timing of which ports opened was driven by commercial potential. To mitigate this concern, I restrict the sample to only include areas far away from ports in the estimation, which were unlikely to be targeted by the policy. Finally, Kelly (2019) shows that in studies with spatially correlated treatment variables, p-values of statistical tests can be biased downward. I therefore use standard errors accounting for spatial correlation in line with (Conley, 1999). Taken together, these exercises provide support for the causal interpretation of the estimates.

# 6 A Model of Trade, Settlement, and Path Dependence

To explore the role of trade and path dependence in determining the location of economic activity, I build a quantitative model. This section outlines the key ingredients of the model. The model builds on Allen and Donaldson (2020) but adapts the model to a pre-industrial context by including land as a factor of production as well as time-varying trade and migration costs. It therefore provides a suitable framework to further explore how the role of significant regional differences in population

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

[41] Moreover, 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.


**Figure 7:** The figure shows the estimated coefficients of the difference in the formation of settlements in grid-cells according to the reduction in shipping times to Europe induced by the reform. **Dependent variable:** An indicator-variable taking the value one if the grid-cell contains a settlement. **Observations:** The unit of analysis is at a 0.5°×0.5° grid-cell. The dataset is a balanced panel at a 10-year frequency for the period 1710-1810 for 5,573 grid cells. 1760 is the omitted year. The full dataset thus contains 11 × 5,573 = 61,303 observations. **Controls:** The left figure includes *audiencia* as well as *audiencia* × 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.

density, path dependence, and exposure to international trade contributes to explain differences in the importance of trade and historical persistence across Spanish America.

## 6.1 Theoretical Framework

**Geography.** The geography of the framework is defined on a finite grid. The $R$ localities (indexed by $i$) have the same geographical surface, and the population is concentrated at the center of the cell where all consumption and production happens. Each grid cell is connected to the adjacent cells through costly trade and migration. Moreover, each location has a location-specific factor productivity $\bar{A}_i$, congestion externality $\bar{u}_i$, and availability of arable land $H_i$. 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 of Europe is the average of the full sample.

**Timing.** The timing of the model follows an overlapping generations structure. Each period is inhabited by agents who are either young or old and every agent lives for only two periods. Adults supply labor and consume. Since growth in pre-industrial cities and towns occurred mainly through migration (Jedwab and Vollrath, 2015; Jedwab, Christiaensen and Gindelsky, 2017), I model population growth as exogenous. As a result, each adult in the model receives one child. The young make decisions on where to live as adults and move there. In the model, each period is assumed to represent a generation of 50 years. This structure greatly simplifies the problem as the equilibrium in each period can be solved separately.

**Consumption.** Preferences are defined over a set of differentiated varieties shipped from all other locations. All locations produce a unique good (Armington, 1969). The utility function takes the following form,

$$U_{it} = u_{it} \sum_{j \in R} \left( q_{jit}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \epsilon_{it}, \tag{7}$$

where $\sigma > 1$ is the constant elasticity of substitution across varieties. Additionally, workers derive utility from local characteristics of the location they live, given by $u_{it}$. Finally, the utility of a worker in location $i$ depends on a draw of a vector $\epsilon_{it}$ from a Fréchet distribution with shape parameter $\theta$ which determines the spread of preferences across all the other localities.

**Production.** Agriculture was the largest sector of the economy (Arroyo Abad and Zanden, 2016), with mining only employing around 0.04 percent of the population at its peak in the late 18th century (Fisher, 1997, p. 64).[42] To reflect this, each location has a continuum of production entities that use labor and land as factors of production. The production technology takes the Cobb-Douglas form,

$$q_{it}(\omega) = A_i l_{it}(\omega)^{\mu} h_i(\omega)^{1-\mu} \tag{8}$$

where $l_{it}(\omega)$ denotes the amount of labor used by production entity $\omega$, $h_i(\omega)$ the amount of land, and $A_i$ captures the total factor productivity of the location. Given the large geographic area, input markets were naturally organized through a range of contractual forms. However, largely free labor was the norm by the 18th century (Allen, Murphy and Schneider, 2012). Moreover, Arroyo Abad, Davies and van Zanden (2012) provide evidence that real wages responded to market conditions in the context of colonial Mexico and Peru. To capture this, I assume that to a first-order approximation, factor markets were competetive. As a result of perfect competition, factors are paid their marginal product, $p_{it} = w_{it} / A_{it} \mu l_{it}(\omega)^{\mu-1} h_i(\omega)^{1-\mu}$. Moreover, in each period and location the markets for land and labor clear, hence $\int l_{it}(\omega) d\omega = L_{it}$ and $\int h_i(\omega) d\omega = H_i$.

**Agglomeration economies.** In the core areas of Spanish America, urbanization was relatively high in the 18th century, at times exceeding that of Spain (Arroyo Abad and Zanden, 2016). While the production technology rules out increasing returns at the level of the firm, the agglomeration spillovers as captured by $\alpha_1$ and $\alpha_2$ opens for the possibility that the total factor productivity to be a function of size and the history of settlement, $A_{it} = \bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2}$. A variety of factors drove agglomeration in pre-industrial contexts (Jedwab, Johnson and Koyama, 2020). For example, contemporaneous increasing returns could reflect factors such as knowledge spillovers, input sharing, or physical security, while the lagged returns could reflect factors such as fixed capital or local knowledge. Similarly, on the demand side agglomeration economies are modelled in a similar manner, $u_{it} = \bar{u}_i L_{it}^{\beta_1} L_{it-1}^{\beta_2}$. The strength of the contemporaneous spillover, determined by $\beta_1$, captures such features as costs related to congestion, while the lagged spillover, determined by $\beta_2$ could capture the housing stock or other persistent amenities.

**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

[42] 75,000 out of 17 million.

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,

$$v_{it}L_{it} = (1-\mu)L_{it}v_{it} + L_{it}w_{it} = \frac{L_{it}w_{it}}{\mu}, \tag{9}$$

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

**Trade.** The model implies a gravity equation for bilateral trade between locations. 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 $t$,

$$X_{ijt} = \frac{1}{\mu}\tau_{ijt}^{1-\sigma}\left(\frac{w_{it}}{\mu A_{it}L_{it}^{\mu-1}H_i^{1-\mu}}\right)^{1-\sigma} P_{jt}^{\sigma-1}w_{jt}L_{jt}. \tag{10}$$

The equation shows that trade between $i$ and $j$ increases with lower prices in $i$, lower trade costs between localities, and higher income in $j$. Trade costs are assumed to be symmetric across locations.[43]

**Migration.** Legal restrictions on labor mobility and coercive labor institutions no longer played an important role by the end of the 18th century (Arroyo Abad and Maurer, 2019). To accommodate this, I assume labor can move freely but subject to mobility frictions that are a function of travel time. The utility derived from a particular destination depends on the deterministic utility $V_{it}$ which depends on the real wage and the local congestion externality $u_{it}$. Moreover, there is an idiosyncratic component to preferences, $\epsilon_{it}$, which is assumed to be independent draws from a Fréchet-distribution with shape parameter $\theta$. Migration costs between two locations $i$ and $j$ are assumed to be time-invariant and given by $\mu_{ij}$. The utility of a young individual moving from location $i$ to $j$ is therefore given by the following expression,

$$V_{ijt} = \frac{V_{jt}}{\mu_{ij}} \times \epsilon_{jt}. \tag{11}$$

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 that $\epsilon_{jt}$ are independent, the population flows in the model is given by the following gravity relationship,

$$L_{ijt} = \mu_{ij}^{-\theta}\Pi_{it}^{-\theta}L_{it-1}V_{jt}^{\theta}, \tag{12}$$

where $\Pi_{it}$ is the expected utility for agents born in region $i$.[44]

**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 ($\boldsymbol{\mu}_i$), an allocation of land $H_i$, and past population distribution $L_{i0}$.

[43] Proofs of existence and uniqueness of the equilibrium depend on symmetric bilateral transportation costs (but not migration costs). I therefore assume that $\tau_{ijt} = \tau_{jit} = \frac{\tau_{ijt}+\tau_{jit}}{2}$ throughout the analysis.

[44] The expected utility of a young person before he knows the realization of the shock is given by,

$$\mathbb{E}\left[V_{it}\right] = \left(\sum_{i\in R}\left(\frac{V_{jt}}{\mu_{ij}}\right)^{\theta}\right)^{\frac{1}{\theta}}. \tag{13}$$

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. $w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j\in R} \tau_{ijt}^{1-\sigma} \left( \frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} \bar{u}_j L_{jt-1}^{\beta_2} H_i^{1-\mu}} \right)^{1-\sigma} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}^{1+\beta_1(\sigma-1)}$,
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.[45] 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 $1.7°\times1.7°$.[46] There are seven parameters, $\{\sigma, \theta, \alpha_1, \alpha_2, \beta_1, \beta_2, \mu\}$, as well as $R$ geographical

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

$$\mathbf{A} = \frac{1}{(b_{11}\theta + \tilde{\sigma}\sigma)\theta} \begin{bmatrix} \gamma_{11}\theta^2 + \gamma_{12}\theta & \gamma_{11}\tilde{\sigma}\sigma\theta - \gamma_{12}b_{11}\theta \\ \theta^2 & -b_{11}\theta^2 \end{bmatrix}, \tag{14}$$

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

[46] Approximately 180km.

fundamentals and local congestion externalities. The estimation proceeds in two steps. First, the equilibrium conditions are inverted in order to back out $\{p_{it}^{\sigma-1}, P_{it}^{\sigma-1}, V_{it}^{\theta}, \Pi_{it}^{\theta}\}_{i\in R}$. Second, I take the logarithm of the endogenous productivity and amenity values and take first-differences to arrive at the estimating equations. 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.

**Structural parameters.** The first parameter needed is the elasticity of substitution between goods produced in different locations. Bajzik et al. (2020) find that most point estimates in the literature are between 1 and 5. 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 (2018) 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 $\sigma$ 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 fewer estimates of the migration elasticity $\theta$. Allen and Donaldson (2018) 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 0.45 and 0.55 following Caselli and Coleman (2001); Arroyo Abad and Zanden (2016).

**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 $\lambda > 0$. Taking the natural logarithm of the gravity equation for trade and the migration (Equations 15 and 16) and inserting $\tau_{ij}$ and $\mu_{ij}$ gives the following relationships,

$$\ln X_{ijt} = \kappa(1-\sigma)\ln T_{ijt} + \ln\left(\frac{w_{it}}{\mu A_{it} L_{it}^{\mu-1} H_i^{1-\mu}}\right)^{1-\sigma} + \ln P_{jt}^{\sigma-1} w_{jt} L_{jt}, \tag{15}$$

$$\ln L_{ijt} = -\theta\lambda \ln T_{ijt} + \ln \Pi_{it}^{-\theta} L_{it-1} + \ln V_{jt}^{\theta}. \tag{16}$$

**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 in a particular locality. Inverting the equilibrium conditions gives the following relationships,

$$p_{it}^{\sigma-1} - \sum_{j\in R} Y_{it}\tilde{T}_{ijt}\left(\frac{Y_{jt}}{Y_{it}}\right) P_{jt}^{\sigma-1} = 0, \tag{17}$$

$$P_{it}^{\sigma-1} - \sum_{j\in R} \tilde{T}_{jit}\left(p_{jt}^{\sigma-1}\right)^{-1} = 0, \tag{18}$$

$$V_{it}^{-\theta} - \sum_{j \in R} M_{jit} \left( \frac{L_{jt-1}}{L_{it}} \right) \Pi^{-\theta} = 0, \tag{19}$$

$$\Pi^{-\theta} - \sum_{j \in R} M_{ijt} V_{jt}^{\theta} = 0, \tag{20}$$

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

**Parameter estimation.** The functional form of the spillovers and the first-order condition of the firms, and the indirect utility function is used to estimate the spillover parameters. Combining these expressions gives the following estimable equations,

$$\Delta \ln p_{it}^{\sigma-1} = (\sigma - 1) \Delta \ln w_{it} + \tilde{\alpha}_1 (1 - \sigma) \Delta \ln L_{it} + \alpha_2 (1 - \sigma) \Delta \ln L_{it-1} + (1 - \sigma) \Delta \ln \bar{A}_i, \tag{21}$$

$$\Delta \ln V_{it}^{\theta} = \theta \Delta \ln w_{it} + \frac{\theta}{1 - \sigma} \Delta \ln P_{it}^{\sigma-1} + \beta_1 \theta \Delta \ln L_{it} + \beta_2 \theta \Delta \ln L_{it-1} + \theta \Delta \ln \bar{u}_i. \tag{22}$$

A challenge of estimating equations 21 and 22 is that $\bar{A}_i$ and $\bar{u}_i$ are unobserved and correlated with the population size $L_{it}$ since agents move to more productive places with less congestion. For example, a high $\Delta \bar{A}_{it}$ increases the real wage which makes $i$ a more attractive location to settle. As a result, the model implies an endogeneity problem when estimating the equation. The key identification assumption is that changes in the local factor productivity, as well as the local congestion, are uncorrelated with population growth once a large range of locational fundamentals is controlled for. While the assumption is untestable in practice, the reduced form results support, as well as several robustness checks, support this assumption. I estimate equations 21 and 22 using the baseline specification given by Equation 4. Lastly, I use the estimated parameters to back out the location-specific amenity and productivity using the same equations in levels.[47]

**Results.** Table 8 contains the parameters in the baseline specification of the model. The contemporaneous and lagged agglomeration spillovers, $\alpha_1$ and $\alpha_2$ are found to be positive. This is consistent with various forms of agglomeration externalities. The point estimate of the agglomeration externality is fairly large. $\alpha_2 > 0$ 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. Given this calibration of the model there exists a unique equilibrium.[48] Table 8 displays the parameter estimates used in the baseline models

[47] In particular, the following equations identify the locality specific fundamentals,

$$\bar{A}_i = \exp\left\{ \frac{1}{1-\sigma} \left( \ln p_{it}^{\sigma-1} - (\sigma - 1) \ln w_{it} - \tilde{\alpha}_1 (1 - \sigma) \ln L_{it} - \alpha_2 (1 - \sigma) \ln L_{it-1} - \kappa ln H_i \right) \right\}, \tag{23}$$

$$\bar{u}_i = \exp\left\{ \frac{1}{\theta} \left( \ln V_{it}^{\theta} - \frac{\theta}{1-\sigma} \ln P_{it}^{\sigma-1} - \beta_1 \theta \ln L_{it} - \beta_2 \theta \ln L_{it-1} - \theta \ln w_{it} + \theta \ln \mu \right) \right\}, \tag{24}$$

where $\kappa = (1 - \mu)(1 - \sigma)$. $\bar{A}_i$ and $\bar{u}_i$ are estimated as the residuals of Equation 21 and Equation 22.

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

of the counterfactual exercises.

*Table 8: Model parameters*

| Parameter | Description |
|---|---|
| Panel (a): Preferences and Technology | |
| $\sigma = 6$ | Elasticity of substitution |
| $\theta = 3$ | Migration Elasticity |
| $\mu = 0.55$ | Labor share of income |
| Panel (b): Trade and Migration Costs | |
| $\kappa(1-\sigma) = -1.06^{***}$ | Elasticity of trade flow wrt. shipping time |
| $-\lambda\theta = -2.8^{***}$ | Elasticity of migration flow wrt. shipping 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. $\alpha_1$, $\alpha_2$ $\beta_1$, and $\beta_2$ are estimated directly from the data on 543 grid-cells. $\sigma$, $\mu$, and $\theta$ are taken from the literature in the baseline case. **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

**Model fit.** This section assesses the performance of the theoretical framework by comparing the model implied with the realized population distribution. Since the population growth after 1810 is not targeted by the calibration of the model, this serves as a test of the relevance of the mechanisms emphasized by the model in explaining population growth in this context. 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 **??** 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 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 9 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 context.

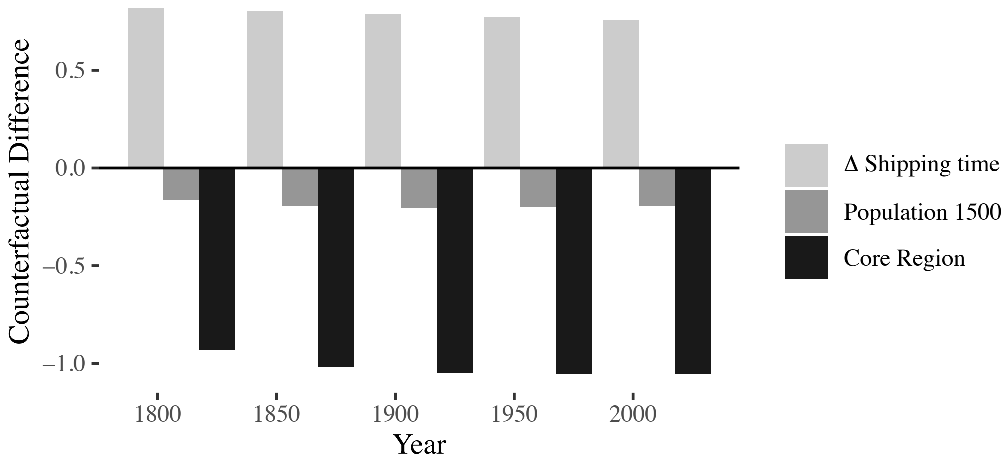


**Figure 8:** The figures show the results from the main counterfactual exercise. For each forward iteration of the model, the share of the number of grid-cells with higher population density under the new regime is compared. The Figure displays the difference in the counterfactual for places with more and less exposure to the reform, coastal versus interior regions, and the core versus the periphery.

## 6.3 Results

This section uses the model to conduct counterfactual exercises. Since there exists a unique dynamic equilibrium, the model yields determinate predictions for the impact of changing 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, denoted by $\Delta L_t = L_t\left(\mathbf{T}^{1810}\right) - L_t\left(\mathbf{T}^{1760}\right)$. In particular, $L_t\left(\mathbf{T}^{1810}\right)$ denotes the model implied population distribution at time $t$ assuming 1810 trade costs. The variables are standardized. 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 how differences in the initial level of population concentration change the impact of the trade cost shock.

**Replicating the reduced-form facts.** Using the model, I simulate the reform several periods ahead. 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. The results of this exercise are displayed in Figure 8. The figure shows that the results mirror the reduced form. First, lower shipping times to Europe increased the population density. A one standard-deviation change in the shipping time increases the model implied effect of the reform by approximately 0.6 standard deviations. Second, the effect is attenuated in locations with larger historical population size. A one standard deviation increase in the population size in 1500 reduces the impact of the reform by approximately 0.1 standard deviations. Finally, the effect of the reform on population density is larger in the fringes, outside the core areas with high density at the time of the reform. The effect of the reform is one standard deviation smaller in the core areas. In sum, the results are consistent with the reform increasing the population pressure outside the most densely settled areas.

**The role of concentration.** In this section, I assess the impact of initial conditions on the impact of the reform. While lower transportation costs tend to make locations with high market access 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.[49] To assess the quantitative importance of this mechanism, the long-run impact of the change in trade costs is calculated under different initial conditions. In particular, I solve for the steady-state of the model while varying the level of population concentration at the time of the reform.

Figure 9 displays the results from this exercise. The x-axis measures the factor with which the size of the ten most populous grid cells is increased. The y-axis measures the marginal impact of changing the shipping time to Europe by one standard deviation. The first column shows that direct trade with Europe increased population density in areas that increased their market access regardless of initial conditions. However, as the initial population concentration increases, the marginal impact of the reform attenuates. While the effect for the baseline case is 0.5, this effect is almost 0.35 for the highest level of concentration. This is consistent with the two competing forces of the model, dynamic agglomeration economies and market access. When initial population concentration is low, historical agglomeration forces are weak, and changes in market access lead to larger changes in the spatial distribution of economic activity. This partly explains why the effect of the reform was smaller in areas with higher initial population density.

**Robustness checks.** While the agglomeration parameters are precisely estimated from the data, I take the elasticity of substitution ($\sigma$) as well as the shape parameter ($\theta$) on the Fréchet-distribution from the literature. 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 plausible alternative values for these parameters that preserve the uniqueness properties of the equilibrium. I find little evidence that this exercise changes the qualitative impact of the reform.

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 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.

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.

Another quantity that 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 essentially unchanged. For the long-run results, this is more

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

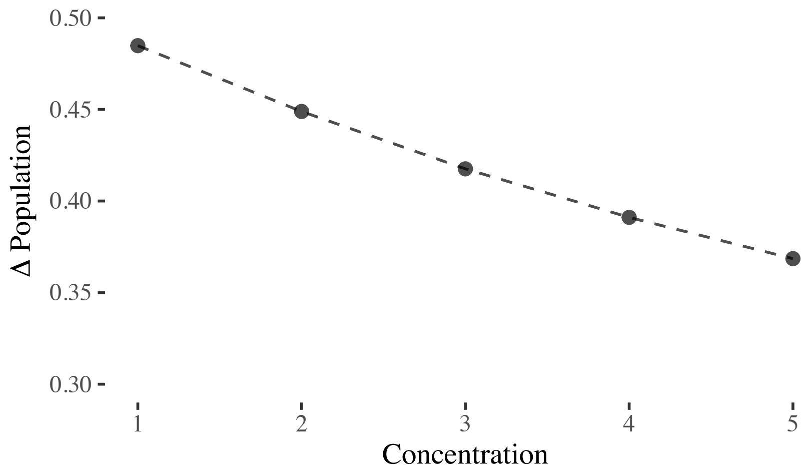


**Figure 9:** The figures show the results from the main counterfactual exercise. For each forward iteration of the model, the share of the number of grid-cells with higher population density under the new regime is compared. The Figure displays the difference in the counterfactual for places with more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

of 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. We might also 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 expensive. In all cases, the model replicated the qualitative results from the reduced form.

In the baseline case, I assume that movement across national borders is costless in the long run. However, as pointed out in Arteaga (2016), borders are potentially endogenous to the reform. 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. Therefore, I ignore border changes between these two periods for the sake of simplicity. Then, I rerun the main analysis. With this extension, I find similar effects. While including costly international migration across countries tends to attenuate the long-term effects of the reform, the effects remain quantitatively and qualitatively similar.

# 7 Conclusion

What explains the significant variation in the persistence of the location of economic activity across different places? I calculate the changes in travel times to Europe induced by the reorganization of maritime communication in the wake of the Bourbon reforms in the second half of the 18th century. Using a difference-in-differences 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 locations of settlements and population growth. I find that a statistically and economically significant positive effect on population density is associated with reduced shipping times to Europe. To explore the mechanisms, I build 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 geographical reorientation towards areas with higher market access. The findings show that the combination of low initial population density and significant changes in trade costs initiated a dispersal of economic activity and growth in the fringes of the Spanish Empire. Taken together, the findings show that an important determinant of persistence in economic geography is the level of development of a country as it opens up to trade.

Both the quantitative and reduced-form evidence shows that changes in trade costs can overcome spatial persistence and have significant 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 the conclusion that what determines the relative weight of history versus market access in the locations of population agglomerations is the sequencing with which a country achieves a high population density versus low trade costs. History will tend to explain the population distribution in places that attain high population density earlier in history, while market access will explain the population distribution in areas that had low density before opening up to trade. Thus, the findings highlight the role of history in shaping the population distribution in places that attained population densities early and show that market access is more important in places that attained high population densities after the large reductions in trade costs in the 19th century, such as the United States and Argentina. In light of 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 presented in this paper suggest that a poor geographic adaption to maritime trade is a cost of reaching high population density early in history.

## References


Abadie, Alberto, Susan Athey, Guido Imbens and Jeffrey Wooldridge. 2017. "When Should You Adjust Standard Errors for Clustering?" *NBER Working Paper* 24003.

Acemoglu, Daron, Simon Johnson and James A Robinson. 2001. "The Colonial Origins of Comparative Development: An Empirical Investigation." *American Economic Review* 91(5):229.

Acemoglu, Daron, Simon Johnson and James A. Robinson. 2002. "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution." *The Quarterly Journal of Economics* 117(4):1231–1294.

Acemoglu, Daron, Simon Johnson and James Robinson. 2005. "The Rise of Europe: Atlantic Trade, Institutional Change, and Economic Growth." *American Economic Review* 95(3):62.

Ahlfeldt, Gabriel M., Stephen J. Redding, Daniel M. Sturm and Nikolaus Wolf. 2015. "The Economics of Density: Evidence From the Berlin Wall." *Econometrica* 83(6):2127–2189.

Alix-Garcia, Jennifer and Emily A. Sellars. 2020. "Locational Fundamentals, Trade, and the Changing Urban Landscape of Mexico." *Journal of Urban Economics* 116(103213).

Allen, Robert C., Tommy E. Murphy and Eric B. Schneider. 2012. "The Colonial Origins of the Divergence in the Americas: A Labor Market Approach." *The Journal of Economic History* 72(4):863–894.

Allen, Treb and Costas Arkolakis. 2014. "Trade and the Topography of the Spatial Economy *." *The Quarterly Journal of Economics* 129(3):1085–1140.

Allen, Treb, Costas Arkolakis and Xiangliang Li. 2020. "On the Equilibrium Properties of Network Models with Heterogeneous Agents." *NBER Working Paper* 27837.

Allen, Treb and Dave Donaldson. 2018. "The Geography of Path Dependence." *Manuscript* .

Allen, Treb and Dave Donaldson. 2020. "Persistence and Path Dependence in the Spatial Economy." *Manuscript* .

Altonji, Joseph G., Todd E. Elder and Christopher R. Taber. 2005. "Selection on Observed and Unobserved Variables: Assessing the Effectiveness of Catholic Schools." *Journal of Political Economy* 113(1):151–184.

Alvarez-Villa, Daphne and Jenny Guardado. 2020. "The Long-Run Influence of Institutions Governing Trade: Evidence from Smuggling Ports in Colonial Mexico." *Journal of Development Economics* 144:102453.

Anderson, James E and Eric Van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review* 93(1):23.

Arkolakis, Costas, Arnaud Costinot and Andrés Rodríguez-Clare. 2012. "New Trade Models, Same Old Gains?" *American Economic Review* 102(1):94–130.

Armington, Paul S. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *Staff Papers (International Monetary Fund)* 16(1):159–178.

Arroyo Abad, Leticia, Elwyn Davies and Jan Luiten van Zanden. 2012. "Between Conquest and Independence: Real Wages and Demographic Change in Spanish America, 1530–1820." *Explorations in Economic History* 49(2):149–166.

Arroyo Abad, Leticia and Jan Luiten van Zanden. 2016. "Growth under Extractive Institutions? Latin American Per Capita GDP in Colonial Times." *The Journal of Economic History* 76(4):1182–1215.

Arroyo Abad, Leticia and Noel Maurer. 2019. "The Long Shadow of History? The Impact of Colonial Labor Institutions on Economic Development in Peru." *SSRN Electronic Journal* .

Arteaga, Fernando. 2016. "Fragmentation of an Empire: The Political Economy of Spain and Its Colonies in the

Late Bourbon Period." *Manuscript* .

Bajzik, Josef, Tomas Havranek, Zuzana Irsova and Jiri Schwarz. 2020. "Estimating the Armington elasticity: The Importance of Study Design and Publication Bias." *Journal of International Economics* 127:103383.

Bakker, Jan David, Stephan Maurer, Jörn-Steffen Pischke and Ferdinand Rauch. 2018. "Of Mice and Merchants: Trade and Growth in the Iron Age." *NBER Working Paper 24825* .

Banerjee, Abhijit and Lakshmi Iyer. 2005. "History, Institutions, and Economic Performance: The Legacy of Colonial Land Tenure Systems in India." *The American Economic Review* 95(4):43.

Barjamovic, Gojko, Thomas Chaney, Kerem Coşar and Ali Hortaçsu. 2019. "Trade, Merchants, and the Lost Cities of the Bronze Age*." *The Quarterly Journal of Economics* 134(3):1455–1503.

Baskes, Jeremy. 2013. *Staying Afloat: Risk and Uncertainty in Spanish Atlantic World Trade, 1760-1820*. Stanford, California: Stanford University Press.

Bleakley, Hoyt and Jeffrey Lin. 2012. "Portage and Path Dependence." *The Quarterly Journal of Economics* 127(2):587–644.

Bosker, Maarten and Eltjo Buringh. 2017. "City seeds: Geography and the Origins of the European City System." *Journal of Urban Economics* 98:139–157.

Bosker, Maarten, Eltjo Buringh and Jan Luiten van Zanden. 2012. "From Baghdad to London: Unraveling Urban Development in Europe, the Middle East, and North Africa, 800–1800." *The Review of Economics and Statistics* 95(4):1418–1437.

Briant, A., P. P. Combes and M. Lafourcade. 2010. "Dots to Boxes: Do the Size and Shape of Spatial Units Jeopardize Economic Geography Estimations?" *Journal of Urban Economics* 67(3):287–302.

Bruhn, Miriam and Francisco A. Gallego. 2011. "Good, Bad, and Ugly Colonial Activities: Do They Matter for Economic Development?" *The Review of Economics and Statistics* 94(2):433–461.

Bryan, Gharad and Melanie Morten. 2019. "The Aggregate Productivity Effects of Internal Migration: Evidence from Indonesia." *Journal of Political Economy* 127(5):40.

Bulmer-Thomas, Victor. 2003. *The Economic History of Latin America since Independence*. Cambridge, Massachusetts: Cambridge University Press.

Buringh, Eltjo. 2013. "The Clio-infra database on urban settlement sizes: 1500–2000.".

Cameron, A Colin, Jonah B Gelbach and Douglas L Miller. 2008. "Bootstrap-Based Improvements for Inference with Clustered Errors." *The Review of Economics and Statistics* 3(90):414–427.

Campante, Filipe and David Yanagizawa-Drott. 2018. "Long-Range Growth: Economic Development in the Global Network of Air Links*." *The Quarterly Journal of Economics* 133(3):1395–1458.

Caselli, Francesco and Wilbur John Coleman. 2001. "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation." *Journal of Political Economy* 109(3):584–616.

Christelow, Allan. 1942. "Contraband Trade between Jamaica and the Spanish Main, and the Three Port Act of 1766." *The Hispanic American Historical Review* 22(2):309.

Coatsworth, John H. 2008. "Inequality, Institutions and Economic Growth in Latin America." *Journal of Latin American Studies* 40(3):545–569.

Coatsworth, John H and Jeffrey G Williamson. 2004. "Always Protectionist? Latin American Tariffs from Independence to Great Depression." *Journal of Latin American Studies* 36(2):205–232.

Conley, T. G. 1999. "GMM Estimation with Cross Sectional Dependence." *Journal of Econometrics* 92(1):1–45.

Cuenca-Esteban, Javier. 2008. "Statistics of Spain's Colonial Trade, 1747–1820: New Estimates and Comparisons with Great Britain." *Revista de Historia Económica / Journal of Iberian and Latin American Economic History* 26(3):323–354.

Davis, Donald R. and David E. Weinstein. 2002. "Bones, Bombs, and Break Points: The Geography of Economic Activity." *American Economic Review* 92(5):1269–1289.

Davis, Donald R. and David E. Weinstein. 2008. "A Search for Multiple Equilibria in Urban Industrial Structure." *Journal of Regional Science* 48(1):29–65.

Dell, Melissa. 2010. "The Persistent Effects of Peru's Mining Mita." *Econometrica* 78(6):1863–1903.

Dell, Melissa and Benjamin A Olken. 2020. "The Development Effects of the Extractive Colonial Economy: The Dutch Cultivation System in Java." *The Review of Economic Studies* 87(1):164–203.

Delventhal, Matthew J, Jesus Fernandez-Villaverde and Nezih Guner. 2019. "Demographic Transitions Across Time and Space." *Manuscript* .

Denevan, William M. 1992. *The Native Population of the Americas in 1492*. Madison, Wisconsin: University of Wisconsin Press.

Dijkstra, E.W. 1959. "A Note on Two Problems in Connexion with Graphs." *Numerische Matamatik* 1:269– 27I.

Elliott, J. H. 2006. *Empires of the Atlantic World: Britain and Spain in America, 1492-1830*. New Haven: Yale University Press.

Engerman, S.L., K.L. Sokoloff, S. Haber, E.V. Mariscal and E.M. Zolt. 2012. *Economic Development in the Americas Since 1500: Endowments and Institutions*. Cambridge, Massachusetts: Cambridge University Press.

Fernández-Villaverde, Jesús, Mark Koyama, Youhong Lin and Tuan-Hwee Sng. 2020. "Fractured-Land and Political Fragmentation." *Manuscript* .

Feyrer, James. 2009. "Distance, Trade, and Income - The 1967 to 1975 Closing of the Suez Canal as a Natural Experiment." *NBER Working Paper 15557* .

Feyrer, James. 2019. "Trade and Income—Exploiting Time Series in Geography." *American Economic Journal: Applied Economics* 11(4):1–35.

Feyrer, James and Bruce Sacerdote. 2009. "Colonialism and Modern Income: Islands as Natural Experiments." *The Review of Economics and Statistics* 2(91):245–262.

Findlay, Ronald and Kevin H. O'Rourke. 2007. *Power and Plenty: Trade, War, and the World Economy in the Second Millennium*. The Princeton Economic History of the Western World Princeton: Princeton University Press.

Fisher, John R. 1993. *El Comercio entre España e Hispanoamérica: 1797-1820*. Number no. 27 *in* "Estudios de historia económica" Madrid: Banco de España, Servicio de Estudios.

Fisher, John R. 1997. *The Economic Aspects of Spanish Imperialism in America, 1492-1810*. Liverpool: Liverpool University Press.

Fisher, John R. 1998. "Commerce and Imperial Decline: Spanish Trade with Spanish America, 1797–1820." *Journal of Latin American Studies* 30(3):459–479.

Fisher, J.R. 1985. *Commercial Relations Between Spain and Spanish America in the Era of Free Trade, 1778-1796*. Monograph series Centre for Latin-American Studies, University of Liverpool.

Flückiger, Matthias, Erik Hornung, Mario Larch, Markus Ludwig and Allard Mees. 2019. "Roman Transport Network Connectivity and Economic Integration." *CESifo Working Paper no. 7740* .

Fouquin, Michel and Jules Hugot. 2016. "Two Centuries of Bilateral Trade and Gravity data: 1827-2014." *CEPII Working Paper* (2016-14).

Frankel, Jeffrey A and David Romer. 1999. "Does Trade Cause Growth?" *American Economic Review* 89(3):379–399.

Galor, Oded and Ömer Özak. 2015. "Land Productivity and Economic Development: Caloric Suitability vs. Agricultural Suitability." *Manuscript* .

Galor, Oded and Ömer Özak. 2016. "The Agricultural Origins of Time Preference." *American Economic Review* 106(10):3064–3103.

García-Herrera, R., G. P. Können, D. A. Wheeler, M. R. Prieto, P. D. Jones and F. B. Koek. 2005. "CLIWOC: A Climatological Database for the World's Oceans 1750–1854." *Climatic Change* 73(1):1–12.

Grafe, Regina and Alejandra Irigoin. 2012. "A Stakeholder Empire: The Political Economy of Spanish Imperial Rule in America." *The Economic History Review* 65(2):609–651.

Grafe, Regina and Maria Alejandra Irigoin. 2006. "The Spanish Empire and its Legacy: Fiscal Redistribution and Political Conflict in Colonial and Post-Colonial Spanish America." *Journal of Global History* 1(2):241–267.

Harley, C. Knick. 1988. "Ocean Freight Rates and Productivity, 1740–1913: The Primacy of Mechanical Invention Reaffirmed." *The Journal of Economic History* 48(4):851–876.

Head, Keith and Thierry Mayer. 2014. Gravity Equations: Workhorse,Toolkit, and Cookbook. In *Handbook of International Economics*. Vol. 4 Elsevier pp. 131–195.

Henderson, J. Vernon, Tim Squires, Adam Storeygard and David Weil. 2018. "The Global Distribution of Economic Activity: Nature, History, and the Role of Trade." *The Quarterly Journal of Economics* 133(1):357–406.

Herzog, Irmela. 2014. "Least cost paths – some methodological issues." *Internet Archaeol* 36.
**URL:** *https://intarch.ac.uk/journal/issue36/5/5-5.html*

Hijmans, Robert J., Susan E. Cameron, Juan L. Parra, Peter G. Jones and Andy Jarvis. 2005. "Very High Resolution Interpolated Climate Surfaces for Global Land Areas." *International Journal of Climatology* 25(15):1965–1978.

Hillmann, Henning and Christina Gathmann. 2011. "Overseas Trade and the Decline of Privateering." *The Journal of Economic History* 71(3):730–761.

Hong, Sok Chul. 2007. "The Burden of Early Exposure to Malaria in the United States, 1850–1860: Malnutrition and Immune Disorders." *The Journal of Economic History* 67(4):1001–1035.

Jedwab, Remi and Alexander Moradi. 2015. "The Permanent Effects of Transportation Revolutions in Poor Countries: Evidence from Africa." *The Review of Economics and Statistics* 98(2):268–284.

Jedwab, Remi and Dietrich Vollrath. 2015. "Urbanization Without Growth in Historical Perspective." *Explorations in Economic History* 58:1–21.

Jedwab, Remi, Edward Kerby and Alexander Moradi. 2017. "History, Path Dependence and Development: Evidence from Colonial Railways, Settlers and Cities In Kenya." *The Economic Journal* 127(603):1467–1494.

Jedwab, Remi, Luc Christiaensen and Marina Gindelsky. 2017. "Demography, Urbanization and Development: Rural Push, Urban Pull and . . . Urban Push?" *Journal of Urban Economics* 98:6–16.

Jedwab, Remi, Noel D Johnson and Mark Koyama. 2020. "Medieval Cities Through the Lens of Urban Economic Theories." *Manuscript* .

Jha, Saumitra. 2013. "Trade, Institutions, and Ethnic Tolerance: Evidence from South Asia." *American Political Science Review* 107(4):806–832.

Jia, Ruixue. 2014. "The Legacies of Forced Freedom: China's Treaty Ports." *Review of Economics and Statistics* 96(4):596–608.

Juhász, Réka. 2018. "Temporary Protection and Technology Adoption: Evidence from the Napoleonic Blockade." *American Economic Review* 108(11):3339–3376.

Kelly, Morgan. 2019. "The Standard Errors of Persistence." *Manuscript* .

Kelly, Morgan and Cormac Ó Gráda. 2019. "Speed Under Sail During the Early Industrial Revolution (c. 1750–1830)." *The Economic History Review* 72(2):459–480.

Klein Goldewijk, Kees, Arthur Beusen, Gerard Van Drecht and Martine De Vos. 2011. "The HYDE 3.1 Spatially Explicit Database of Human-Induced Global Land-Use Change over the past 12,000 Years." *Global Ecology and Biogeography* 20(1):73–86.

Kuethe, Allan J. and Kenneth J. Andrien. 2014. *The Spanish Atlantic World in the Eighteenth Century: War and the Bourbon Reforms, 1713–1796*. Cambridge, Massachusetts: Cambridge University Press.

Mahoney, James. 2010. *Colonialism and Postcolonial Development: Spanish America in a Comparative Perspective*. Cambridge, Massachusetts: Cambridge University Press.

Maloney, William F. and Felipe Valencia. 2016. "The Persistence of (Subnational) Fortune." *The Economic Journal* 126(598):2363–2401.

Maurer, Stephan and Ferdinand Rauch. 2019. "Economic Geography Aspects of the Panama Canal." *Manuscript* .

Menard, Russell R. 1991. Transport Costs and Long-Range Trade, 1300–1800: Was There a European "Transport Revolution" in the Early Modern Era? In *The Political Economy of Merchant Empires: State Power and World Trade, 1350–1750*, ed. James D. Tracy. 1 ed. Studies in Comparative Early Modern History Cambridge: Cambridge University Press pp. 228–275.

Michaels, Guy and Ferdinand Rauch. 2018. "Resetting the Urban Network: 117-2012." *The Economic Journal* 128(608):378–412.

Miguel, Edward and Gérard Roland. 2011. "The Long-Run Impact of Bombing Vietnam." *Journal of Development Economics* 96(1):1–15.

Monte, Ferdinando, Stephen J. Redding and Esteban Rossi-Hansberg. 2018. "Commuting, Migration, and Local Employment Elasticities." *American Economic Review* 108(12):3855–3890.

Morten, Melanie and Jaqueline Oliveira. 2018. "The Effects of Roads on Trade and Migration: Evidence from a Planned Capital City." *Manuscript* .

Motamed, Mesbah J., Raymond J. G. M. Florax and William A. Masters. 2014. "Agriculture, Transportation and the Timing of Urbanization: Global Analysis at the Grid Cell Level." *Journal of Economic Growth* 19(3):339–368.

Nagy, David Krisztian. 2020. "Hinterlands, City Formation and Growth: Evidence from the U.S. Westward Expansion." p. 93.

Noguer, Marta and Marc Siscart. 2005. "Trade Raises Income: A Precise and Robust Result." *Journal of International Economics* 65(2):447–460.

North, Douglass C. 1968. "Sources of Productivity Change in Ocean Shipping, 1600-1850." *Journal of Political Economy* 76(5):953–970.

Oster, Emily. 2019. "Unobservable Selection and Coefficient Stability: Theory and Evidence." *Journal of Business & Economic Statistics* 37(2):187–204.

O'Rourke, Kevin H. 2006. "The Worldwide Economic Impact of the French Revolutionary and Napoleonic Wars, 1793–1815." *Journal of Global History* 1(1):123–149.

Parry, J. H. 1990. *The Spanish Seaborne Empire*. Berkeley, California: University of California Press.

Pascali, Luigi. 2017. "The Wind of Change: Maritime Technology, Trade, and Economic Development." *American Economic Review* 107(9):2821–2854.

Prados de la Escosura, Leandro and Gabriel Tortella Casares. 1983. "Tendencias a Largo Plazo del Comercio Exterior Español, 1714–1913." *Revista de Historia Económica / Journal of Iberian and Latin American Economic*

*History* 1(2):353–367.

Rahn Phillips, Carla. 1990. The Growth and Composition of Trade in the Iberian Empires, 1450–1750. In *The Rise of Merchant Empires: Long-Distance Trade in the Early Modern World, 1350-1750*, ed. James D. Tracy. Studies in Comparative Early Modern History Cambridge: Cambridge University Press.

Ramankutty, Navin and Jonathan A. Foley. 1999. "Estimating Historical Changes in Global Land Cover: Croplands from 1700 to 1992." *Global Biogeochemical Cycles* 13(4):997–1027.

Ramíres Bibiano, Torres and Javier Ortíz de la Tabla. 1978. *Reglamento y Aranceles Reales para el Comercio Libre de España a Indias de 12 Octubre de 1778*. Seville: Escuela de Estudios Hispano-Americanos.

Redding, Stephen J and Daniel M Sturm. 2008. "The Costs of Remoteness: Evidence from German Division and Reunification." *American Economic Review* 98(5):1766–1797.

Redding, Stephen J., Daniel M. Sturm and Nikolaus Wolf. 2010. "History and Industry Location: Evidence from German Airports." *The Review of Economics and Statistics* 93(3):814–831.

Redding, Stephen J and Esteban Rossi-Hansberg. 2017. "Quantitative Spatial Economics." *Annual Review of Economics* (9):21–58.

Rodriguez, Francisco and Dani Rodrik. 1999. "Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence." *NBER Working Paper 7081* .

Rönnbäck, K. 2012. "The Speed of Ships and Shipping Productivity in the Age of Sail." *European Review of Economic History* 16(4):469–489.

Silva, J. M. C. Santos and Silvana Tenreyro. 2006. "The Log of Gravity." *The Review of Economics and Statistics* 88(4):641–658.

Stangl, Werner. 2018. "'The Empire Strikes Back' ?: HGIS de las Indias and the Postcolonial Death Star." *International Journal of Humanities and Arts Computing* 12(2):138–162.

Stangl, Werner. 2019*a*. "Data: Mail land routes of Spanish America, 1745-1808.".
**URL:** *https://doi.org/10.7910/DVN/W4C9H7*

Stangl, Werner. 2019*b*. "Data: Places gazetteer of Spanish America, 1701-1808.". type: dataset.
**URL:** *https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/FUSJD3*

Stangl, Werner. 2019*c*. "Demographic data, 1701-1808.".
**URL:** *https://doi.org/10.7910/DVN/QABIBG*

Tobler, Waldo. 1993. "Three Presentations on Geographical Analysis and Modeling." *Technical Report* .

Tombe, Trevor and Xiaodong Zhu. 2019. "Trade, Migration, and Productivity: A Quantitative Analysis of China." *American Economic Review* 109(5):1843–1872.

Verhagen, Philip, Jamie Joyce and Mark R. Groenhuijzen, eds. 2019. *Finding the Limits of the Limes: Modelling Demography, Economy and Transport on the Edge of the Roman Empire*. Computational Social Sciences Cham: Springer International Publishing.

Walker, Geoffrey J. 1979. *Spanish Politics and Imperial Trade, 1700-1789*. London, UK: Palgrave Macmillan.

Weiss, D. J., A. Nelson, H. S. Gibson, W. Temperley, S. Peedell, A. Lieber, M. Hancher, E. Poyart, S. Belchior, N. Fullman, B. Mappin, U. Dalrymple, J. Rozier, T. C. D. Lucas, R. E. Howes, L. S. Tusting, S. Y. Kang, E. Cameron, D. Bisanzio, K. E. Battle, S. Bhatt and P. W. Gething. 2018. "A global map of travel time to cities to assess inequalities in accessibility in 2015." *Nature* 553(7688):333–336.
**URL:** *http://www.nature.com/articles/nature25181*

White, Devin Alan. 2015. "The Basics of Least Cost Analysis for Archaeological Applications." *Advances in*

*Archaeological Practice* 3(4):407–414.

Zou, Hui and Trevor Hastie. 2005. "Regularization and Variable Selection via the Elastic Net." *Journal of the Royal Statistical Society: Series B (Statistical Methodology)* 67(2):301–320.

Özak, Ömer. 2010. "The Voyage of Homo-œconomicus: Some Economic Measures of Distance." *Manuscript* .

Özak, Ömer. 2018. "Distance to the Pre-Industrial Technological Frontier and Economic Development." *Journal of Economic Growth* 23(2):175–221.

# 8 Tables

*Table 1: Summary Statistics of main dataset*

| Statistic | N | Mean | St. Dev. | Min | Median | Max |
|---|---|---|---|---|---|---|
| #Cities 1710-1810 | 55,154 | 0.11 | 0.31 | 0 | 0 | 1 |
| Population 1760 | 55,154 | 2,566.04 | 7,133.60 | 0.00 | 248.65 | 152,161.50 |
| Population 1810 | 55,154 | 3,095.90 | 9,151.38 | 0.00 | 304.47 | 250,848.50 |
| Shipping time 1760 (days) | 55,154 | 83.08 | 25.19 | 35.49 | 82.19 | 158.67 |
| Shipping time 1810 (days) | 55,154 | 77.06 | 25.04 | 26.46 | 73.58 | 151.90 |
| Δ Shipping time (days) | 55,154 | 6.02 | 7.68 | 0.00 | 4.35 | 27.32 |
| Elevation | 55,154 | 0.23 | 0.42 | 0 | 0 | 1 |
| Terrain ruggednes | 55,154 | 188.07 | 214.44 | 1.28 | 96.49 | 1,139.80 |
| Average crop suitability | 55,154 | 0.00 | 1.00 | −1.86 | −0.11 | 3.23 |
| Mining center | 55,154 | 0.03 | 0.18 | 0 | 0 | 1 |
| Average Temp. (Celsius) | 55,154 | 17.93 | 7.33 | −2.12 | 19.03 | 28.83 |
| Precipitation (mm.) | 55,154 | 1,162.72 | 950.92 | 0.49 | 890.98 | 7,482.85 |
| Coffee | 55,154 | 7.02 | 1.36 | 2 | 8 | 9 |
| Tobacco | 55,154 | 6.67 | 1.33 | 2.00 | 6.78 | 8.75 |
| Cotton | 55,154 | 6.54 | 1.64 | 1 | 7.0 | 9 |
| Wheat | 55,154 | 6.64 | 1.61 | 1.02 | 7.31 | 8.75 |
| Maize | 55,154 | 6.16 | 1.66 | 1.00 | 6.13 | 8.75 |
| Sugar cane | 55,154 | 6.76 | 1.44 | 1 | 7.8 | 9 |
| Dist. Coast (km) | 55,154 | 412.17 | 317.95 | 0.19 | 336.61 | 1,471.73 |
| Dist. River (km) | 55,154 | 387.57 | 436.48 | 0.02 | 226.78 | 2,481.35 |
| Dist. Port 1750 (km) | 55,154 | 812.69 | 673.36 | 3.76 | 621.79 | 3,157.83 |
| Decade | 55,154 | 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 5,014 grid cells ($5,014 \times 11 = 55,154$). *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).

*Table 4: Ports 1700 - 1810*

| *Port* | *Country* | *Direct trade (decade)* | *Longitude* | *Latitude* |
|---|---|---|---|---|
| Cadiz | Spain | <1700 | -6.28 | 36.53 |
| Acapulco | Mexico | <1700 | -99.91 | 16.85 |
| Portobelo | Panama | <1700 | -79.65 | 9.55 |
| Panama | Panama | <1700 | -79.53 | 8.95 |
| El Callao | Peru | <1700 | -77.15 | -12.06 |
| Cartagena de Indias | Colombia | <1700 | -75.55 | 10.42 |
| Veracruz | Mexico | <1700 | -96.14 | 19.19 |
| Batabano | Cuba | 1765 | -82.29 | 22.72 |
| Isla de Trinidad | Trinidad and Tobago | 1765 | -61.51 | 10.65 |
| Isla Margarita | Venezuela | 1765 | -63.85 | 10.95 |
| La Habana | Cuba | 1765 | -82.35 | 23.14 |
| Monte-Christi | Dominican Republic | 1765 | -71.64 | 19.85 |
| San Juan de Puerto Rico | Puerto Rico | 1765 | -66.12 | 18.47 |
| Santiago de Cuba | Cuba | 1765 | -75.82 | 20.022 |
| Santo Domingo | Dominican Republic | 1765 | -69.94 | 18.48 |
| Trinidad | Cuba | 1765 | -79.98 | 21.80 |
| Campeche | Mexico | 1770 | -90.54 | 19.84 |
| Arica | Chile | 1778 | -70.32 | -18.48 |
| Buenos Aires | Argentina | 1778 | -58.37 | -34.61 |
| Chagres | Panama | 1778 | -80.00 | 9.32 |
| Concepcion | Chile | 1778 | -73.05 | -36.83 |
| Guayaquil | Ecuador | 1778 | -79.88 | -2.19 |
| Montevideo | Uruguay | 1778 | -56.20 | -34.91 |
| Nuevitas | Cuba | 1778 | -77.27 | 21.55 |
| Omoa | Honduras | 1778 | -88.04 | 15.78 |
| Riohacha | Colombia | 1778 | -72.91 | 11.55 |
| Santa Marta | Colombia | 1778 | -74.21 | 11.24 |
| Cumana | Venezuela | 1788 | -64.18 | 10.47 |
| La Cruz | Venezuela | 1788 | -64.64 | 10.21 |
| La Guaira | Venezuela | 1788 | -66.93 | 10.60 |
| San Blas | Colombia | 1789 | -105.29 | 21.53 |
| Maracaibo | Venezuela | 1793 | -71.62 | 10.65 |
| Matanzas | Cuba | 1793 | -81.58 | 23.05 |
| Villahermosa | Mexico | 1793 | -92.93 | 17.99 |
| Acajutla | El Salvador | 1796 | -89.83 | 13.59 |
| Isla de Carmen | Mexico | 1796 | -91.81 | 18.65 |
| Puerto Cabello | Venezuela | 1798 | -68.01 | 10.48 |
| El Realejo | Nicaragua | 1796 | -87.17 | 12.54 |
| San Andres | Colombia | 1798 | -81.71 | 12.58 |
| Santo Tomas de Castilla | Guatemala | 1798 | -89.00 | 15.64 |
| Valparaiso | Chile | 1798 | -71.60 | -33.05 |
| Baracoa | Cuba | 1803 | -74.50 | 20.35 |
| Manzanillo | Mexico | 1803 | -104.28 | 19.12 |
| Sisal | Mexico | 1807 | -88.21 | 20.69 |
| San Bernardo | United States | 1808 | -96.63 | 28.62 |
| Matina | Costa Rica | 1811 | -83.29 | 10.08 |
| Manta | Ecuador | - | -80.91 | -0.97 |
| Esmeraldas | Ecuador | - | -79.90 | 0.95 |
| Trujillo | Peru | - | -79.00 | -8.10 |
| Huacho | Peru | - | -77.61 | -11.11 |
| Paita | Peru | - | -81.11 | -5.09 |
| Huarmey | Peru | - | -78.15 | -10.07 |
| Maldonado | Uruguay | - | -54.95 | -34.90 |
| Carupano | Venezuela | - | -63.25 | 10.67 |
| Barcelona | Venezuela | - | -64.66 | 10.13 |
| Barranquilla | Colombia | - | -74.80 | 10.96 |
| Buenaventura | Colombia | - | -77.35 | 3.88 |
| Puntarenas | Costa Rica | - | -84.83 | 9.98 |
| Tela | Honduras | - | -87.46 | 15.76 |
| Tuxpan | Mexico | - | -97.40 | 21.86 |

*Table 2: The shipping time elasticity of trade 1797 - 1820*

| *Outcome*: | Value of exports (ln) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel (a): OLS Estimator | | | | |
| ln Shipping time | $-2.19^{*}$ | $-3.30^{***}$ | $-3.13^{***}$ | $-2.87^{***}$ |
| | (1.17) | (0.97) | (1.03) | (1.11) |
| Panel (b): PPML Estimator | | | | |
| ln Shipping time | $-2.59^{*}$ | $-3.34^{***}$ | $-3.09^{***}$ | $-3.22^{***}$ |
| | (1.17) | (0.86) | (0.83) | (0.86) |
| *Observations* | 211 | 211 | 211 | 211 |
| Year FE | | ✓ | ✓ | |
| Region FE | | ✓ | ✓ | ✓ |
| Viceroyalty FE | | | ✓ | |
| Region × Year FE | | | | ✓ |

Note: The table shows the relationship between shipping time and the value of exports from Spain. Shipping time denotes the shipping time from Spain. The value of trade is measured in *reales de vellón*. The sample contains ports with limited direct trade with Spain prior to the reform period. The data is from Fisher (1993). Robust standard errors in paranthesis. $^{***}p < .01$, $^{**}p < .05$, $^{*}$ $p < .1$

*Table 5: 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 (log) | 0.378*** | 0.291*** | 0.498*** | 0.400** |
| | (0.102) | (0.101) | (0.140) | (0.137) |
| Panel (b): $\Delta T$ <Median | | | | |
| Population density 1500 (log) | 0.495*** | 0.412*** | 0.590*** | 0.495*** |
| | (0.077) | (0.093) | (0.082) | (0.092) |
| Panel (c): $\Delta T \geq$Median | | | | |
| Population density 1500 (log) | 0.302*** | 0.198*** | 0.038 | 0.004 |
| | (0.110) | (0.072) | (0.176) | (0.166) |
| Country FE | | | ✓ | ✓ |
| Controls | | ✓ | | ✓ |
| *Observations* | 120 | 119 | 120 | 119 |
| *Adjusted R-squared* | 0.224 | 0.424 | 0.358 | 0.572 |

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 6: 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 | $-4.747^{***}$ | $-3.700^{***}$ | $-6.478^{***}$ | $-5.801^{***}$ |
| | (1.321) | (1.333) | (2.103) | (1.736) |
| Panel (b): $\Delta T$ <Median | | | | |
| Distance to coast | $7.222^{***}$ | $6.247^{**}$ | $7.473^{**}$ | $6.246^{**}$ |
| | (2.756) | (2.912) | (3.130) | (2.656) |
| Panel (c): $\Delta T$ ≥Median | | | | |
| Distance to coast | $-5.292^{***}$ | $-3.960^{*}$ | $-9.301^{***}$ | $-9.702^{***}$ |
| | (1.834) | (2.046) | (1.645) | (1.530) |
| Country FE | | | ✓ | ✓ |
| Controls | | ✓ | | ✓ |
| *Observations* | 124 | 119 | 124 | 119 |
| *Adjusted R-squared* | 0.267 | 0.352 | 0.525 | 0.565 |

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 7: Event-study specification*

| *Dependent variable*: | Indicator variable for grid-cell containing a settlement | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1710) | −0.137 | −0.137 | −0.072 | −0.050 | −0.050 |
| | (0.063) | (0.063) | (0.040) | (0.040) | (0.040) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1720) | −0.113 | −0.113 | −0.056 | −0.038 | −0.038 |
| | (0.054) | (0.054) | (0.035) | (0.036) | (0.036) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1730) | −0.083 | −0.083 | −0.028 | −0.013 | −0.013 |
| | (0.044) | (0.044) | (0.032) | (0.033) | (0.033) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1740) | −0.043 | −0.043 | −0.005 | 0.009 | 0.009 |
| | (0.033) | (0.033) | (0.023) | (0.026) | (0.026) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1750) | −0.033 | −0.033 | 0.014 | 0.021 | 0.021 |
| | (0.021) | (0.021) | (0.012) | (0.014) | (0.014) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1770) | 0.007 | 0.007 | 0.005 | 0.009 | 0.009 |
| | (0.015) | (0.015) | (0.014) | (0.013) | (0.013) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1780) | 0.041 | 0.041 | 0.011 | 0.016 | 0.016 |
| | (0.023) | (0.023) | (0.022) | (0.021) | (0.021) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1790) | 0.080 | 0.080 | 0.018 | 0.026 | 0.026 |
| | (0.031) | (0.031) | (0.035) | (0.033) | (0.033) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1800) | 0.109 | 0.109 | 0.043 | 0.059 | 0.059 |
| | (0.030) | (0.030) | (0.034) | (0.033) | (0.033) |
| $\Delta$ T $\times$ $\mathbb{1}$ (*year* = 1810) | 0.124 | 0.124 | 0.059 | 0.078 | 0.078 |
| | (0.032) | (0.032) | (0.035) | (0.034) | (0.034) |
| Audiencia FE | | ✓ | ✓ | ✓ | ✓ |
| Audiencia × Decade FE | | | ✓ | ✓ | ✓ |
| Controls | | | | ✓ | ✓ |
| Controls × Decade FE | | | | | ✓ |
| Mean dep. var. | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| *Observations* | 61,303 | 61,303 | 61,303 | 61,303 | 61,303 |

*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 8: Heterogeneity by crop suitability*

| *Dependent variable*: | Indicator for grid-cell containing a settlement | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| T | $-0.031^{*}$ | $-0.037^{**}$ | $-0.005$ | $-0.013$ |
| | (0.017) | (0.014) | (0.015) | (0.013) |
| T × Crop suitability | $-0.038^{**}$ | $-0.032^{**}$ | $-0.026$ | $-0.026^{*}$ |
| | (0.016) | (0.012) | (0.016) | (0.014) |
| Viceroyalty FE × Year | ✓ | ✓ | | |
| Audiencia FE × Year | | | ✓ | ✓ |
| Geographic Controls | | ✓ | | ✓ |
| Mean dep. var. | 0.1 | 0.1 | 0.1 | 0.1 |
| *Observations* | 61,303 | 61,303 | 61,303 | 61,303 |
| *Adjusted R-squared* | 0.853 | 0.855 | 0.859 | 0.860 |

*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 10: Correlation of population between the model and the data*

| Year | Changes | Levels |
|---|---|---|
| $\text{Population}_{1810}$ | 0.306 | 0.878 |
| $\text{Population}_{1860}$ | 0.572 | 0.689 |
| $\text{Population}_{1910}$ | 0.573 | 0.457 |
| $\text{Population}_{1960}$ | 0.537 | 0.206 |
| $\text{Population}_{2010}$ | 0.523 | 0.145 |

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

*Table 11: Shipping time and city population*

| *Dependent variable*: | Population size (log) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Shipping Time (log) | $-0.544^{*}$ | $-0.320$ | $-0.399^{*}$ | $-0.424^{**}$ | $-0.273$ |
| | (0.311) | (0.233) | (0.223) | (0.212) | (0.223) |
| City FE | | ✓ | ✓ | ✓ | ✓ |
| Decade FE | | ✓ | ✓ | | |
| Controls | | | ✓ | ✓ | ✓ |
| Viceroyalty × Decade FE | | | | ✓ | |
| Audiencia × Decade FE | | | | | ✓ |
| *Observations* | 606 | 606 | 606 | 606 | 606 |
| *Adjusted R-squared* | 0.018 | 0.156 | 0.193 | 0.191 | 0.201 |

Note: The unit of analysis is at the city-level. **Dependent variable:** City population from Buringh (2013). **Controls:** Elevation, crop suitability, the location of active mines, and distance to the coastline. **Standard errors:** Clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}$ $p < .1$

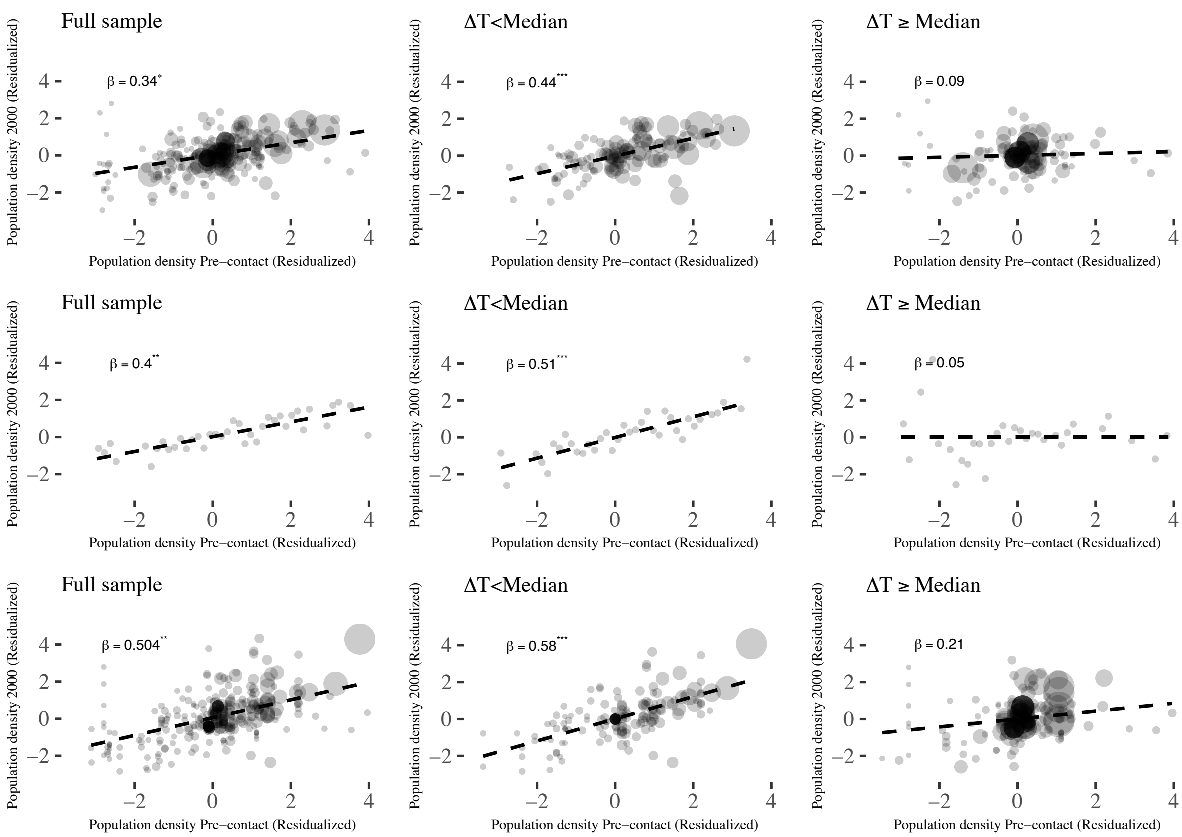


**Figure 10:** The figure shows the relationship between pre-contact population density and the population density in year 2000 at the level of the province. The left figure shows the relationship for the full sample. The middle figure shows the relationship for provinces with below median change in 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 people per square kilometre pre-contact. The dependent variable is the log of people per square km in 2000. The full sample contains 337 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.

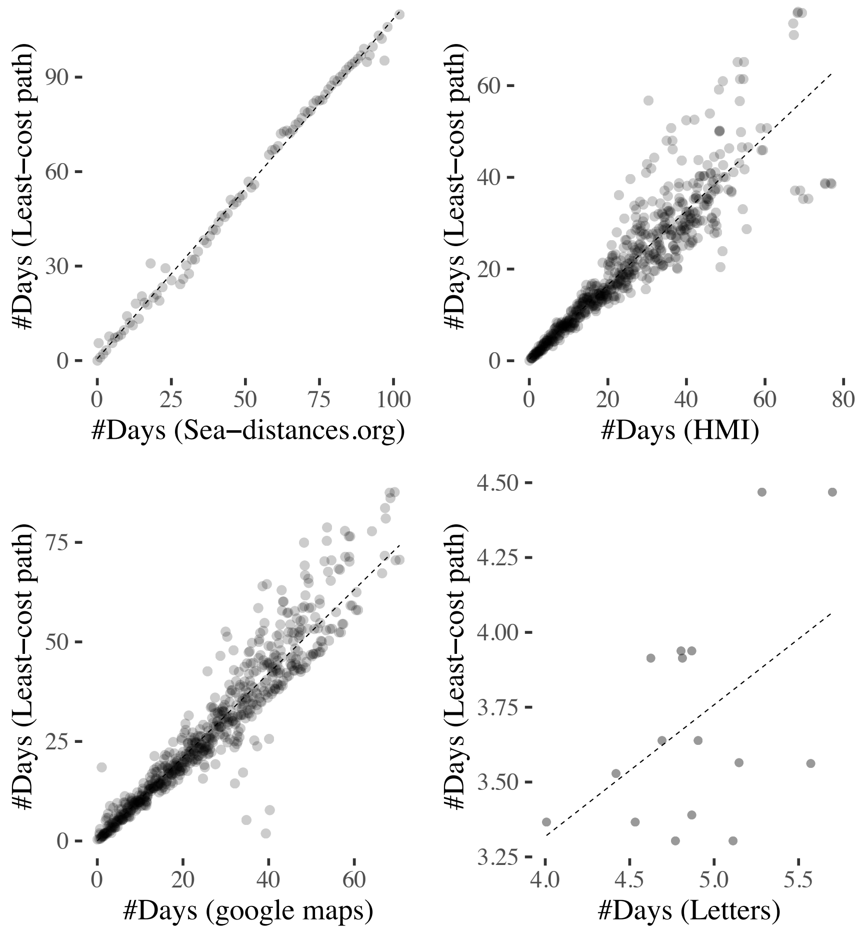


**Figure 11:** The figures show the results from the main validation exercises. The top-left figure shows the relationship between sailing times produced by the least-cost path on the constructed cost-surface and sailing times from sea-distances.org for voyages between Cadiz and 21 ports in Spanish America. The travel times are set to 4 knots which is the average speed attained over the cost-surface. The top-right figure shows the relationship between bilateral shipping times between large cities generated by the least-cost path on the constructed cost-surface and the Human Mobility Index developed in Özak (2010, 2018). The bottom-left figure shows the relationship between bilateral shipping times between major cities generated by the least-cost path on the constructed cost-surface and google maps.


**Figure 12:** The figures show the results from the main validation exercises. The top-left figure shows the relationship between sailing times produced by the least-cost path on the constructed cost-surface 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. The top-right figure shows the relationship between bilateral shipping times between large cities generated by the least-cost path on the constructed cost-surface and the Human Mobility Index developed in Özak (2010, 2018). The bottom-left figure shows the relationship between bilateral shipping times between major cities generated by the least-cost path on the constructed cost-surface and google maps.

# 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 $\Omega$ 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 $\mu$ is the constant labor share. Firms maximize profits which gives the demand for labor of firm $\omega$ 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 $j$ is given by $V_{ij} = \frac{V_j}{\mu_{ij}} \epsilon_j$ where $\epsilon_j$ is an iid draw from a Fréchet-distribution with shape parameter $\theta$ and $V_{ij} = V_j \,/\, \mu_{ij}$ (time subscripts are surpressed in the derivations to follow). An individual chooses to move from $i$ to $j$ if the realized utility of that location is higher, which happens with probability $Pr\left( V_{ij} \epsilon_j \geq V_{ik} \epsilon_k \forall k \neq j \in R \right)$. Since the shock is iid and there is a continuum of agents in each location this corresponds to the share moving, denoted $\pi_{ij}$. It follows that the conditional probability of moving is,

$$\pi_{ij} | \epsilon_j = Pr\left( \epsilon_k \leq \frac{V_{ij} \epsilon_j}{V_{ik}} \epsilon_k \forall k \neq j \in R \right) = \prod_{k \neq j} Pr\left( \epsilon_k \leq \frac{V_{ij} \epsilon_j}{V_{ik}} \epsilon_k \right). \tag{A.6}$$

As a result, the unconditional distribution is given by,

$$\pi_{ij} = \int_0^\infty f(\epsilon_j) \prod_{k \neq j} Pr\left(\epsilon_k \leq \frac{V_{ij}\epsilon_j}{V_{ik}}\epsilon_k\right) d\epsilon_j = \int_0^\infty \theta \epsilon_j^{-1-\theta} \exp\{-\epsilon_j^{-\theta}\} \exp\{-V_{ij}^{-\theta} \epsilon_j^{-\theta} \sum_{k \neq j} V_{ik}^{\theta}\} d\epsilon_j \tag{A.7}$$

$$= \int_0^\infty \theta \epsilon_j^{-1-\theta} \exp\{-\epsilon_j^{-\theta} \Phi_j\} d\epsilon_j = \Phi_j^{-1} = \frac{V_{ij}^{\theta}}{\sum_{k \in R} V_{ik}^{\theta}} = \frac{(V_j \,/\, \mu_{ij})^{\theta}}{\sum_{k \in R} (V_k \,/\, \mu_{ik})^{\theta}}, \tag{A.8}$$

which follows after making the substitution defining $x = \epsilon_j^{-\theta}\Phi_j$. The expected utility (prior to the realization of shocks) for an agent living in location $i$ is given by $E[\max_{j \in R} V_{ij}]$. To derive the expression define $\psi_{ij}$ which gives the utility expected to be derived from location $j$. It follows that $\psi_{ij}|\epsilon_j = V_{ij}\epsilon_j Pr\left(\epsilon_k \leq \frac{V_{ij}\epsilon_j}{V_{ik}}\epsilon_k \forall k \neq j \in R\right) = V_{ij}\epsilon_j \prod_{k \neq j} Pr\left(\epsilon_k \leq \frac{V_{ij}\epsilon_j}{V_{ik}}\epsilon_k\right)$. As a result, the unconditional expectation is given by,

$$\psi_{ij} = \int_0^\infty f(\epsilon_j) V_{ij} \epsilon_j \prod_{k \neq j} Pr\left(\epsilon_k \leq \frac{V_{ij}\epsilon_j}{V_{ik}}\epsilon_k\right) d\epsilon_j. \tag{A.9}$$

Again using the distributional assumptions and rearranging gives

$$\psi_{ij} = \theta V_{ij} \int_0^\infty \epsilon_j^{-\theta} \exp\{-\epsilon_j^{-\theta}\Phi_j\} \epsilon_j. \tag{A.10}$$

Substituting with $x = \epsilon_j^{-\theta}\Phi_j$, it follows that $\psi_{ij} = C V_{ij} \Phi_j^{\frac{1-\theta}{\theta}}$. Then summing over $\psi_{ij}$ gives $\Pi_i = \sum_{k \in R} \psi_{ik} = \left(\sum_{k \in R} V_{ik}^{\theta}\right)^{\frac{1}{\theta}}$. The number of people moving from $i$ to $j$ is the $L_{ijt} = \pi_{ij} L_{it-1} = L_{it-1} V_j^{\theta} \Pi_i^{-\theta} \mu_{ij}^{-\theta}$ which is the gravity equation for migration in the model.

**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,

$$\frac{w_{it} L_{it}}{\mu} = \frac{1}{\mu} \sum_{j \in R} \tau_{ijt}^{1-\sigma} p_{it}^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt} \tag{A.11}$$

$$w_{it}^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{A_{it} \mu L_{it}^{\mu-1} H_i^{1-\mu}}\right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.12}$$

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

$$w_{it}^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu \bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2} L_{it}^{\mu-1} H_i^{1-\mu}}\right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.13}$$

$$w_{it}^{\sigma} L_{it} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu \bar{A}_i L_{it}^{\alpha_1+\mu-1} L_{it-1}^{\alpha_2} H_i^{1-\mu}}\right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.14}$$

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j \in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu \bar{A}_i L_{it-1}^{\alpha_2} H_i^{1-\mu}}\right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}, \tag{A.15}$$

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,

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j\in R} \tau_{ijt}^{1-\sigma} \left( \frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} H_i^{1-\mu}} \right)^{1-\sigma} \left( \bar{u}_j L_{jt}^{\beta_1} L_{jt-1}^{\beta_2} \right)^{\sigma-1} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}, \tag{A.16}$$

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j\in R} \tau_{ijt}^{1-\sigma} \left( \frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} H_i^{1-\mu}} \right)^{1-\sigma} \left( \bar{u}_j L_{jt-1}^{\beta_2} \right)^{\sigma-1} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}^{1+\beta_1(\sigma-1)}, \tag{A.17}$$

$$w_{it}^{\sigma} L_{it}^{1+\tilde{\alpha}_1(1-\sigma)} = \sum_{j\in R} \tau_{ijt}^{1-\sigma} \left( \frac{1}{\bar{A}_i L_{it-1}^{\alpha_2} \bar{u}_j L_{jt-1}^{\beta_2} H_i^{1-\mu}} \right)^{1-\sigma} V_{jt}^{1-\sigma} w_{jt}^{\sigma} L_{jt}^{1+\beta_1(\sigma-1)}, \tag{A.18}$$

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,

$$\frac{w_{it} L_{it}}{\mu} = \frac{1}{\mu} \sum_{j\in R} \tau_{jit}^{1-\sigma} p_{jt}^{1-\sigma} P_{it}^{\sigma-1} w_{it} L_{it}, \tag{A.19}$$

$$1 = \sum_{j\in R} \tau_{jit}^{1-\sigma} \left( \frac{w_{jt}}{\bar{A}_i L_{it}^{\alpha_1} L_{it-1}^{\alpha_2} L_{it}^{\mu-1} H_i^{1-\mu}} \right)^{1-\sigma} \left( \frac{u_{it} w_{it}}{V_{it}} \right)^{\sigma-1}, \tag{A.20}$$

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

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

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.

$$L_{it} V_{it}^{-\theta} = \sum_{i\in\Omega} \mu_{jit}^{-\theta} \Pi_{jt}^{-\theta} L_{jt-1}. \tag{A.23}$$

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,

$$L_{it-1} = \sum_{i\in\Omega} \mu_{ijt}^{-\theta} \Pi^{-\theta} L_{it-1} V_{jt}^{\theta}. \tag{A.24}$$

**Uniqueness of the Equilibrium.** The results that guarantee uniqueness of the equilibrium are found in Allen and Donaldson (2018) and Allen, Arkolakis and Li (2020). 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,

$$w_{it}^{1-\sigma} A_{it}^{\sigma-1} \propto P_{it}^{\sigma-1} w_{it} L_{it} \tag{A.25}$$

$$w_{it} \propto u_{it}^{\frac{\sigma-1}{1-2\sigma}} V_{it}^{\frac{1-\sigma}{1-2\sigma}} L_{it}^{\frac{1}{1-2\sigma}} A_{it}^{\frac{1-\sigma}{1-2\sigma}} \tag{A.26}$$

$$w_{it} \propto u_{it}^{-\tilde{\sigma}} V_{it}^{\tilde{\sigma}} L_{it}^{\frac{1}{1-2\sigma}} A_{it}^{\tilde{\sigma}} \tag{A.27}$$

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

$$\left(u_{it}^{-\tilde{\sigma}} V_{it}^{\tilde{\sigma}} L_{it}^{\frac{1}{1-2\sigma}} A_{it}^{\tilde{\sigma}}\right)^{\sigma} L_{it} = \sum_{j\in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{L_{it}^{\mu-1} H_i^{1-\mu}}\right)^{1-\sigma} A_{it}^{\sigma-1} u_{jt}^{\sigma-1} \left(u_{jt}^{-\tilde{\sigma}} V_{jt}^{\tilde{\sigma}} L_{jt}^{\frac{1}{1-2\sigma}} A_{jt}^{\tilde{\sigma}}\right)^{\sigma} V_{jt}^{1-\sigma} L_{jt}, \tag{A.28}$$

$$V_{it}^{\tilde{\sigma}\sigma} L_{it}^{\frac{\sigma}{1-\sigma}\tilde{\sigma}+1} = \sum_{j\in R} \tau_{ijt}^{1-\sigma} \left(\frac{1}{\mu H_i^{1-\mu}}\right)^{1-\sigma} L_{it}^{(1-\mu)(1-\sigma)} A_{it}^{\sigma-1-\tilde{\sigma}\sigma} u_{it}^{\tilde{\sigma}\sigma} u_{jt}^{\sigma-1-\tilde{\sigma}\sigma} L_{jt}^{\frac{\sigma}{1-\sigma}\tilde{\sigma}+1} A_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{1-\sigma+\tilde{\sigma}\sigma}. \tag{A.29}$$

Inserting the agglomeration spillovers gives the following three equilibrium conditions,

$$\begin{aligned} V_{it}^{\tilde{\sigma}\sigma} L_{it}^{\sigma(1-\alpha_1-\beta_1\sigma\tilde{\sigma})-(1-\mu)(1-\sigma)} = & \textstyle\sum_{j\in R} \left(\frac{\tau_{ijt}}{\mu H_i^{1-\mu}}\right)^{1-\sigma} \bar{A}_i^{(\sigma-1)\tilde{\sigma}} \bar{u}_{it}^{\tilde{\sigma}\sigma} \bar{u}_{jt}^{\tilde{\sigma}(\sigma-1)} \bar{A}_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{\tilde{\sigma}(1-\sigma)} \\ & L_{it-1}^{\tilde{\sigma}(\alpha_2(\sigma-1)+\sigma\beta_2)} L_{jt-1}^{\tilde{\sigma}(\beta_2(\sigma-1)+\alpha_2\sigma)} L_{jt}^{\tilde{\sigma}(1+\beta_1(\sigma-1)+\alpha_1\sigma))}. \end{aligned} \tag{A.30}$$

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

$$\begin{aligned} V_{it}^{\tilde{\sigma}\sigma} L_{it}^{\tilde{\sigma}(1-\alpha_1(\sigma-1)-\beta_1\sigma)-(1-\mu)(1-\sigma)} = & \textstyle\sum_{j\in R} \left(\frac{\tau_{ijt}}{\mu H_i^{1-\mu}}\right)^{1-\sigma} \bar{A}_i^{(\sigma-1)\tilde{\sigma}} \bar{u}_{it}^{\tilde{\sigma}\sigma} \bar{u}_{jt}^{\tilde{\sigma}(\sigma-1)} \bar{A}_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{\tilde{\sigma}(1-\sigma)} \\ & \times L_{it-1}^{\tilde{\sigma}(\alpha_2(\sigma-1)+\sigma\beta_2)} L_{jt-1}^{\tilde{\sigma}(\beta_2(\sigma-1)+\alpha_2\sigma)} L_{jt}^{\tilde{\sigma}(1+\beta_1(\sigma-1)+\alpha_1\sigma))}. \end{aligned} \tag{A.31}$$

$$\Pi_{it}^{\theta} = \sum_{i\in R} \mu_{ij}^{-\theta} V_{jt}^{\theta}. \tag{A.32}$$

$$L_{it} V_{it}^{-\theta} = \sum_{i\in R} \mu_{ji} \Pi_{jt}^{-\theta} L_{jt-1}, \tag{A.33}$$

Ordering the endogenous variables as $L$, $V$, $\Pi$ gives the following matrices of coefficients,

$$\mathbf{B} = \begin{bmatrix} \tilde{\sigma}(1-\alpha_1(\sigma-1)-\beta_1\sigma)-(1-\mu)(1-\sigma) & \tilde{\sigma}\sigma & 0 \\ 0 & 0 & \theta \\ 1 & -\theta & 0 \end{bmatrix}, \tag{A.34}$$

$$\mathbf{\Gamma} = \begin{bmatrix} \tilde{\sigma}(1+\beta_1(\sigma-1)+\alpha_1\sigma)) & \tilde{\sigma}(1-\sigma) & 0 \\ 0 & \theta & 0 \\ 0 & 0 & -\theta \end{bmatrix}. \tag{A.35}$$

Taking the inverse of **B** gives,

$$\mathbf{B}^{-1} = \frac{1}{(b_{11}\theta+\tilde{\sigma}\sigma)\theta} \begin{bmatrix} \theta^2 & 0 & \tilde{\sigma}\sigma\theta \\ \theta & 0 & -b_{11}\theta \\ 0 & b_{11}\theta+\tilde{\sigma}\sigma & 0 \end{bmatrix} \tag{A.36}$$

Therefore,

$$\mathbf{A} = \mathbf{\Gamma}\mathbf{B}^{-1} = \frac{1}{(b_{11}\theta+\tilde{\sigma}\sigma)\theta} \begin{bmatrix} \gamma_{11}\theta^2+\gamma_{12}\theta & 0 & \gamma_{11}\tilde{\sigma}\sigma\theta-\gamma_{12}b_{11}\theta \\ \theta^2 & 0 & -b_{11}\theta^2 \\ 0 & -\theta(b_11\theta+\tilde{\sigma}\sigma) & 0 \end{bmatrix} \tag{A.37}$$

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

$$\rho(\mathbf{A}) \leq 1, \tag{A.38}$$

where,

$$\mathbf{A} = \frac{1}{(b_{11}\theta+\tilde{\sigma}\sigma)\theta} \begin{bmatrix} \gamma_{11}\theta^2+\gamma_{12}\theta & \gamma_{11}\tilde{\sigma}\sigma\theta-\gamma_{12}b_{11}\theta \\ \theta^2 & -b_{11}\theta^2 \end{bmatrix}. \tag{A.39}$$

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 Allen, Arkolakis and Li (2020) 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 $\Omega$ 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,

$$\begin{aligned} V_{it}^{\tilde{\sigma}\sigma} L_i^{\tilde{\sigma}(1-(\alpha_1+\alpha_2)(\sigma-1)-(\beta_1+\beta_2)\sigma)-(1-\mu)(1-\sigma)} = \textstyle\sum_{j\in R} \left(\frac{\tau_{ijt}}{\mu H_i^{1-\mu}}\right)^{1-\sigma} & \bar{A}_i^{(\sigma-1)\tilde{\sigma}} \bar{u}_{it}^{\tilde{\sigma}\sigma} \bar{u}_{jt}^{\tilde{\sigma}(\sigma-1)} \\ \times \bar{A}_{jt}^{\tilde{\sigma}\sigma} V_{jt}^{\tilde{\sigma}(1-\sigma)} L_{jt}^{\tilde{\sigma}(1+(\beta_1+\beta_2)(\sigma-1)+(\alpha_1+\alpha_2)\sigma))}, \end{aligned} \tag{A.40}$$

$$V_i^{-\theta} L_i = \sum_{i\in R} \mu_{ij}^{-\theta} V_j^{\theta}, \tag{A.41}$$

Writing out the system gives the following matrices of coefficients,

$$\mathbf{B} = \begin{bmatrix} \tilde{\sigma}(1-(\alpha_1+\alpha_2)(\sigma-1)-(\beta_1+\beta_2)\sigma)-(1-\mu)(1-\sigma) & \tilde{\sigma}\sigma \\ 1 & \theta \end{bmatrix}, \tag{A.42}$$

$$\mathbf{\Gamma} = \begin{bmatrix} \tilde{\sigma}(1+(\beta_1+\beta_2)(\sigma-1)+(\alpha_1+\alpha_2)\sigma)) & \tilde{\sigma}(1-\sigma) \\ 0 & \theta \end{bmatrix}. \tag{A.43}$$

Which again gives the following conditions for uniqueness,

$$\rho(\mathbf{A}) \leq 1, \tag{A.44}$$

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

$$\mathbf{A} = \frac{1}{(b_{11}\theta + \tilde{\sigma}\sigma)\theta} \begin{bmatrix} \gamma_{11}\theta^2 + \gamma_{12}\theta & \gamma_{11}\tilde{\sigma}\sigma\theta - \gamma_{12} b_{11}\theta \\ \theta^2 & -b_{11}\theta^2 \end{bmatrix}. \tag{A.45}$$

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,

$$p_{it}^{\sigma-1} - \sum_{j\in R} T_{ijt} P_{jt}^{\sigma-1} \frac{Y_{jt}}{Y_{it}} = 0, \tag{A.46}$$

$$P_{it}^{\sigma-1} - \sum_{j\in R} T_{jit} \left(p_{jt}^{\sigma-1}\right)^{-1} = 0, \tag{A.47}$$

$$V_{it}^{-\theta} - \sum_{j\in R} M_{jit} \left(\frac{L_{jt-1}}{L_{it}}\right) \Pi^{-\theta} = 0, \tag{A.48}$$

$$\Pi^{-\theta} - \sum_{j\in R} M_{ijt} V_{jt}^{\theta} = 0. \tag{A.49}$$

**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,

$$\Delta \ln p_{it}^{\sigma-1} = (\sigma-1)\Delta \ln w_{it} + \tilde{\alpha}_1(1-\sigma)\Delta \ln L_{it} + \alpha_2(1-\sigma)\Delta \ln L_{it-1} + (1-\sigma)\Delta \ln \bar{A}_i. \tag{A.50}$$

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,

$$\Delta \ln V_{it}^{\theta} = \theta \Delta \ln w_{it} + \frac{\theta}{1-\sigma}\Delta \ln P_{it}^{\sigma-1} + \beta_1 \theta \Delta \ln L_{it} + \beta_2 \theta \Delta \ln L_{it-1} + \theta \Delta \ln \bar{u}_i. \tag{A.51}$$

# B Data Sources

## B.1 Cross-validating Hyde 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.

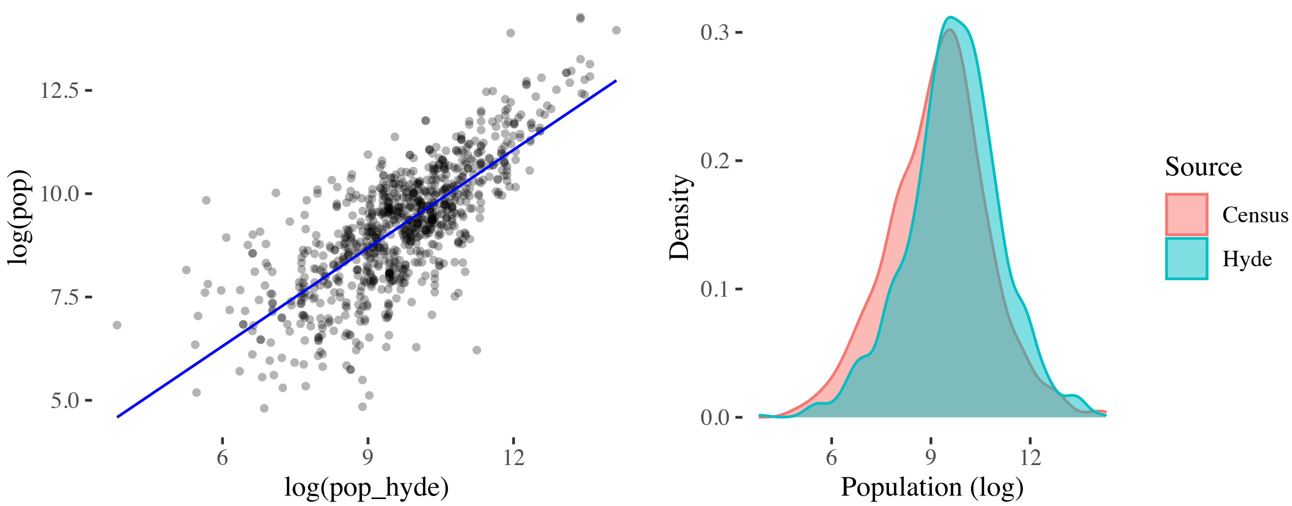


**Figure A1:** The figure shows the relationship between population counts in census data and in Hyde 3.1. The left figure is a scatter plot of the logarithm of the two variables. The righ figure shows the density plots of the two variables.

## 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) and 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.

# References

Allen, Treb, Costas Arkolakis and Xiangliang Li. 2020. "On the Equilibrium Properties of Network Models with Heterogeneous Agents." *NBER Working Paper* 27837.

Allen, Treb and Dave Donaldson. 2018. "The Geography of Path Dependence." *Manuscript* .

Elliot, Robert, Stephen DeGloria and Shawn Riley. 1999. "A Terrain Ruggedness Index that Quantifies Topographic Heterogeneity." *Intermountain Journal of Sciences* 5(1-4):23–27.

Galor, Oded and Ömer Özak. 2015. "Land Productivity and Economic Development: Caloric Suitability vs. Agricultural Suitability." *Manuscript* .

Galor, Oded and Ömer Özak. 2016. "The Agricultural Origins of Time Preference." *American Economic Review* 106(10):3064–3103.

Ramankutty, Navin and Jonathan A. Foley. 1999. "Estimating Historical Changes in Global Land Cover: Croplands from 1700 to 1992." *Global Biogeochemical Cycles* 13(4):997–1027.