Free and Protected: Trade Costs and Economic Development*

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Abstract

How do trade costs shape economic development in the long-run? This paper analyzes the role of international trade costs in economic development using a staggered lifting of restrictions on long-distance trade in goods within the Spanish Empire. Using detailed georeferenced data on infrastructure, physical geography, and maritime travel from historical logbooks, I show that the reform induced large reductions in international trade costs. A difference-in-difference approach shows that the lower international trade costs induced by the opening of long-distance trade promoted the formation of new settlements and population growth and that the reform had substantial spatial spillovers. The effects are stronger in the periphery, locations with lower population density, and in areas suitable for export agriculture. Moreover, I show that the reforms accelerated the formation of settlements in coastal areas. Examining the mechanisms, I find evidence consistent with lower international trade costs enabling the production of high-value agricultural commodities in coastal areas. To assess the long-run and aggregate effects, I use the changes in trade costs to estimate the parameters of a dynamic spatial general equilibrium model. A series of counterfactual exercises quantify the role that the timing of the reform as well as the initial spatial distribution of population plays in determining the long-run impact of the trade cost shock. Taken together, the findings demonstrate that lower international transportation costs can promote growth and diversification in economies that specialize in commodity exports, but that the effects are highly contingent on initial geography and endowments.

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1 Introduction

In the last centuries, international trade has been characterized by rapid reductions in transportation costs between countries. Yet, to what extent this has promoted economic growth in developing countries is contested. On the one hand, trade is often considered detrimental for economies with a comparative advantage in primary commodities (Mokyr (1976); Krugman (1987); Matsuyama (1992)). According to this view, lower trade costs can lead to further specialization in sectors with low productivity growth and impair institutions. On the other hand, since patterns of specialization depend on transportation costs (Deardorff (2014)), lower transport costs can promote economic diversification by enabling the growth of new sectors. The goal of this paper is to shed light on the role of international trade costs in economic development and specialization patterns in the long-run.

To study this question, I exploit a large-scale historical experiment: the reorganization of maritime trade routes in the Spanish Empire in the 18th century. To promote a comparative advantage in the extraction of bullion, imperial commercial policy severely restricted long-distance trade of goods with Europe. However, driven by political developments in Europe, Spanish policymakers gradually lifted these restrictions in the second half of the 18th century. While only four ports had a license to trade goods with Europe in 1765, by 1800 this had increased to 50. By this time, no major ports were subject to restrictions for trade in goods with Europe (see Figure 1). The reform reduced empire-wide trade costs in different years and different locations. This variation is very well suited to study the impact of trade costs on economic development for several reasons. First, while I show that the policy caused large and spatially heterogeneous variation in international trade costs, these changes were limited to the costs of trading goods. This is in contrast to standard approaches relying on changes in effective distance for identification, which typically change numerous aspects of long-distance communication.[1] Second, the geographic scope of the reforms allows me to consider the policy's heterogeneous effects, while keeping formal institutions and legal origins fixed. Finally, compared to papers studies of single countries or regions, the geographic scope also provides significant gains in terms of external validity.[2]

I study the long-run impact of these policies in three steps. First, I quantify how the reforms affected empire-wide bilateral shipping times. To this end, I construct a grid covering the full extent of the Spanish Empire in the 18th century. On this grid, I construct a network of bilateral trade costs between all adjacent cells, accounting for shipping both on land and sea. For maritime shipping, I estimate accurate sailing speeds from historical maritime logbooks and georeferenced wind data. Travel on land accounts for a variety of geographic features that determine speed such as elevation, landcover, as well as infrastructure such as roads, and ports. I cross-validate the resulting shipping times with various historical sources, which confirms the accuracy of the approach. As there are many potential routes between any two cells, I use the route that minimizes shipping cost according to the Dijkstra algorithm (Dijkstra (1959)), subject to restrictions in place in a given decade. This results in bilateral shipping time matrices for each decade between 1710-1810. These time-varying measures of bilateral shipping times and market access are then matched with data on geographic characteristics and agricultural productivity to construct a balanced panel covering the Spanish Empire between 1710 and 1810.

Next, I study the reduced form effect of lower international trade cost on the formation and incorporation

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

[2] REF

of new settlements as well as population growth. To this end, I match the grid-cells to population data and a detailed territorial gazetteer of the Spanish Empire during the Bourbon period (roughly 1710-1810). The gazetteer contains the date of formal incorporation in the Spanish Empire for localities with legal status *city*, *town*, and *village*. At the heart of the research design is a difference-in-difference approach, which compares changes in the prevalence of settlements in localities where trade costs changed differentially because of the reform. The identification assumption is that changes in the prevalence of cities in such localities would have been the same in the absence of the reforms. Pre-trend checks and several robustness exercises support a causal interpretation of the estimates. I also examine the economy-wide effects of lower international trade costs, recognizing that improving the connectivity in one location may affect the population growth in other localities through trade and migration linkages. To capture these spatial interdependencies, I follow Donaldson and Hornbeck (2016) and calculate the market access for each cell by decade. To account for potential endogeneity and measurement error, I instrument local market access with the change in shipping time to Europe induced by the reforms.

In order to shed light on the long-run effects of the reforms, I use a dynamic spatial general equilibrium model following Allen and Arkolakis (2014) and Allen and Donaldson (2018). In the model, regions with heterogeneous amenities and productivities are linked through costly migration and trade. Mobile workers choose where to live subject to mobility constraints and the utility derived from each location depends on locational fundamentals as well as agglomeration and congestion forces. By incorporating dynamic agglomeration forces, it is well-suited to capture the dynamic adjustment of economic geography to shocks such as changes to trade costs. My analysis departs from Allen and Donaldson (2018) only in the identification of the model. In particular, within grid-cell changes in trade costs allow me to identify model parameters as well as locational fundamentals under weaker and more transparent assumptions. The identification of the model relies on the assumption that the *changes* in trade costs induced by the reforms are uncorrelated to *changes* in geographical fundamentals and amenities. While this is an untestable assumption, the reduced form evidence and in particular the absence of pre-trends provides support for it. This structural model serves several purposes. First, the model provides validation of the reduced form because it captures spillovers. Second, a series of counterfactual exercises sheds more light on effect heterogeneity, particularly, the influence of initial conditions. Finally, the model provides estimates of the welfare effect of the policy.

I find that the reform had large and heterogeneous effects on trade costs between Europe and the Americas. While the median reduction in shipping time is 16 days, the average is 12 days. The reduction ranges from 0 to 60 days, which is roughly half of the average voyage duration.[3] These changes in trade-costs affected population growth and the incorporation of towns and cities into the empire. In the preferred specification, a ten percent reduction in shipping times increases the probability of a locality containing a city, town, or village by five percent. This translates into an elasticity of seven percent from increased market access. Thus, the formation of new settlements was highly responsive to changes in shipping costs to Europe in this context. The elasticity of the population size with respect to market access mirror these results, with a one percent increase in market access increasing the population by 0.2 percent. Next, I look at the heterogeneity of these effects. Three patterns emerge. First, the effect is smaller in localities with higher population density. Second, it is larger in the peripheral regions of the Spanish Empire, showing that improved market access was associated with an empire-wide decentralization of economic activity.[4] Finally,

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

[4]This is consistent with findings in Redding and Sturm (2008) and Banerjee, Duflo and Qian (2020) who also find market access

the effect was substantially larger in coastal areas and I provide evidence that the reform increased the importance of coastal proximity. In particular, I find evidence consistent with lower trade costs accelerating the formation of settlements in coastal areas, a process which was already underway at the time of the reform.

Next, I explore different mechanisms potentially explaining this effect. Data on trade volumes and prices of Spanish American exports provide evidence of large increases in trade volumes with Spain. Consistent with increased reliance on commodity exports, I show the effects are larger in areas with higher suitability for high-value export crops.[5] Also, I show the effect is driven by places where the policy changed the shortest sailing route to Europe. Taken together, the findings are therefore consistent the with faster sailing promoting growth in coastal areas suitable for exports in agricultural commodities. In turn, this promoted population growth in coastal areas as well as the establishment of new population centers to intermediate trade in new agricultural commodities.

Finally, I use the quantitative framework to study the long-run effects. Having confirmed that the model matches first-order patterns in the data, I simulate the reform and find that the model matches salient features of the reduced form exercise. The trade cost shock induced by the reform increased population density in areas with higher reductions in shipping times to Europe. Moreover, the reform increased the coastal population density and had larger effects in the periphery than in the core. I then use the model is used to run a series of counterfactual simulations. First, I find that lower initial population density tends to increase the effect of the reform and coastal population density. Second, I find an earlier opening of trade would have increased the coastal population density in 1810. Finally, I find that the *long-run* population distribution depends on the timing of the trade-cost shock. An earlier opening of long-distance trade would have increased the coastal population density in the long-run. Taken together, the results show that the impact of the trade-cost shock is highly contingent on initial conditions. Therefore, the sequencing of agglomeration and trade cost reductions is crucial for explaining the long-run impact of trade cost shocks on economic geography in this particular context. Moreover, the model confirms that the reform induced growth in the periphery of the Spanish Empire.

My findings contribute to the debate on the effects of international trade on economic development. Trade is typically considered detrimental to development for economies with a comparative advantage in primary commodities since these sectors have fewer growth enhancing externalities (Grossman and Helpman (1990, 1991)) and are more volatile (Blattman, Hwang and Williamson (2007)). In models where firm technology exhibit increasing returns to scale, lower trade costs are benefit economies specializing in manufacturing, making other countries worse off, (Krugman (1991); Matsuyama (1992); Krugman and Venables (1995)). In addition, there is a sizeable literature on the role of international trade in shaping institutions in resource dependent countries, (see for example Levchenko (2007, 2013)). According to this view, higher export revenue might incentivize institutional reforms that consolidate political power, at the expense of long-run growth, (Acemoglu and Robinson (2000); Robinson, Torvik and Verdier (2006)). Altogether, the literature suggest that lower international trade costs should have a muted effect or even hinder development in countries with poor economic institutions or countries that are specialized in primary commodities. Contrary to this consensus, I provide evidence that lower international trade costs promoted economic development and diversification by enabling increased production of goods with lower value to weight ratio. The paper thus provides empirical evidence that beyond factors typically emphasized

leads to a decentralization of economic activity, albeit in very different contexts.

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

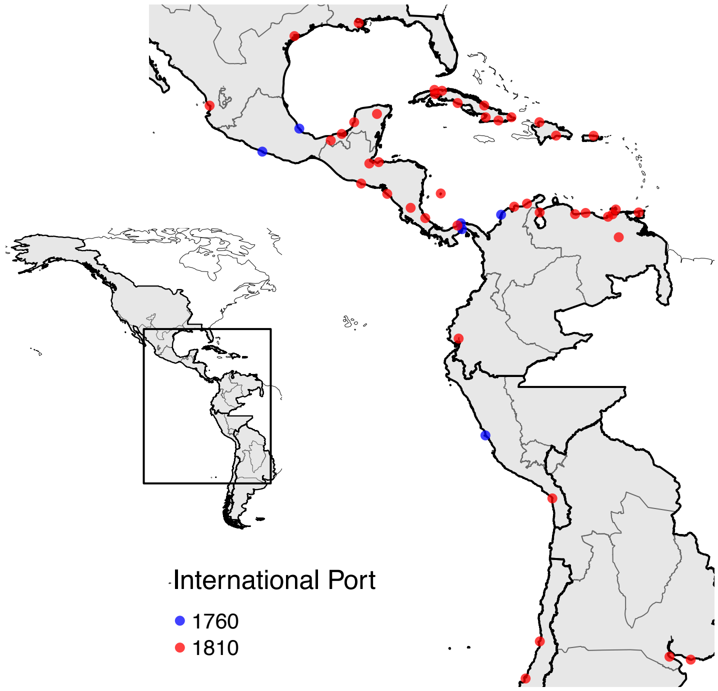

Figure 1: The map shows the extent of the territory claimed by the Spanish Empire in 1790 with its ports according to status. Ports marked in blue were licensed for long-distance trade prior to 1765 (Callao, Cartagena, Veracruz, Panama, Acapulco), while those marked in red were licensed to trade with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

in the literature, such as endowments, technology, and institutions, international trade costs can play an important role in shaping patterns of international specialization.

This paper also contributes to a literature on the role of locational fundamentals and historical precedent in determining the location of economic activity (Davis and Weinstein (2002); Redding, Sturm and Wolf (2010); Bleakley and Lin (2012); Jedwab and Moradi (2015); Jedwab, Kerby and Moradi (2017))[6][7] How urban systems reconfigure to lower trade costs can have important implications for how trade shapes development in the long-run. In a seminal paper, Henderson et al. (2018) argue that the relative importance of geographic fundamentals for agriculture and trade is shaped by the stage of structural transformation as trade costs fell in the 19th century. In late-developing countries, low transport costs preceded structural transformation. This promoted agglomeration in localities with high market access. However, among early-developers structural change occurred prior to reductions in transportation costs. As a result, agglomerations in agriculturally productive hinterlands persisted. This shows that with time-varying locational fundamentals and path dependence, spatial misallocation can be important, (see also Michaels and Rauch (2018)).

This paper extends this line of inquiry in at least four ways. First, while Henderson et al. (2018) document a robust relationship between the level of development and coastal agglomeration, they ultimately rely on cross-sectional variation. This makes their estimates vulnerable to confounders varying at the country level. In this paper, I use time-variation in trade costs *within* countries to identify the effect under weaker assumptions. In particular, I am able to control for time-invariant as well as time-variant country-level

[6]See Maloney and Caicedo (2016) and Alix-Garcia and Sellars (2020) for papers addressing the question in the context of Latin America.

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

confounders. Second, while the literature has so far relied on the reduced-form evidence, this paper uses a quantitative model to study long-run and aggregate impact. This enables counterfactual exercises and control for spillovers. Third, I provide estimates of dynamic spillovers relying on weaker assumptions than Allen and Donaldson (2018). Finally, I provide estimates of the welfare effects implied by these mechanisms. Taken together, the results provide support for models where initial economic geography mediates the impact of trade cost shocks, (see for example, Krugman (1991)).[8] Further, it highlights that beyond structural change, the long-run impact of trade cost shocks on economic geography is contingent on initial conditions in urban agglomeration.

Next, the paper builds upon a literature which considers the impact of trade on national income. While several papers have documented a positive cross-sectional relationship between trade and national income, (Frankel and Romer (1999); Noguer and Siscart (2005)), a number of challenges arise from this approach. 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, (see for example Feyrer (2009, 2019); Feyrer and Sacerdote (2009); Pascali (2017)). These papers uncover large elasticities national income with respect to trade. This is puzzling since the quantitative literature provides modest effects (Arkolakis, Costinot and Rodríguez-Clare (2012)), which highlights that mechanisms typically not emphasized in the trade literature can be important. A variety of such channels have been documented in the literature. Historical trade integration has been shown to shape institutions (Acemoglu, Johnson and Robinson (2005); Jha (2013); Puga and Trefler (2014)), structural change (Jia (2014), Fajgelbaum and Redding (2014)), state formation (Fenske (2014)), and urban agglomeration (Wahl (2016); Nagy (2018, 2020); Alvarez-Villa and Guardado (2020)).

This paper builds on the literature in two main ways. First, I use time-variation in trade costs to study the impact of trade in goods on city locations. Second, I estimate the effects without relying on changes in transportation technology. These features are important for several reasons. For one, changes in transportation technology do more than lowering trade costs. In particular, changes in effective distance affect travel and migration costs, (see for example Campante and Yanagizawa-Drott (2018) or Söderlund (2019)). Moreover, within-country variation allows for an analysis of 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 in this paper shed light on the mechanisms through which lower trade costs affect national income. I show that trade induced urbanization and promoted cities situated in locations with higher market access, which can go some way in explaining discrepancy between the quantitative and reduced-form estimates.

Finally, the paper contributes to a literature exploring the long-term economic impact of colonial institutions, (see for example 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 (see Grafe and Irigoin (2006, 2012); Coatsworth (2008); Bruhn and Gallego (2011); Engerman et al. (2012)). The results in this paper shed light on findings of a seminal paper, Acemoglu, Johnson and Robinson (2002). They establish a negative correlation between population density in 1500 and 2000. They argue that the population density at the time of settlement shaped incentives faced by early settlers. In particular, lower initial population density necessitated institutions enabling broad participation in the economy to ensure subsistence. These institutions were more compatible with modern economic growth and thus caused divergence between areas with different initial population density. However, the mechanisms

[8] See for example Brülhart (2011) for a review of the literature.

underlying this *reversal of fortune* remain poorly understood. The results in this paper lend support to this interpretation. However, rather than solely being attributed to differences in institutions governing property rights, the growth of the periphery in the second half of the 18th century is at least in part driven by broader participation in long-distance trade. More broadly, this paper contributes by providing evidence on the role of colonial maritime institutions in shaping long-run development and specialization patterns, which has not received attention in the literature so far. This paper contributes by showing when city location is affected by changes in international transportation costs. In light of the high degree of persistence in urban form, this has important long-run consequences.

The paper is structured as follows. Section 2 presents the historical background. Section 3 presents the data sources. Section 4 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 reforms and the historical relationship between trade reform and economic development within the Spanish Empire, and how the policies could influence long-run regional development patterns.

The Spanish Commercial System. Spanish commercial policy sought to promote state wealth acquisition through trade surpluses (Walker (1979); Findlay and O'Rourke (2007)). To this end, several policies restricted the free flow of goods across the Atlantic. First, it restricted the points of entry and exit by directing Atlantic trade through the four main ports in the Americas (Cartagena, Callao, Portobello/Nombre de Dios, and Veracruz) and only Sevilla/Cádiz in Europe. Second, it restricted participation to Spanish merchants. Foreigners who wanted to participate in the trade needed to partner with Spanish companies. Third, the frequency of travel and the routes were limited. Typically, only two fleets left Spain every year: the New Spain *flota* destined for Veracruz, and the *Tierra Firme galeones* destined for Cartagena and Portobello. In the Pacific, shipping was conducted by *Armada del Sur*, which carried goods from the trade fairs in Portobello to Pacific ports in South America.[9][10] Finally, there were high tax rates on imports and exports. The duties typically depended on the origin of the good, with lower rates on goods originating from Spain.[11]

The system was designed to ensure the steady flow of bullion across the Atlantic and to prevent economic diversification to sectors competing with Spain. It achieved this in several ways. For one, it facilitated the naval defense of convoys, which could concentrate on fewer ports. Moreover, it limited imports to the Americas, thus ensuring a favorable trade balance. This limited the flow of bullion to other places than Spain. However, it also served to keep prices for Spanish exports artificially high, (see for example Baskes (2013)). Naturally, it marginalized large areas that remained isolated from the official trade

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

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

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

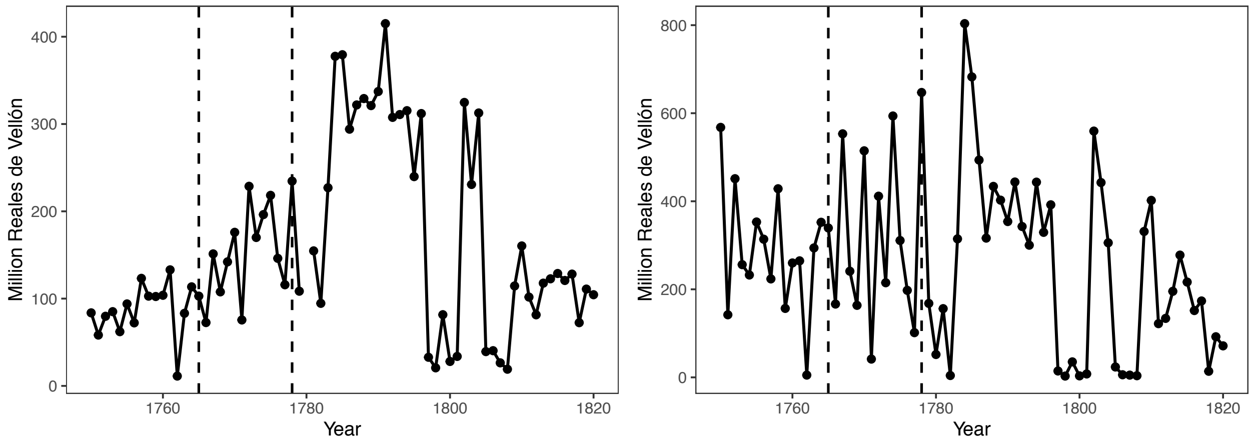

Figure 2: The left figure the value of non-bullion exports from Spain to American ports from 1750-1820. The right panel denotes bullion exports to Spain for a 1750-1820. The vertical lines denote the beginning and end of the main part of the liberalization. The large drop in 1797 is due to the british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

routes.[12] According to Fisher, "The inevitable consequences ... were economic underdevelopment in the peripheral regions of America, at least until the liberalisation of trade in the second half of the eighteenth century", Fisher (1997) p. 73.

Reforming Trans-Atlantic Trade. Beginning in the 18th century, Spanish reformers were induced by geopolitical considerations, originating mainly in Europe, to overhaul the external trading system, Mahoney (2003, 2010). In the immediate aftermath of Spain's defeat in the Seven Years' War, a technical commission (the *junta de comercio*) was appointed under Charles III to assess and reform the system. The *junta de comercio* proposed the abolition of the Cádiz monopoly as well as the fleet system. Further, it proposed opening 14 ports on the Iberian Peninsula as well as 35 ports in the Americas, Fisher (1997).[13] Four ports in the Caribbean were opened already in 1765.[14] The liberalization measures culminated in the decree of free trade in 1778 which opened the main remaining ports[15] In the 1780s, the remaining ports followed. The Spanish communication with the Americas was disrupted during the Napoleonic wars. As a result, trade with neutral nations during the Napoleonic war was allowed. The 18th century marked the definitive end of Spain's ability to enforce protected trade with the colonies. As a result, by the beginning of the 19th century, Spanish America enjoyed *de facto* although not *de jure* unrestricted trade with foreigners (Fisher (1998)).

The historical literature emphasizes the role of European interstate competition and Spanish state

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

[13]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 policy 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).

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

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

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

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

While it is generally agreed upon that the reforms had large effects on trade volumes, the magnitudes are disputed (Escosura and Casares (1983); Cuenca-Esteban (2008)). Colonial imports to Spain increased tenfold and exports from Spain to the colonies fourfold (Fisher (1985)), while more modest estimates are found in Cuenca-Esteban (2008) which also suggests large effects (see Figure 2). However, there is little doubt that trade increased substantially during the period. As a result of these developments, several formerly marginal areas in the Spanish empire became important economic regions. "...for the first time, the metropolis succeeded in unleashing the agricultural potential of its American possessions, whilst also promoting the continued expansion of mining production. The relationship between this economic growth and the liberalization of trade is abundantly clear", (Fisher (1997) p. 197). Moreover, the population and economies of previously stagnant peripheral colonies in Spanish America grew rapidly (Mahoney (2003); Bulmer-Thomas (2003)).[16] In summary, the historical literature suggests the restrictions imposed on trade in goods with the Americas stunted economic development and efforts induced by European interstate competition to relax these had large effects on trade and regional development in the second half of the 18th century.[17]

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

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

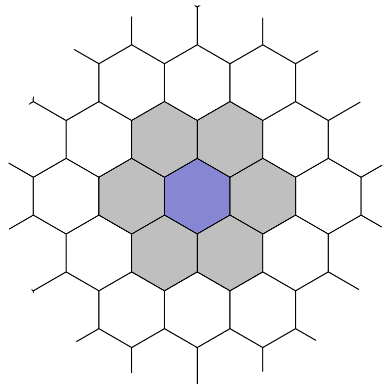

Figure 3: This figure shows a grid-cell and its six adjacent cells that constitute the unit of analysis. The final dataset consists of 6,662 grid-cells of 0.5°×0.5°.

3 Data

To quantitatively assess the impact of the reforms, I construct a dataset containing geographic, demographic, and economic data of the Spanish Empire in the 18th century. The dataset consists of 6,662 grid-cells of 0.5°×0.5° which approximates an upper bound of the distance and adult can travel per day on flat terrain.[18] See Figure 3 for a snapshot of a grid-cell and its six adjacent cells and Figure 5 for a depiction of the full extent of the study area, which covers the territories of several contemporary nation-states.[19] I aggregate the dataset by decade for the 100 years spanning 1710-1810. This period roughly covers the rule of the Bourbon dynasty, beginning just after the War of Spanish Succession and ending with the outbreak of the Wars of Independence, and results in a balanced panel of $6,662 \times 11 = 73,282$ observations. I aggregate several data sources to this level. Details about the datasets and the implementation can be found in the Appendix while summary statistics of the main variables can be found in Table 1.

3.1 Population and and Settlements

Settlements. The main outcome of interest is city formation and population growth. I construct the main sample from a territorial gazetteer of 15,000 places that existed in the Spanish Empire during the 18th and early 19th century. The dataset is based on official records as well as various secondary sources, Stangl (2019*a*).[20] It contains the founding, legal status, position in the ecclesiastical hierarchy, as well as the longitude and latitude of each locality. In the main analysis, I restrict the sample to places with the legal status of *city* or *town* as well as villages and fortified frontier settlements such as *presidios*. This avoids the common pitfalls associated with using population thresholds for defining a city.[21] The status of *city* was

and Mexico City. Merchants in Mexico City blocked the rise of Veracruz by purchasing and distributing directly to Mexico City (Mahoney (2010)).

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

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

[20]"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 very mostly not written for giving geographic information but may touch one specific detail or incidentally expose some relevant information. Non-archival contemporary sources include mostly highly systematic sources for information like so-called "Foreigner Guides" (printed calendar-manuals which included also lists of office holders of many parts of the Empire), maps, or geographical descriptions both printed and manuscripts." Stangl (2018).

[21]For example ....

the highest legal status afforded a population center in Spanish America and was typically granted by the crown. Below the city in the hierarchy was the town (*villa*). In some cases, settlements were abandoned (such as Buenos Aires) or moved (such as Guatemala). In these cases, the date of founding is the founding of the first city in both cases. Moreover, different cities and towns could have very different functions. The location of the city is determined by the functional center of the city.[22] Altogether, the final dataset contains 2,125 places spanning 1710 and 1810. This results in slightly above ten percent of decade $\times$ cell combinations containing a city in the final dataset. Figure 10 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*b*). It contains demographic data for various administrative entities between 1710 and 1810. Unfortunately, this data is cross-sectional. As a result, it does not lend itself to the panel dimension of the main dataset. Therefore, I use population estimates from HYDE 3.1, Klein Goldewijk et al. (2011). The dataset is a raster file of population density spanning the whole study region at 10-year intervals.[23] It extrapolates of various historical population statistics to create granular population data spanning the whole globe. I assess the quality of this extrapolation by cross-validating against historical census data. In the Appendix, I show that population density data from Hyde 3.1 is highly correlated with the census data.[24] Further, I use city-level population data from Buringh (2013). A city is included in the database when it has more than 4,000 inhabitants. I restrict the dataset to cities for which there is data in 1750. This constitutes 211 cities which are observed in 1750 and 1800. This further validates the rasterized population data and enables studying city-level growth in more detail which I do exploring mechanisms.

Finally, I add three datasets to measure contemporary outcomes. Following Henderson, Storeygard and Weil (2012) and later work, regional development and population density is proxied using satellite imagery on light density averaged annually since 1992. Data on contemporary population density is from the Gridded Population of the World which is distributed by the (CIESIN) at Columbia University. These two data sources are highly correlated and capture urban agglomeration and economic activity which is the main outcome of interest in this part of the analysis. To assess what the data capture in this context, I cross-validate the data with state-level as well as grid-cell level measures of income which shows the variables are highly correlated.[25]

3.2 Sailing and Trade Data

Sailing data. To infer the sailing speeds, I combine information on maritime logbooks with data on wind patterns. I calculate voyage durations using logbooks from the CLIWOC database (Climatological Database for the World's Oceans), García-Herrera et al. (2005). The data was originally compiled for studying historical oceanic climate conditions and contains around 280,000 logbook entries for Spanish, Dutch, French, English, and Swedish ships between 1750 and 1850. The logbook entries contain the daily longitude and latitude, wind speed and direction as well as several voyage-level characteristics such as the ship name, origin and destination, captain name, and ship type.[26] I use the daily change in longitude and latitude

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

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

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

[25] Data on income and the state-level is from Maloney and Caicedo (2016), Bruhn and Gallego (2011). The variable measures income in 2005 PPP US dollars.

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

to infer the average daily travel speed. I follow Kelly and Ó Gráda (2019) and remove observations for which either the inferred speed is implausibly high (above 10 knots), or are located in coastal areas. Next, I calculate the relationship between average wind speed, direction, and travel speed. To do this, I combine the logbooks with information on the average velocity and direction of the sea-surface winds. This dataset is provided by the US National Oceanic and Atmospheric Administration (NOAA).[27] I download and average speed and direction by $0.5° \times 0.5°$ cells for each week between 2011 and 2017.[28] The strength of this data is the higher spatial resolution. However, using contemporary data to proxy historical wind conditions could introduce measurement error. Therefore, I cross-validate the contemporary and historical wind data as recorded in the logbooks.

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 vellon* in constant prices). Moreover, it contains estimates of the composition of trade. I use this data to assess the relationship between changes in trade costs and trade volumes. To estimate the parameters of the model one needs to estimate the gravity equation. To do this I use data on bilateral trade flows at the country level (Fouquin and Hugot (2016)). The full dataset contains 1.9 million bilateral trade observations. I restrict this dataset to be between 1820 and 1870 which roughly proxies the period prior to the introduction of steamships. Next, I restrict the sample to the countries in the analysis which results in 801 bilateral trade pair observations. The trading status of each port is from the decree itself *Reglamento y aranceles reales para el comercio libre de España a Indias de 12. de octubre de 1778*, as well as Fisher (1997). I cross-check these sources with various other secondary sources and list the ports, their location, as well trading privileges is listed in the Appendix.

3.3 Geography and Infrastructure

I add several controls for geographic fundamentals and variables to explore mechanisms. First, I use various sources to proxy for agricultural land quality for important high-value export crops in the Spanish America in the second half of the 18th century. Crop suitability for cotton, tobacco, sugarcane, and cacao is provided by FAO's Global Agro-Ecological Zones and averaged at the grid-cell level. These constitute around 27.3 of total exports from Spanish America to Spain in this period and measure the potential yield under rain-fed, low-input agriculture, thus reflecting agricultural suitability using traditional technology. Second, I incorporate data on the potential agricultural output (measured in calories) to proxy wages. I use a measure of agricultural potential constructed by Galor and Özak (2015) and Galor and Özak (2016). The data measure the maximum attainable yield measured in calories that can be achieved for a variety of crops. A compelling feature of the Galor and Özak measure is that it captures features of the natural environment affecting attainable yields, but that are exogenous to human intervention. In addition to measures of potential agricultural productivity, the location of the principal mining centers in the 18th century. In total 78 locations across the Spanish Empire that mined for silver, mercury, gold, salt, emeralds, copper, platinum, or iron. This data is from Fisher (1997). Together, mining, cotton, tobacco, sugarcane, and cacao exports make up around 83.7 of all imports from Spanish America to Spain in the period.

[27] The data is available here https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs.

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

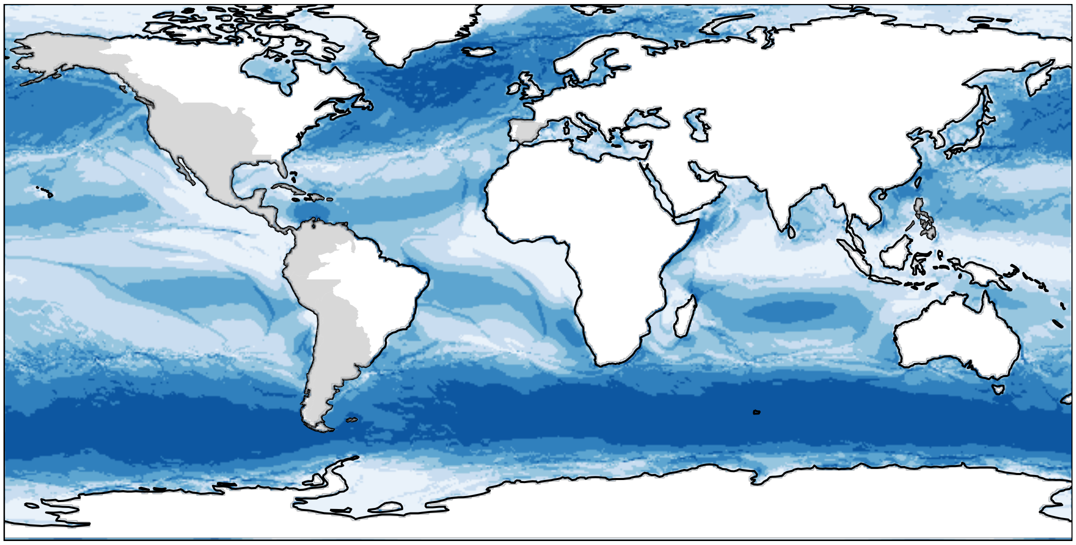

Figure 4: The figure shows the cost surface of maritime travel between 1750 and 1850. The map plots the average cost for each $1° \times 1°$ grid-cell where darker colors indicate that the cell can be crossed at higher speed. Grey areas denote territory claimed by the Spanish Empire in 1790. The cost 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. Source: NOAA and CLIWOC.

Finally, I aggregate a range of geographical variables at the grid-cell level as controls. In particular, I calculate the terrain ruggedness index, average slope, and elevation by grid-cell. To proxy for the disease environment, I construct a dummy variable that takes the value one if the average elevation is below 1500m.[29] This is largely done to allow for time-variant impact of geographic features that could be correlated with changes in remoteness through a variety of mechanisms, (see for example Scott (2009), Nunn and Puga (2012)). Moreover, I include controls on potential vegetation to proxy for different geographic 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. To control for time-varying effects of distance to waterways and fresh-water access I use data on river flows from, Lehner, Verdin and Jarvis (2008). Finally, information on climatic variation is from Hijmans et al. (2005).

4 Trade Costs and Market Access

To estimate the impact of the reform, I calculate bilateral shipping times and market access. This serves two purposes. First, changes in shipping times provide a time-varying instrument for actual trade costs. Second, I use trade costs to estimate the structural model. In this section I detail how the bilateral travel times are estimated.

[29]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.

4.1 Calculating Trade Costs

Maritime Transport. I calculate maritime transportation costs by estimating sailing speeds from logbooks using georeferenced data on wind patterns. To do this, the world was divided into a matrix of 0.5° × 0.5° cells.[30] For each square, weekly data on wind direction and speed was averaged over the period 2011 - 2017 (see Figure 14). I impose the following flexible relationship for the sailing time between adjacent grid-cells i and j,

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

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

Estimating T_{ij} requires a large sample of historical travel times as well as granular data on wind conditions. I estimate the function relying on data from CLIWOC (García-Herrera et al. (2005)). Three restrictions are made on the sample to facilitate the calculations. First, observations, when the ship is anchored in port, are dropped. Second, logbook entries in coastal waters are removed. This is because coastal navigation faced additional constraints to wind conditions. Finally, to reduce measurement error, observations with implausibly high speeds are dropped which I define as average daily speeds above ten knots. This results in 234,950 logbook entries in the final dataset. The estimated travel time function $\hat{T}_{ij}$, is obtained by estimating T_{ij} using a Lasso-regression where the tuning-parameter is determined by cross-validation (Tibshirani (1996)). Table REF contain the results. The resulting average travel time by ship in the sample is around 4 knots, which corresponds closely to other estimates of speed under sail. Figure 5 contains the resulting cost surface.

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

$$\hat{T}_{ij} = \kappa_i \times 5.36^{-1} \times \exp\{3.5|slope_{ij} + 0.05|\} \tag{2}$$

where $slope_{ij}$ measures the slope between cells i and j and κ_i is a coefficient determined by the landcover in cell i. I assume that travel on flat terrain on a road happens at 4.5km per hour.[31]

I rely on data on official travel routes in the Spanish Empire during the Bourbon period to measure the location of roads. I follow the literature and assume pace off the path to only be sixty percent of the pace on the path. Additional geographic attributes can further facilitate or impede movement and I rely on the literature for the terrain coefficients.[32] Six terrain types have a natural mapping between historical land cover data and the terrain coefficients. These are dense forests, grassland, deserts, open shrubland, and

[30] Approximately 50km at the equator.

[31] 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.

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

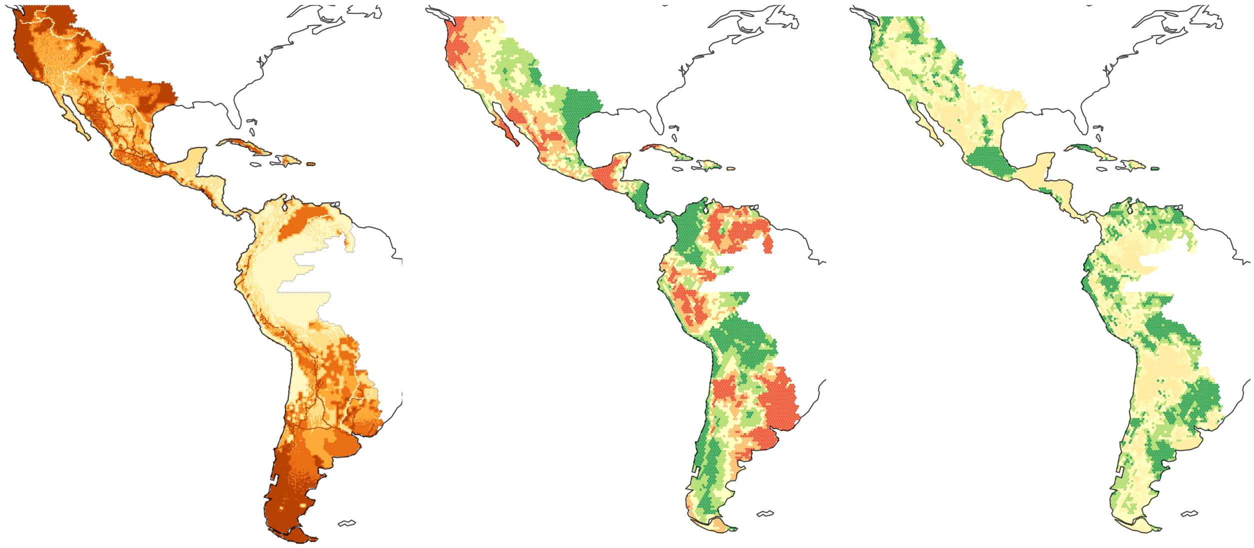

Figure 5: The left figure plots the cost surface for travel over land. Darker colors indicate that the cell can be traversed faster. The figure in the centre shows the residualized change in shipping times to Europe between 1760 and 1810 at the level of 6,662 0.5°×0.5° grid-cells. Darker colors indicate larger reductions shipping times to Europe. The figure on the left shows the residualized change in market access 1760 and 1810 at the level of 6,662 0.5°×0.5° grid-cells. Darker colors indicate larger increases in market access. Controls include elevation, distance to the coastline, terrain ruggedness, agroclimatic suitability for various cash crops, and whether the grid-cell overlaps an active mine.

dense shrubland.[33] Finally, major rivers and lakes are included. In contrast to Western Europe and the United States, navigable rivers played a more limited role in Spanish America. I interpret rivers and lakes mainly as obstacles to mobility. In the baseline case, I assume that lakes have to be circumnavigated, while rivers can be crossed at every point by reducing the pace 50 percent. Further, I assume the location of rivers and lakes to be time-invariant, which is a reasonable assumption at the level of aggregation used in the analysis. Figure 5 shows the resulting cost surface.[34]

4.2 Least-Cost Path Problem

Once the time of passing between all adjacent cells is known, one can calculate bilateral time between all grid-cells by searching for the minimum-cost route of getting from a cell i to any other cell j. The estimates of shipping times between each adjacent cell are used to construct a matrix of bilateral travel times between all the cells, $\mathbf{T}_t$, which I refer to as the transition matrix in decade t. This matrix has $R \times R$ dimensions and is calculated by decade between 1760 and 1810.[35] Since there will be many alternative paths to ship a good between localities i and j, I assume goods shipping follows the least-cost path according to the Dijkstra algorithm (Dijkstra (1959)). An entry in the matrix, T^t_{ij} denotes the travel time in decade t between (not necessarily adjacent cells) i and j measured in days. Denote $\mathbb{1}^n_{ij}$, an indicator variable which is defined in

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

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

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

the following manner,

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

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

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

$\mathbf{T}_t$ is calculated for each decade from 1760 to 1810 to capture the effect of the reform and I assume $\mathbf{T}_k = \mathbf{T}_{1760}$ for all $k \leq 1760$. This transition matrix forms the basis for both the reduced form and the structural exercise. In the reduced form exercises, particular emphasis will be put on the column containing bilateral travel times between Europe and each cell in Spanish America.

The definition of market access used here follows Donaldson and Hornbeck (2016). The market access ($MA_{i(t)}$) for a given locality is the sum of the population of all other localities, discounted by bilateral travel times, scaled by a trade elasticity θ. Having estimates for bilateral travel times for all localities, the main explanatory variable is the actual market access of a given grid-cell which is given by the following expression,

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

where T_{ij}^t measures the number of days shipping from i to j at time t, L_j^t the population size in j at t, and θ captures the distance elasticity (Donaldson and Hornbeck (2016)). For the baseline estimates θ is set to -1. The expression for $MA_{i(t)}$ then corresponds to the market potential (Harris (1954)). In this case, $MA_{i(t)}$ will increase with one unit if an area one day away grows with one person. The literature has produced several estimates of the trade elasticity θ. Donaldson and Hornbeck (2016) find a trade elasticity of 3.88. In a robustness exercise, I follow Jedwab and Storeygard (2017) and set $\theta = 3.8$ because their distance measure also reflects travel times. This is also in line with Simonovska and Waugh (2014) who find estimates between 2.8 and 4.5. I provide robustness of the main results to elasticity parameters of this paper in the Appendix.

4.3 Results and Assessment of the Shipping Times

Results. Figure 6 documents a substantial change in both shipping times and market access between 1760 and 1790. The average shipping time is around 11 percent lower, while the average market access increases by around 30 percent. These averages mask significant heterogeneity. The median reduction in shipping times is around 16 days of travel. This ranges from the largest reduction of 60 days' shorter travel to no change in shipping times. The average shipping time prior to the reform is around 150 days. Figure 4 shows the geographic variation in the reduction of shipping time where darker colors indicate larger changes. Localities with the largest reductions are in the River Plate region, Venezuela and parts of Central America. These areas experienced large changes in market access and shipping times as a result of the policies. As can be seen in the figure, changes in market access largely mirror the changes in shipping times.

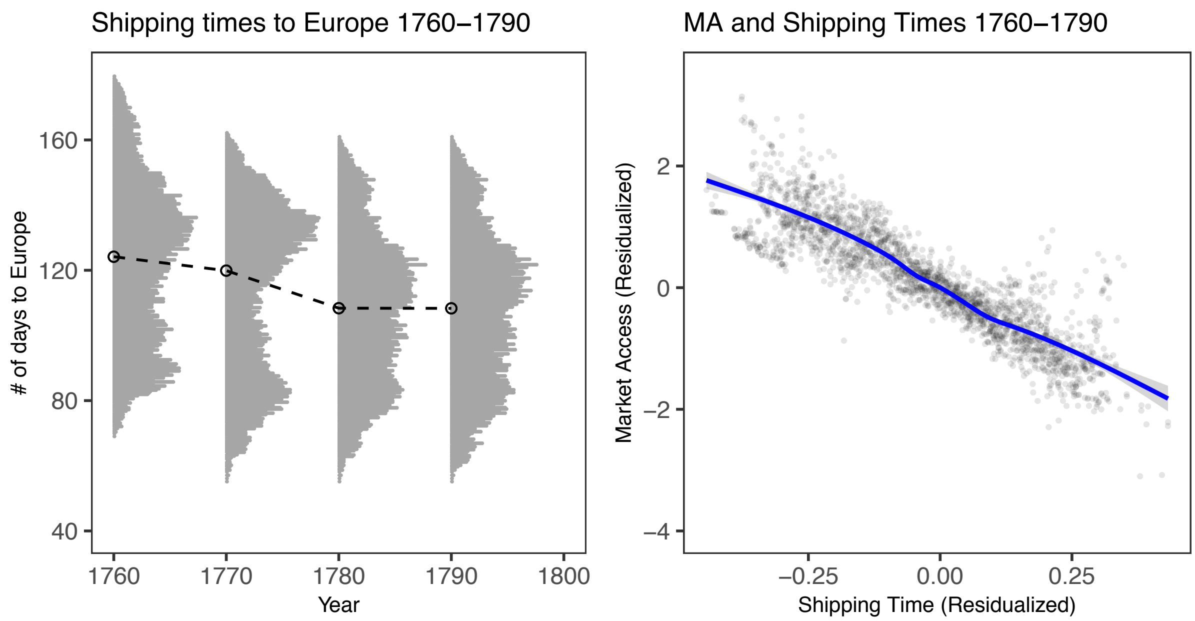

Figure 6: The figure shows shipping times and market access by decade between 1760 and 1790 for the $0.5° \times 0.5°$ grid-cells used in the main analysis. The left panel displays number of days travel from a grid-cell to Europe. The right panel displays the logarithm of market access with $\theta = -1$.

Assessing the Shipping Times. How precise are these estimates? As a first pass, the cost-minimizing routes reflect routes used during this period. For example, Pacific and Atlantic ports are connected by the Panama isthmus. Mexico City is connected through Veracruz and Acapulco, and Potosi and Arica with Callao. I also quantitatively assess the precision of the estimates. To do this, the results are cross-validated against several other data sources. First, I compare the results to measures sailing times according to seadistances.org.[36] For each port, I calculate the sailing time from Europe (Cadiz) to all the ports in the dataset for which the website records information. The average speed of 3.9 knots is used, which makes up the average speed of Spanish freight ships in 1750 (Kelly and Ó Gráda (2019)). As can be seen in Figure 12, these two measures are shown to be highly correlated and robust to including controls. Next, I assess the correlation between predicted time travel and the duration of mail between major ports. Data on the speed of mail is from Baskes (2013). Again, there is a strong correlation between predicted distance and the speed of mail in the dataset. This pattern is robust to controlling for geodesic distance, viceroyalty, as well as the longitude and latitude. Finally, I assess the correlation between historical and modern wind patterns. The CLIWOC database contains daily georeferenced data on wind speed and direction between 1750 and 1850. As can be seen in Table 2, there is a strong correlation between the wind speed and direction in these two datasets.

5 Reduced-Form Evidence

In this section, I present the main empirical specification, reduced-form results, and mechanisms. The section aims at identifying the *causal* effect of lower international trade costs on economic development. While I provide evidence that the timing of the reform is not related to population growth and the

[36] A free database of bilateral sailing times between major ports around the world.

formation of settlements prior to the reform, there are other potential challenges. For one, there are likely to be spillovers between treated and less treated areas due to trade and migration linkages. Moreover, measurement error is likely to be non-trivial in this context. For these reasons, I also provide several robustness checks of the main results towards the end of this section.

5.1 Methodology

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

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

where $y_{i(a,t)}$ is an indicator equal to one if a settlement is present in cell i at time t and zero otherwise. $T_{i(t)}$ measures the number of days of travel from the grid-cell to Europe in decade t. I include the vector of controls, $x_{i(t)}$, to capture the geography, climatic characteristics, and historical resource availability of a given cell. The baseline model controls for elevation, distance to the coastline, terrain ruggedness, agroclimatic suitability for various cash crops, and whether the grid-cell contains an active mine. In some specifications these variables are interacted with decade indicator variables, which allows each feature to vary in importance over time.[37] Given the long time-horizon this is an important issue for several reasons. For example, while elevation or the location of bodies of water are fixed over time, the effect of these factors could have changed with irrigation techniques or the disease environment. Next, I include *audiencia*-by-decade fixed effects in the baseline specification, $\gamma_a \times \tau_t$. These account for shocks affecting all localities within a given *audiencia* in a particular decade.[38] Here $\epsilon_{i(t)}$ is an error term potentially spatially correlated across nearby cells. In the baseline specification, standard errors are clustered at the level of the treatment assignment (Abadie et al. (2017)).[39] In this case the treatment is assigned at the port-level which results in 50 clusters. The coefficient β captures the change in the probability of a cell containing a city for a one-unit change in shipping time to Europe. My key identification assumption is that *changes* in the rate of city formation 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 are elaborated upon below.

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

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

where $\widehat{MA}_{i(t)}$ is market access for cell i in decade t as predicted by shipping time to Europe. The parameter of interest, β, measures the change in the probability of a settlement in grid-cell i given a one percentage

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

[38] Figure 6 as well as Figure 11 shows the geographic extent of the *audiencia* and viceroyalties in 1790.

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

change in market access. The interpretation of β as a local average treatment effect relies on further assumptions. I assume that the reform only affected market access through its effect on shipping times to Europe. This is a plausible assumption as the reforms changed rules for trade in goods, not maritime communication more *per se*. Moreover, it is assumed that the change in shipping time is correlated with the change in market access during the period. Under these additional assumptions, the coefficient β will identify the effect of increased market access for localities that increased their maritime connectivity to Europe as a result of the reforms.[40]

Event Study. To assess the dynamics, I calculate the time-varying impact of the changes in shipping times on city formation. To quantify this effect, consider the following dynamic regression model,

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

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

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

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

where $y_{i(a,c)}$ denotes population density in year 2000 and X'_i a vector of control variables. The vector includes the distance to the closest port in 1750, the distance to the coastline for each grid-cell as well as the population size in 1750. Standard errors are again clustered at the port-level in the main specifications.[41] The interpretation of the coefficient rests on changes in shipping times to be independent of counterfactual long-run outcomes.[42] This is naturally a stronger assumption than required for the specifications relying on exogenous timing. I therefore provide several exercises that support the identifying assumptions below.[43]

[40]The monotonicity assumption is satisfied by construction.

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

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

[43]Table A10 presents several placebo-checks showing that the change in maritime remoteness is only related to the population after the opening of trade, and not before, also in the cross-section. Second, I calculate the bias-adjusted estimates in line with Altonji, Elder and Taber (2005) and Oster (2019) to show that very strong selection on unobservable characteristics is necessary to explain the estimated coefficients for most of the specifications. Finally, I rely on causal random forest estimation to estimate the impact of historical port locations on long-run development, Wager and Athey (2017).

To facilitate the interpretation of coefficients, I standardize shipping times unless stated otherwise. Finally, because several of the variables in the analysis exhibit fat-tailed distributions which sometimes include 0, I transform variables using the inverse hyperbolic sine function. This allows me to interpret coefficients as approximately percentage changes (Card and DellaVigna (2020)).

5.2 Results

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

5.2.1 Shipping Times, Market Access, and City Formation

Table 3 and Figure 6 show the strong first-stage relationship between shipping times to Europe and market access. The table shows that a one-unit standard deviation increase in the shipping time, reduces market access by around 0.7 standard deviations ($\beta = -0.77$ in the preferred specification). Column (1) shows the most parsimonious specification, only controlling for year fixed-effects. Seen in light of the large geographic area, different places are likely to experience different shocks. Columns (2) addresses this by controlling for viceroyalty times decade fixed-effects. This absorbs all time-variant shocks common to the viceroyalty. Different development trajectories within viceroyalties can still give rise to differences in the formation of settlements unrelated to changes in shipping times. As a result, the controls interacted with decade effects are included in Columns (3) and (4), absorbing time-variant effects of demographics as well as geographic fundamentals.

Table 3: Shipping Time, Market Access, and City Formation

City Formation	(1)	(2)	(3)	(4)
Panel A: IV				
Market Access	0.048^{***}	0.050^{***}	0.043^{***}	0.039^{***}
	(0.015)	(0.016)	(0.014)	(0.012)
Panel B: Reduced Form				
Shipping Time	-0.215^{***}	-0.254^{***}	-0.216^{***}	-0.200^{***}
	(0.066)	(0.088)	(0.076)	(0.058)
Panel C: OLS				
Market Access	0.054^{***}	0.054^{***}	0.054^{***}	0.048^{***}
	(0.008)	(0.009)	(0.009)	(0.008)
F-statistic (effective)	121.51	154.02	172.06	210.38
Viceroyalty FE $\times$ Decade		✓		
Audiencia FE $\times$ Decade			✓	✓
Controls				✓
Observations	73,282	73,282	73,282	73,282

Note: Market access is standardized. The unit of analysis is at a 0.5°×0.5° grid-cell. The dependent variable is a dummy taking the value 1 if the grid-cell contains a city. 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**. **Geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain *audiencia* fixed-effects. **First-stage F-statistic** takes into account clustering following Olea and Pflueger (2013). **Standard errors** are clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 3 shows the relationship between market access, shipping times, and the formation of new settlements. Panel A presents the IV-estimates for the coefficient β in equation 7, Panel B the reduced form, and Panel C the corresponding OLS estimates. In the preferred specification, Column (4), I find that a 100 percent increase in market access increases the probability of a settlement forming by around 4 percentage points ($\beta = 0.039$). The IV-estimates are larger than the corresponding OLS estimate in Panel C of 0.04. This suggests that positive biases from omitted variables or reverse causality are more relevant than attenuation bias in this context. The estimated parameters are stable across the different specifications, ranging from 0.048 to 0.039. A weak first-stage will bias the estimates towards the OLS estimates. However, there is a strong first stage in all the specifications as can be seen in Table 4, ($F = 210.3$ in the preferred specification).[44] Finally, Table 5 shows the effect on population growth. These estimates mirror the ones for city formation, a one percent increase in market access, increases the population size by around 0.2 percent in the baseline model ($\beta = 0.245$). The next sections examine the timing of the average effect as well as effect heterogeneity.

5.2.2 Timing of the Effect

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

Figure 7 shows the estimated coefficients using the baseline specification (decade $\times$ *audiencia* fixed effects, *audiencia* fixed effects, and geographic as well as agroclimatic controls). The plotted coefficients give the estimated difference between exposed and unexposed localities in year j relative to 1760, the which is the year prior to the policy. The right-panel shows the impact of exposure to the reform on the formation of new settlements. Consistent with the identification assumption, there is no significant difference in the change of settlement in areas with high or low exposure to the reform prior to the reform.[45] After the reform, the difference is increasing relative to 1760. Areas with a 100 percent higher reduction in shipping time to Europe have a 0.5 percentage point higher probability of having a city than in 1760 ($\tau_{1790} = 0.005$). The effect is precisely estimated and an effect size of zero can be rejected at conventional levels by 1800. The left-panel shows the corresponding estimates for market access. This effect also coincides with the reform. A 100 percent reduction in the shipping time to Europe increases market access by 0.025 percent relative to 1760 ($\tau_{1790} = 0.03$).

Table 6 summarizes several alternative approaches to get these estimates. The table shows the estimated coefficients for different specifications. Column (1) presents the estimate only including time fixed-effects. Column (2) adds grid-cell fixed-effects to controls for differences in levels between areas with different treatment intensity. To control for different trends in areas differentially affected by the policy, Column (3) includes *audiencia* $\times$ decade fixed-effects. Column (4) interacts the post-dummy variable with geographical controls. Column (5) adds various agro-climatic controls to the specification, for the same reasons. Taken together, this shows that the reforms promoted more rapid city formation in areas exposed to the reforms.

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

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

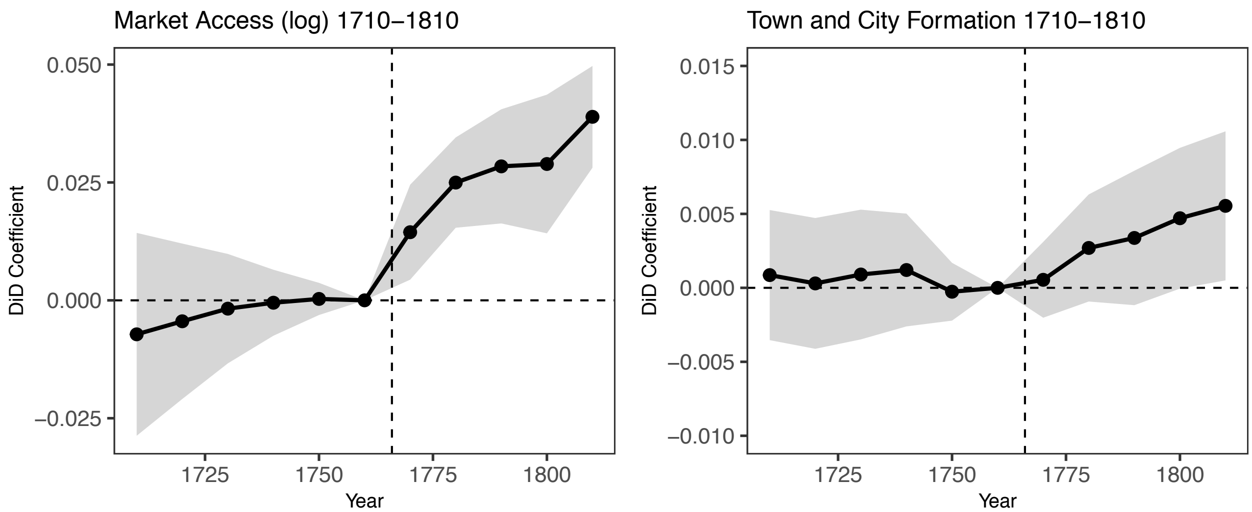

Figure 7: The figure shows the estimated coefficients of the difference in the formation of settlements and market access in grid-cells according to the reduction in shipping times to Europe. The dependent variable is an indicator-variable taking the value one if the grid-cell contains a settlement or market access. In the left panel, the dependent variable is market access (log). In the right panel, the dependent variable is an indicator variable for if a grid-cell overlaps a settlement. The specification includes *audiencia* as well as *audiencia* times decade fixed-effects. 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 6,662 grid cells. 1760 is the omitted year. The full dataset thus contains 10 × 6,662 = 66,620 observations. The geographical controls contain elevation, crop suitability, the location of active mines, (log) distance to the coastline, and terrain ruggedness. Standard errors are clustered at the port-level.

5.2.3 Heterogeneity

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

The results can be seen in Table 7. The first column estimates the baseline specification with *audiencia* × decade fixed effects, while the second column adds the main set of controls used in the analysis. The estimated effect in the core is somewhat mixed. There is a negative effect estimated for the core areas. However, part of the effect can be attributed to differences captured by the controls. When adding these controls there is no statistically significant impact. The lowest effect is estimated for the semi-periphery. For these *audiencias* the effect is indistinguishable from zero. The largest effects are found in the peripheral areas. A one-unit reduction in shipping time increases city formation by around eight percentage points. Taken together, these results show that the effect is mainly driven by the periphery.

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

Coasts and Hinterlands. With few navigable rivers, transportation mainly relied on mule and ox carts at least until the second half of the 18th century. This prevented the production of export commodities, except for commodities with very high value to weight ratio such as bullion, from taking place outside of the coastal areas. The main effect of increased access to international trading opportunities should be concentrated in coastal areas. To assess this I split the sample into a coastal area (cells within 100km of the coastline) and an hinterland (above 100km from the coastline).[47] The results from this exercise can be seen in Panel C and Panel D of Table 7. In the preferred specification a one-standard deviation increase in market access increases the probability of city formation by seven percentage points ($\beta = 0.07$). This is significantly higher than in the hinterland where the corresponding estimate is less than half a percentage point ($\beta = 0.05$) and never reaches statistical significance. These results are therefore supportive of the effect being stronger in coastal areas.

5.2.4 Long-Run Implications: Gradients in Distance to the Coast

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

$$\begin{aligned} y_{i(t,a)} &= \alpha_a + \beta_1 \text{Coast}_i + \beta_3 \text{Free}_i + \beta_2 \text{Post}_t + \\ & \phi_1(\text{Free}_i \times \text{Post}_t) + \phi_2(\text{Coast}_i \times \text{Post}_t) + \phi_3(\text{Free}_t \times \text{Coast}_i) + \\ & \theta(\text{Free}_i \times \text{Coast}_i \times \text{Post}_t) + \epsilon_{i(t,a)} \end{aligned} \tag{10}$$

where $Coast_i$ denotes the (log) distance to the coastline, $Free_i$ denotes a measure of reduction in shipping times (either the difference in shipping times between 1760 and 1810 or higher than median difference),[48] and $Post_t$ is an indicator variable taking the value one after 1765. Estimating $\theta > 0$ is consistent with the trade reforms accelerating the formation of new settlements in coastal areas.

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

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

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

Table 8: Market Access and Coastal Cities

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

Note: Specifications contain grid-cell and viceroyalty × year fixed-effects. **The dependent variable** is a dummy taking the value one if the grid-cell contains a city. The dataset is a balanced panel at a 10 year frequency for the period 1720-1820 of 6,662 grid cells (**11 × 6,662 = 73,282 observations**). ***Periphery*** is indicator taking the value one if the grid-cell falls within the audiencias of Buenos Aires, Caracas, Santiago or outside areas pertaining to an audiencia, ***Free*** takes the value one if the grid-cell has above median reduction in shipping time, ***Post*** is one for observations after 1765. ***Coastdist*** is the log distance to the coastline. **Controls** include elevation, average slope, the terrain ruggedness index, longitude and latitude. **Standard errors** are clustered at the level of the closest port. ***p < .01, ***p < .05, ** The interaction between the differential change in the effect of coastal proximity is larger in the periphery. This shows that the importance of coastal proximity increases more for treated areas in the periphery. Taken together, the effects in Table 8 show that the reforms accelerated city formation in coastal areas. This effect is especially pronounced in the periphery.

Have these effects persisted to the present? Table 9 shows that coastal population density is higher in areas that experienced a higher exposure to the reforms. The difference in population density between coasts and hinterland is higher for places more exposed to the reform. Moreover, cells with higher exposure to the reform are also more likely to contain a coastal city in 2000.[49] Taken together, the results from Table 8 and Table 9 support the interpretation that the reforms increased the population in coastal areas.

5.3 Robustness

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

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

Assessing Spatial Autocorrelation. Kelly (2019, 2020) shows that in the studies spatially correlated treatment variables, p-values of statistical tests can be biased downward. Moreover, the issue is not remedied by traditional methods such as Conley standard errors or clustering methods. To explore whether the results in Section 5 suffer from this, I conduct two exercises. I first test for spatial correlation of the residuals in the baseline specification.[50] Second, I estimate the effect in placebo regressions using randomly-generated spatially-autocorrelated noise instead of the explanatory variable. I do this under different assumptions on the strength of autocorrelation. Taken together, these exercises provide some evidence that the residuals in the regressions presented in Section 6.5 exhibit spatial autocorrelation. To remedy this, I use the covariance matrix estimator suggested in Kelly (2020). This approach corrects for spatial correlation by making parametric assumptions about the distribution and spatial dependence of

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

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

the residuals. As shown in that paper, how well this function form assumption captures the structure of the residual is testable by looking at the correlation between the residuals implied by the model and the residuals backed out from the regression.

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

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

5.4 Mechanisms

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

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

Commodity Prices. If the reforms increased trade volumes, this can be expected to have led to lower prices where these commodities traded, at least in the short-run. In this section, I consider the prices of commodities produced in the Spanish empire. Posthumus (1946) and Jacks, O'Rourke and Williamson (2011) provide monthly price data on 49 commodities traded in Amsterdam between 1750 and 1800. Out of these 49, three commodities were important agricultural exports in the Spanish Empire. These were sugar, tobacco, and cocoa.[51] I consider if the prices of these commodities dropped more relative to the others after 1778 which was the year most ports were liberalized.[52] Consider the following specification,

$$Price_{c(t)} = \alpha_c + \beta \text{America}_c \times \text{Post}_t + \phi \text{War}_t \times \text{America}_c + \epsilon_{c(t)}, \tag{11}$$

where $Price_{c(t)}$ measures the price level of commodity c in year t (in guilders), $America_c$ is a dummy for American export commodities, $Post_t$ is a dummy variable taking the value one after 1778, and $\epsilon_{c(t)}$ is an error term. To account for disruptions of Atlantic trade induced by naval conflicts, $America_c$ is interacted with the indicator variable War_t. The variable equals one for years in which Atlantic maritime powers were among the belligerents (Seven Years' War, American Revolutionary War, and the French Revolutionary War). The standard errors are clustered at the commodity-level to account for time-varying volatility, as documented in Jacks, O'Rourke and Williamson (2011). Table 11 shows the results. For all the specifications there is a negative estimate of the interaction between $America_c \times Post_t$, suggesting the reform induced higher quantities of these traded commodities. Column (4) shows the effect is robust to controlling for a differential impact of disruption of Atlantic trade for the different commodities. In sum, both the increase in trade volumes and price reductions are consistent with the reform spurring increased trade within the Spanish Empire.

The Role of Export Crop Suitability. If increased export opportunities were important in driving the observed effects, one would expect the effects to be stronger in areas suitable for the production of agricultural exports. To assess this, I use measures of crop suitability from FAO. In particular, the suitability for cacao, sugarcane, cotton, and tobacco is averaged by the grid-cell level. These commodities constitute 27.3 of exports from Spanish America between 1782 and 1796. If new settlements formed as a result of new commercial opportunities, presumably the effect is stronger in areas with higher agroclimatic suitability for export agriculture. Table 12 presents the results. The average agroclimatic suitability is interacted with the

[51] In a robustness check I include commodities that were produced elsewhere, but that were close substitutes of commodities produced in Spanish America (indigo and cotton).

[52] I also calculate the effect for the full sample as a robustness check.

change in the distance to Europe. The estimates in Table 12 support the notion that agroclimatic suitability is an important mediating factor. Across all the specifications longer shipping times to Europe is associated with a lower probability of a grid-cell containing a settlement. This effect is significantly smaller in localities with higher suitability for export agriculture.

The slave trade. The above results point towards the increased importance of high-value agricultural exports playing an increasingly important economic role. This section considers if this stimulated increased demand for slaves. Did the slave trade contribute to increased population growth in places with increased market access? To investigate this, I use data from Eltis (2018). This database contains 36,000 trans-Atlantic voyages which makes up around 80 percent of voyages disembarking captives in the Americas. In the database there are 71 ports in Spanish America that took part in the slave trade.[53] For each port, I count the number of ships with the port as a first destination.

Figure 15 shows the time-variation in the number of ships disembarking captives in at Spanish ports from 1710 to 1810. The time-variation in number of arriving ships for Spanish ports tracks the reform for both the trans-Atlantic and intra-American slave trades. The exercise is repeated with the North American and Brazilian ports, which do not display such a pattern. This provides suggestive evidence that the reform increased the demand for slave labor in Spanish America. To assess this more in detail, the number of ships arriving at each port is aggregated by year and the differential across ports affected by the policy is estimated. To do this, I calculate the shipping time to Europe for each slave port by decade between 1710 and 1810. This will capture how intensively a given region is treated by the opening in trade of goods. Table 13 displays the results. The first column contains only controls for decade fixed-effects, while Column (2) and (3) also include port fixed effects. Column (3) also controls for port level linear time-trends. While the relationship between the trade reform and number of arrivals from the trans-Atlantic slave trade is mixed, there is a negative relationship between arrivals from the intra-American slave trade and shipping times to Europe. The estimates suggest that places which reduced their shipping times to Europe more, had more arrivals of slave ships, which is consistent with an increased importance of high-value agricultural commodity exports.

Urbanization and Population Density. Next, I analyze if urbanization and increased population density is a factor promoting the formation of cities and towns. To explore this, I use two data sources. First, I use spatially disaggregated data on the size of the urban population and population density (Klein Goldewijk et al. (2011)). The data is averaged at the grid-cell level and included as the dependent variable in the baseline specification. Second, I use information on the city population from Buringh (2013) which contains the population size for the largest cities in the Spanish Empire. A city is included in the database when it has more than 4,000 inhabitants. I restrict the dataset to cities for which there is data in 1750. This constitutes 211 cities which are observed in 1750 and 1800.

The main results of this exercise are presented in Table 14. Panel A shows the relationship between market access and population density. The point estimates are economically and statistically significant. Across the different specifications, a one percent increase in market access increases the population density

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

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

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

To investigate which of these two effects dominates, the sample is split into localities for which the shortest path to Europe changed and not. This captures areas that gained from the reforms due to less transshipment and the areas that gained from faster sailing. The results can be seen in Table 15. The table shows that the largest effect is found for localities that experience changes in routes. For places that only saved in transshipment costs the effect is small and imprecise. Taken together, the findings in this section points the effect being driven by the establishment of new trade routes, but that less transshipment also mattered.

Frontier expansion. During the second half of the 18th century, Spanish policy makers promoted the formation of *presidios* and missions in frontier areas (Parry (1990)). Table 7 shows that the effect of increased market access was larger in the peripheral locations of the Spanish Empire. Did increases in market access promote town and city formation through facilitating settlement in frontier areas? To investigate this, I contrast the effect of reductions in shipping costs in areas with low vs. high state presence. Two approaches are taken to proxy for state presence. First, similar to Acemoglu, García-Jimeno and Robinson (2015) distance state infrastructure is used. To do this, I use a dataset on around 900 post offices in Spanish America in the 18th century. Second, the level of state presence is assumed to be lower in areas outside *audiencia* borders. These different approaches delineate roughly similar areas.[54] The estimated effects are presented in Table 16. Taken together, it shows city formation was more responsive to changes in shipping times and market access in areas with *more* state presence. While there is a larger effect in places with less colonial presence, having at least some state capacity seems important for increases in market access to translate into increased growth.

[54]See Section REF in the Appendix.

5.4.1 Discussion of the Mechanisms

Several patterns emerge from the analysis of the mechanisms. The reform induced substantially lower shipping times to Europe which increased market access. This increase in market access is associated with increases in trade between Spain and Spanish America, particularly in places with larger increases in market access. Changes in commodity prices are consistent with changes increases in volumes of high-value agricultural commodities. Taken together, these patterns are faster sailing of individual ships allowed for increased specialization in a wider range of commodities, such as more perishable agricultural goods, to be shipped over long distances. New commercial opportunities in turn increased the population density in coastal areas and areas suitable for the cultivation of high-value agricultural commodities. The estimates suggest this economic expansion to be followed by increased reliance on slavery, with potentially adverse effects on long-run economic development in the context of the Americas (see for example Sokoloff and Engerman (2000), Nunn (2008), Bruhn and Gallego (2011), and Acemoglu, García-Jimeno and Robinson (2012)).

6 The General Equilibrium Effect of the Reform

The reduced form evidence shows a strong relationship between reductions in trade costs, population growth, and the formation of new settlements. This is driven by population growth in less densely settled areas. In light of this evidence, I now layout a canonical dynamic spatial general equilibrium framework that incorporates these channels. I proceed by estimating a structural model, for two purposes. First, it allows for studying long-run effects. Second, it accounts for spatial spillovers and hence serves as a robustness check to the reduced form results. I estimate the model using the data from the reduced form estimation. The time-varying nature of transportation costs are used to identify model parameters.

6.1 Theoretical Framework

The model follows the setup in and Allen and Donaldson (2018) but the time-variation in trade costs induced by the reform allows me to estimate the parameters of the model under weaker assumptions. The economy consists of several locations indexed by i where $i \in R$ over discrete time periods $t = .., 1760, 1810, 1860, ...$ where each generation represents 50 years. Every agent lives for two periods, and supplies labor inelastically in the second period while making decisions on where to locate in the first period. The size of the population in period 0 exogenous and given by $\{L_{i0}\}_{i \in R}$.

Geography. The geography of the framework is defined on a finite grid. Localities (grid-cells) have some geographic surface of similar size and the population is concentrated in the center of the cell where all consumption and production happens. This geography can be represented by a graph of edges (shipping time) and vertices (settlements). Each grid-cell is connected to the adjacent cells in a network through trade and migration. These network links can be transited by workers and goods can be moved, but it is costly. Furthermore, each location has a fundamental productivity A_i which determines the productivity of labor in location i, and each location also has an amenity value of u_i which governs the utility associated with settling in locality i.

Consumption. The demand side of the model consists of two parts. First, the utility of a representative agent in region $i \in R$ depends on agglomeration spillovers. The strength of the contemporaneous spillover effect, determined by β_1, could for example capture costs related to congestion, while the lagged spillover, determined by β_2 could capture the housing stock or other persistent amenities. Second, utility depends on consumption of goods produced in all other regions. Each region is assumed to produce a unique good that enters the utility function with constant elasticity of substitution (Armington (1969)).[55] In particular, the utility of a representative agent in region $r \in R$ is given by the following function,

$$\bar{u}_i L_{jt}^{\beta_1} L_{jt-1}^{\beta_2} \left(\sum_{i \in \Omega} q_{ij}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{12}$$

where q_{ij} denotes the quantity of a good shipped from region i and region j, σ is the elasticity of substitution between any two goods, L_t denotes the labor force in region j at time t, and β_1 and β_2 denote the strength of contemporaneous and past amenity spillovers respectively. Solving the consumers problem gives rise to the aggregate price index P_{it}.

Production. Production in each region is characterized by perfect competition. Each period, firms maximize profits taking wages, prices, productivity and the supply of labor available in each locality. In each locality a continuum of firms indexed by h produce a unique good with constant returns to scale technology with the following production function,

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

where $l_{it}(h)$ denotes the amount of labor used by h, $\bar{A}_i$ is an exogenous productivity shifter, and L_{it} denotes the total population in region i at time t. α_1 and α_2 denote the strength of contemporaneous and historical agglomeration spillovers respectively. The firms take A_{it} and L_{it} as exogenously given. Each period the whole labor force produces the variety of region i, hence $\int l_{it}(h)dh = L_{it}$. Moreover, since there is perfect competition, $w_{it} = \frac{p_{it}}{A_{it}}$. While the production technology rules out increasing returns at the level of the firm, the agglomeration spillovers as captured by α_1 and α_2 opens for the possibility of increasing returns at the level of the region as a whole.

Land. Trade balance in each locality and the assumption that income from land is allocated lump-sum to all inhabitants implies that ....

Trade. The framework described above is amenable to incorporating both international and intra-national trade. Trade costs between region i and j are time-varying and take the iceberg form. For one unit q_{ijt} to arrive in j at time t, τ_{ijt} units of the good need to be shipped. Using he 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,

$$X_{ijt} = \tau_{ijt}^{1-\sigma} \left(\frac{w_{it}}{A_{it}} \right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{14}$$

The equation shows that trade between i and j increases with lower prices in i, lower trade costs between the locality, and higher income in j. Proofs of existence and uniqueness of the equilibrium depends on symmetric bilateral transportation costs (but not migration costs). Therefore it is assumed that $\tau_{ijt} = \tau_{jit} = \frac{\tau_{ijt}+\tau_{jit}}{2}$ throughout.

[55]This is an appealing assumption in an historical context since trade was characterized by different types of goods being traded until the 20th century.

Migration. The young at time $t-1$ choose location in t in order to maximize utility. The utility of a particular location depends on the deterministic utility V_{it} which depends on real wage of the locality in addition to the utility derived from local amenities as captured by u_i. In addition, there is an idiosyncratic component to preferences, ϵ_{ijt}, which enters multiplicatively and is assumed to be independent draws from a Fréchet-distribution with shape parameter θ. Migration between two locations i and j is costly, time-invariant, and given by μ_{ij}. Migration between Europe and the Americas is assumed infinite, such that $\mu_{ie} = \mu_{ei} = \infty$ for all i in the Americas.[56] The utility of a young individual moving from location i to j is therefore given by the following expression,

$$V_{ijt} = \frac{V_{jt}}{\mu_{ij}} \times \epsilon_{ijt}. \tag{15}$$

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

$$\mathbb{E}\left[V_{it}\right] = \left(\sum_{i \in R} \left(\frac{V_{jt}}{\mu_{ij}}\right)^{\theta}\right)^{\frac{1}{\theta}}. \tag{16}$$

Again using the properties of the Fréchet-distribution gives the following gravity relationship of migration flows between i and j,

$$L_{ijt} = \mu_{ij}^{-\theta} \Pi_{it}^{-\theta} L_{it-1} V_{jt}^{\theta}, \tag{17}$$

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

Equilibrium and Steady-State. A geography is a sequence of variables that are assumed exogenous in the model, $G_t = \{\bar{A}_i, \bar{u}_i, \boldsymbol{\tau}_{it}, \boldsymbol{\mu}_i, L_{i0}\}_{i \in R}$ where $\boldsymbol{\tau}_i$ and $\boldsymbol{\mu}_i$ are vectors of dimension $|R| \times 1$. 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 payment to labor ($w_{it}L_{it} = \sum_{j \in R} X_{ijt}$), trade is balanced ($w_{it}L_{it} = \sum_{j \in R} X_{jit}$), the total population equals the population arriving at a location ($L_{it} = \sum_{j \in R} L_{jit}$), and the total population equals the number of people exiting a location ($L_{it-1} = \sum_{j \in R} L_{ijt}$). 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. $w_{it}^{\sigma} L_{it}^{1-\alpha_1(\sigma-1)} = \sum_{i \in R} K_{ijt} L_{jt}^{\alpha_1(\sigma-1)} V_{jt}^{1-\sigma} w_{jt}^{1-\sigma}$,
2. $w_{it}^{1-\sigma} L_{it}^{\beta_1(1-\sigma)} V_{it}^{\sigma-1} = \sum_{i \in R} K_{jit} L_{jt}^{\alpha_1(\sigma-1)} w_{jt}^{1-\sigma}$,
3. $L_{it} V_{it}^{-\theta} = \sum_{i \in R} \mu_{ji} Pi_{jt}^{-\theta} L_{jt-1}$,
4. $L_{it-1} = \sum_{i \in R} \mu_{ij}^{-\theta} \Pi^{-\theta} L_{it-1} V_{jt}^{\theta}$,

[56] I relax this assumption as a robustness check.

where $K_{ijt} = \left(\frac{\tau_{ijt}}{\bar{A}_i L_{it-1}^{\alpha 2} \bar{u}_j L_{jt-1}^{\beta 2}}\right)^{1-\sigma}$.

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* $E^*(G_0) \neq E^*(G_0')$*.*

Allen and Donaldson (2018) and Allen, Arkolakis and Li (2015) show the parameter space under existence and uniqueness of the equilibrium holds.[57] and whether this holds in the current context depends on the parameter estimates. The next section structurally estimates the model, and shows that the conditions of uniqueness of equilibrium holds in the current context. The model cannot be solved in closed form. In order to solve it the equilibrium conditions are combined to reduce the dimensionality of the problem and the solved numerically.[58]

6.2 Parameter Estimation and Identification

In order to quantify the effect of opening Trans-Atlantic trade the parameters of the model are estimated using the changes in trade costs induced by the reform. To facilitate estimating and solving the model, the model is derived on a smaller grid of 543 cells. There are six parameters, $\{\sigma, \theta, \alpha_1, \alpha_2, \beta_1, \beta_2\}$, as well as $|R|$ geographic fundamentals and local amenities, $\{\bar{A}_{it}, \bar{u}_{it}\}_{i\in R}$ which are backed out from the data. The estimation proceeds in three steps. First, the trade costs and migration costs are calculated by estimating the gravity equation for trade and migration respectively. Second, given these trade and migration costs, the equilibrium conditions are inverted in order to back out the endogenous variables for which there is no data, $\{p_{it}^{\sigma-1}, P_{it}^{\sigma-1}, V_{it}^{\theta}, Pi_{it}^{\theta}\}_{i\in R}$. Third, I take the logarithm of the endogenous productivity and amenity values, $A_{it} = \bar{A}_i L_{it}^{\alpha_1} L_{it}^{\alpha_2}$ and $u_{it} = \bar{u}_{it} L_{it}^{\beta_1} L_{it}^{\beta_2}$, and take first differences, to arrive at the estimating equations. Finally, the local amenities and productivities are calculated as the residuals of the estimated model. I further elaborate on the steps of this procedure as well as the underlying assumptions for identifying the parameters below.

[57] In particular, Allen and Donaldson (2018) show that in this class of models, existence and uniqueness is guaranteed by the spectral norm of **B** being less than one. With the parameters of the baseline model the spectral norm equals 0.97, where **B** is given by the following expression,

$$\mathbf{B} = \begin{bmatrix} \frac{\theta(1+\alpha_1\sigma+\beta_1(\sigma-1))-(\sigma-1)}{\sigma+\theta(1+(1-\sigma)\alpha_1-\beta_1\sigma)} & \frac{(\sigma-1)(\alpha_1+1)}{\sigma+\theta(1+(1-\sigma)\alpha_1-\beta_1\sigma)} \\ \frac{\theta}{(\sigma+\theta(1+(1-\sigma)\alpha_1-\beta_1\sigma))\tilde{\sigma}} & \frac{\theta(1-(\sigma-1)\alpha_1-\beta_1\sigma)}{\sigma+\theta(1+(1-\sigma)\alpha_1-\beta_1\sigma)} \end{bmatrix}. \tag{18}$$

[58] In particular, the $4 \times R$ equations are combined into R equations that are only functions of the indirect utilities in each location. This is done by exploiting results in Allen and Arkolakis (2014) that shows that the destination and origin fixed effects are proportional. As a result, the wage can be eliminated from the equation system. The resulting equilibrium condition is homogenous in labor, and therefore does not pin down the population size, however, this is backed out from the data. The following equation is solved numerically

$$V_i^{\tilde{\sigma}\sigma} L_i^{\gamma_1} = \sum_{s\in\Omega} \tau_{ij}^{1-\sigma} \bar{A}^{(\sigma-1)\tilde{\sigma}} \bar{u}_i^{\tilde{\sigma}} \bar{u}_j^{(\sigma-1)\tilde{\sigma}} \bar{A}_j^{\sigma\tilde{\sigma}} L_{i,t-1}^{\gamma_2} L_{j,t-1}^{\gamma_3} V_j^{(1-\sigma)\tilde{\sigma}} L_j^{\gamma_4} \tag{19}$$

where $\gamma_1 = \tilde{\sigma}(1-\alpha_1(\sigma-1)-\beta_1\sigma)$, $\gamma_2 = \tilde{\sigma}(\alpha_2(\sigma-1)+\beta_2\sigma)$, $\gamma_3 = \tilde{\sigma}(\alpha_2\sigma+\beta_2(\sigma-1))$, $\gamma_4 = \tilde{\sigma}(1+\alpha_1\sigma+\beta_1(\sigma-1))$, and finally $L_i = V_i^{-\theta} \sum_{s\in\Omega} \left(\sum_{k\in\Omega} \mu_{sk}^{-\theta} V_k^{\theta}\right)^{-1} L_{s,t-1}$.

Step 1: Gravity Equations. To estimate the 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 $\lambda > 0$. I ignore a time subscripts for κ and λ because I find very similar estimates when I allow the parameters to be time-variant. Taking the natural logarithm of the gravity equation for trade and the migration (equations 10 and 12) and inserting τ_{ij} and μ_{ij} gives the following relationships,

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

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

where the last two terms in each regression are interpreted as origin and destination fixed effects respectively. The equations are estimated using OLS with standard errors clustered at the origin and destination pair. The results are given in Table 17. The table shows there is a strong relationship between travel time and trade volumes as well as migration. A one percent increase in the travel time reduces trade flows with 0.6 percent and migration with 2.5 percent. Using these estimates, a matrix of trade as well as migration costs can be calculated. These matrices will be used in the quantitative exercises as well as in backing out the remaining structural parameters of the model.

Step 2: Model Inversion. The equilibrium conditions in Definition 1 are used to invert the model to solve for the endogenous variables given the data. Imputing data on the population size and wages as proxied by agricultural productivity, all the parameters as well as the exogenous amenity and productivity values are identified. The model is inverted in the following manner,

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

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

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

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

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

Step 3: Parameter Estimation. The expressions for the amenity and productivity are used in order to identify the parameters of the model. Taking the logarithm of these variables of the productivity term A_{it} gives the following expression,

$$\Delta ln\left(p_{it}^{\sigma-1}\right) = (\sigma-1)\Delta ln\left(\tilde{w}_i\right) + \alpha_1(1-\sigma)\Delta ln\left(L_{it}\right) + \alpha_2(1-\sigma)\Delta ln\left(L_{it-1}\right), \tag{26}$$

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

Next, taking the logarithm of the indirect utility function V_{it} and taking first differences gives the following expression,

$$\Delta ln\left(V_{it}^{\theta}\right) = \theta \Delta ln\left(\tilde{w}_{it}\right) + \frac{\theta}{\sigma - 1} \Delta ln\left(P_{it}^{1-\sigma}\right) + \beta_1 \theta \Delta ln\left(L_{it}\right) + \beta_2 \theta \Delta ln\left(L_{it-1}\right). \tag{27}$$

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

Finally, I use the estimated parameters to back out the location specific amenity and productivity using the same equations in levels. In particular, the following equations are used to obtain the locational fundamentals, ...

Results. Table 18 contains the baseline estimates of Equation (26) and (27). For both estimating equations the both the OLS and IV-estimates are presented. There is a strong first stage for both equations, (36 and 25 respectively). The agglomeration spillovers are precisely estimated while the amenity spillovers are less precise. I then solve for the model parameters and calculate the covariance matrix using the delta-method. Since the amenity spillovers are less precise solve the model with alternative amenity spillovers as a robustness check. The elasticity of substitution σ and the migration elasticity θ are taken from the literature and set to 5 and 3 respectively. However, I provide evidence that the results are robust to different parameter values. The contemporaneous agglomeration spillover, α_1 is found to be negative. This means that there are negative externalities in co-location at the level of aggregation under consideration. It is worth pointing out that this does not rule out positive agglomeration externalities at lower resolutions. The lagged agglomeration externality however is positive, meaning that there are productivity gains in locating in locations that have a history of being more densely settled in the past. This could reflect different types of fixed capital or infrastructure investments with low depreciation. The contemporaneous amenity spillover is positive, showing that places with higher population density are more attractive in this context. However, the lagged amenity spillover is negative but significantly smaller. Given these parameter values there is a unique equilibrium.[59] Table 19 displays the parameter estimates used in the baseline models of the counterfactual exercises.

6.3 Model Fit

This section assesses the performance of the theoretical framework comparing the evolution of the spatial distribution of economic activity predicted by the model with the realized population growth between 1760 and 1810. The model is solved for the initial population distribution in 1760 and solved forward one generation, giving the model implied population distribution in 1810. The population distribution in

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

Table 19: Model Parameters

Productivity		Amenity	
σ (Elasticity of Subs.)	5	θ (Migration Elasticity)	3
α_1 (Contemp. Prod. Spillover)	0.2	β_1 (Contemp. Amenity Spillover)	0.13
α_2 (Lagged Prod. Spillover)	-0.26	β_2 (Lagged Amenity Spillover)	0.025

Note: The table shows the parameters used for the baseline simulation exercises. α_1, α_2 β_1, and β_2 are estimated directly from the data. σ and θ are taken from the literature in the baseline case.

1810 implied by the model is then compared to the population in the data. As the population is highly persistent over time, both levels and changes are compared. One period in the model, taken to represent one generation, is assumed to be 50 years.

Table 20 displays the results of this exercise. Panel A displays shows the relationship between the model implied population in 1810 and the realized population in 1810 conditional on the baseline control variables. The table shows there is a robust relationship between the model implied population distribution and the realized population distribution. A one percent increase in the model implied population, increases the average population with around 1.3 percentage points. 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. A one percent increase in the model implied growth rate between 1760 and 1810 increases the realized population growth by around 0.2 percentage points. This relationship is also highly robust to including the various controls. Unfortunately, the lack of high-resolution 18th-century spatial data prevents me from testing the model on most variables other than population. In the first counterfactual exercise in the next section, the model is validated further by comparing the reduced form effects to the model simulation of the reform. Taken together, these exercises show that the mechanisms emphasized by the model are relevant in the current context.

6.4 Counterfactuals

This section uses the model to conduct counterfactual exercises. Since there exists a unique general equilibrium in the model, the counterfactuals yield determinate predictions for the impact of the changes in the policy. The key object of interest is the population distribution under the scenario of changing trade costs, relative to the counterfactual of trade costs remaining constant. Thus, unless stated otherwise the results are reported relative to the baseline of non-changing trade costs. Throughout the section, $L_t^{T_0}$ will denote the population allocation at time t assuming the trade costs T_0 remained constant after 1760. Moreover, $L_t^{T_1}$ denotes the model implied population distribution with changing trade costs. The object of interest is $\bar{L}_t = L_t^{T_1} - L_t^{T_0}$, which is the ratio of population assuming changes in trade costs, relative to the baseline of no changes in costs. Henceforth, I refer to $\bar{L}_t$ as the effect of the reform. Throughout variables are standardized in order to facilitate interpretation.

I present several counterfactual exercises below. First, I show that the model replicates the three broad patterns of the reforms documented in the reduced form analysis. Second, I consider a different timing of the reform. In particular, what would be the long-run impact in the case where the reforms happened earlier in time. Finally, I consider the role of initial conditions in determining the effect of the reform. The welfare effects of these different policy scenarios are then quantified.

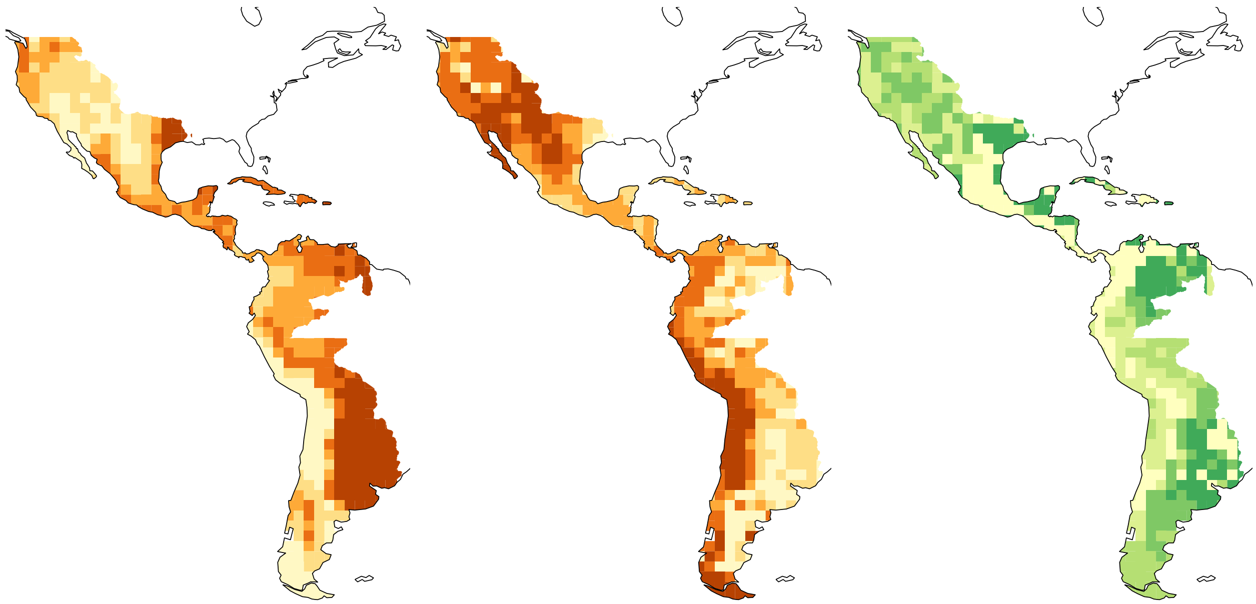

Figure 8: The figures show the results from the structural estimation. The left map shows the geographic fundamental productivity by grid-cell, which is the residual from Equation (19). The center map shows the amenity value for each grid-cell, which is the residual from Equation (20). The right map shows the change in population induced by the change in trade costs according to the model with the estimated parameters. In all the maps, darker colors indicate higher values.

The Impact of the Reform. Starting out, the long-run impact of the policy is simulated and compared to the reduced form. 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 lower trade costs relative to the baseline of unchanged trade costs, $\bar{L}_{1810}$.

The results from this exercise are displayed in the right map in Figure 8. In the map, darker colors indicate a higher population density relative to what would have been achieved with constant trade-costs ($\bar{L}_{1810}$). Hence, it shows the regions that grow more as a result of the reform lowering trade costs. The figure shows that the results mirror the reduced form. First, the lower trade costs increase the coastal population density. A one standard deviation increase in the distance to the coastline (around 340km), reduces $\bar{L}_{1810}$ with 0.019 standard deviations. Second, areas with larger reductions in trade costs to Europe grow relative to the baseline as a result of the reform. In particular, a one standard deviation reduction in shipping time increases $\bar{L}_{1810}$ with 0.14 standard deviations. Finally, the effects are concentrated in the periphery. The effect in the periphery is 0.86 standard deviations lower in the core regions of Mexico and Peru.

Long-run Effects. Next, I solve the model 200 years forward in time to 1960 comparing the population distribution relative to the baseline. Figure 9 displays the effects from this exercise. Point estimates are similar as for the effect in 1810. The effect is larger closer to the coast, in areas with larger reductions in trade costs, and outside the core region for all the years. For 1960 a one standard deviation increase in the distance to the coastline reduces the effect of the policy by 0.023 standard deviations. Increasing the shipping time to Europe increases the population size relative to the baseline by 0.18 standard deviations. Moreover, the effect is one standard deviation smaller in the core area. As can be seen Figure 9, this effect is highly persistent. The effect of the policy can still be seen after 200 years. Moreover, the effect is slightly

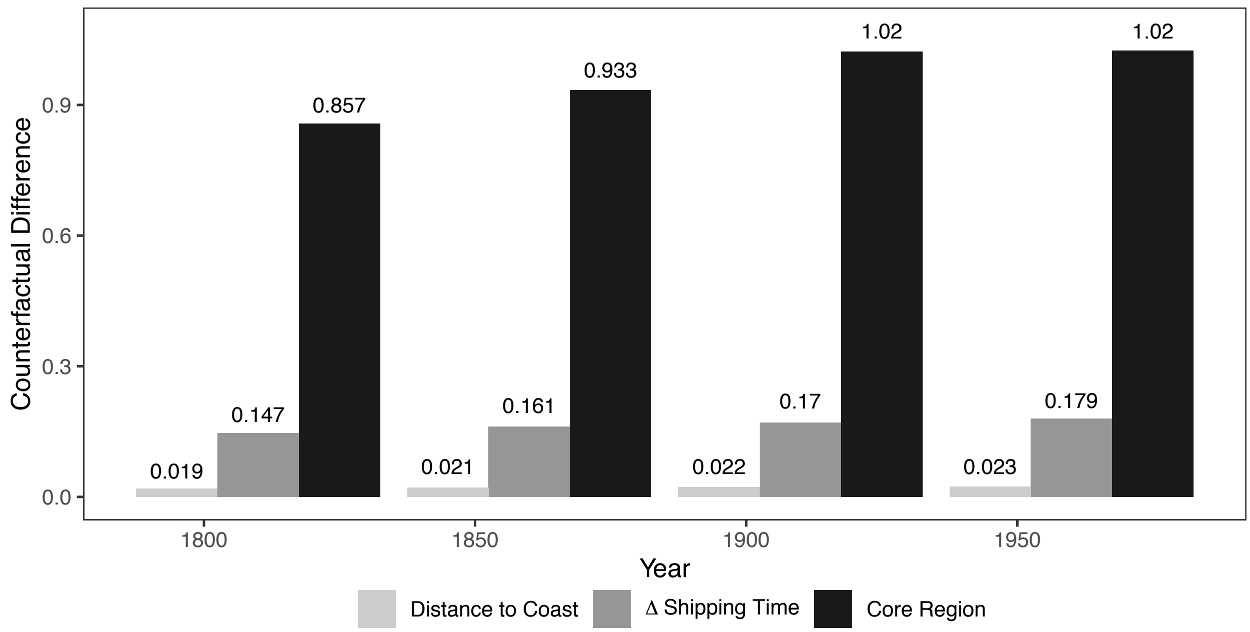

Figure 9: The figures show the results from the structural estimation. The left map shows the geographic fundamental productivity by grid-cell, which is the residual from Equation (19). The center map shows the amenity value for each grid-cell, which is the residual from Equation (20). The right map shows the change in population induced by the change in trade costs according to the model with the estimated parameters. In all the maps, darker colors indicate higher values.

increasing each generation which is consistent with agglomeration and amenity externalities increasing the effect in the long-run.

The Role of Initial Conditions. In this section I assess the impact of initial conditions on the impact of the reform. While lower transportation costs tend to make coastal localities more attractive, 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.[60] To assess the quantitative significance of this mechanism, the long-run impact of the change in trade costs are assessed with different initial conditions. In particular, I solve the model forward using the population distribution in 1700 and 1600 as initial conditions.

Panel A of Table 21 displays the results from this exercise. The first column shows that the impact of the reform is positive for all initial conditions. A one standard deviation reduction in the trade cost increases the relative population size by around 0.14 standard deviations. Moreover, the reform increases the population in coastal areas regardless of the initial condition. This is also the case for the effect of the reform in the core. The reform affects the population distribution less in the core region. However, the two latter effects are attenuated when using the population in 1700 or 1600 as initial condition. As a results, the model confirms that a more interior initial condition tends to reduce the responsiveness of the population distribution to changing trade costs. This is clear from the tendency of the coastal population density to be more strongly affected by the trade cost shock, the lower the initial level of population. Does this conditional nature of the trade cost shock matter for welfare through the mechanisms emphasized by the model? To assess this the I compare the welfare between the two scenarios. The results from this

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

exercise show that a geography that is more responsive to increases in trading opportunities is beneficial in terms of welfare, although the effects are quantitatively small.

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

The results of this exercise can be seen in Panel B of Table 21 If trans-Atlantic trade had been opened already in 1700 there would have been a higher population density in coastal areas by the year 1810. A one standard deviation increase in the distance to the coast increases the ratio by around 0.03 standard deviations, implying that the population density implied by the earlier opening would be more concentrated along the coast. Moreover, the core regions have relatively higher population density in 1810 the later trade was opened.[61] Taken together, this supports the view that low coastal population density partly is driven by the late opening of trans-Atlantic trade during the colonial era that has persisted until the present. Moreover, the findings are consistent with the restrictions on trade stunting economic development in the periphery and that the lifting of these being responsible for the growth in the periphery starting in the second half of the 18th century. However, an earlier opening of trade with Europe would again only have modest effects on welfare through the mechanisms emphasized by the model.

6.5 Robustness Checks

Alternative Spillover Parameters. While the agglomeration parameters are precisely estimated, this is not the case for the amenity spillovers. I therefore, repeat the exercise to assess if it affects the results. For all the parameters I solve the model by perturbating the parameter estimates. Taken together, I find little evidence that this exercise changes the qualitative impact of the reform.

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

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

Secular change in trade costs. Another quantity which we might expect to undergo secular change over the simulation period is trade-costs. I assess this by assuming a five percent reduction in trade costs over

[61] This effect is robust to changing the definition of what constitutes a coastal area.

the reform period. The estimates from the model remain largely unchanged. For the long-run results, this is more of a concern. Assuming a five percent reduction in trade costs each generation, the model is solved forward. Again, there is little to suggest the results are vulnerable to assumptions about trade costs.

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

7 Conclusion

This paper uses the abrupt opening of Trans-Atlantic trade within the Spanish Empire to study the impact of trade costs on economic development in the long-run. I calculate the changes in travel times to Europe induced by a reorganization of the maritime communication in the wake of the Bourbon reforms in the second half of the 18th century. Using a difference-in-difference research design that relies on comparing areas within the same region that differentially reduced its shipping time to Europe due to the policy, I estimate the impact of lower trade costs on the location of cities and population growth. I find a statistically and economically significant positive effect on urbanization associated with reduced travel time to Europe. Moreover, the opening of Atlantic communication is associated with a change in the role of economic fundamentals, in particular an increased importance of coastal proximity. I present evidence consistent with increased importance of Trans-Atlantic trade and specialization in high-value agricultural commodities being an important mechanism explaining the effect. To assess the aggregate impact and conduct counterfactual simulations, the calculated changes in remoteness are used to estimate the parameters of a dynamic spatial general equilibrium model. Consistent with the reduced form evidence, the model shows that the late opening of the Trans-Atlantic trade reduced the coastal population concentration, but less so in sparsely populated the colonial periphery. The effect is contingent on initial conditions. Lower levels of population density facilitated the geographic reorientation towards coastal areas. Finally, I find that these effects have a limited impact on welfare through the mechanisms highlighted by the model.

These findings have several implications. First, the effects found show that the increased economic importance of the colonial periphery in the 18th century are to a large extent driven by lower international trade costs. This raises questions about the role of institutions governing property rights in engineering the reversal of fortune and as a consequence the primacy of these institutions in explaining comparative development in general. Second, I provide evidence that lower international trade costs promoted economic development and diversification. The paper thus provides empirical evidence that beyond factors typically emphasized in the literature, such as endowments, technology, and institutions, international trade costs can play an important role in shaping patterns of international specialization. Finally, the results provide empirical support for models where initial economic geography and agglomeration mediate the impact of trade cost shocks.

Beyond the economic mechanisms emphasized in this paper, a potentially important mechanism through which the Bourbon commercial reforms affected development trajectories was by accelerating independence movements. Alesina and Spolaore (2003) (p. 191) argues that increased reliance on international trade was an important impetus for the independence movements in Latin America.[62] Lower trade costs increased the reliance on international trade in the colonial periphery, making economic independence more attractive for political elites and in turn promoting political fragmentation. As such, an important issue that this paper does not address is how broader participation in international trade lead to political fragmentation and ultimately the emergence of stable national borders. Future research should quantitatively examine the role of trade costs in shaping political fragmentation and national borders, which remain important impediments to economic integration to this day.

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

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8 Tables

Table 1: Summary Statistics - Main Variables

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

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

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

	(1)	(2)	(3)	(4)
Panel A: Knots (daily average)				
θ_{ij}	0.036***	0.085***	0.085***	0.071***
	(0.012)	(0.015)	(0.015)	(0.011)
Wind speed$_i$	0.346***	0.315***	0.315***	0.424***
	(0.009)	(0.011)	(0.011)	(0.007)
Panel B: Wind Speed 1750-1850				
Wind speed (Beaufort)	0.357***	0.343***	0.343***	0.331***
	(0.018)	(0.035)	(0.035)	(0.016)
Panel C: Wind Direction 1750-1850				
Wind direction (Degrees)	0.226***	0.247***	0.246***	0.173***
	(0.013)	(0.016)	(0.016)	(0.014)
Year + Month FE	✓	✓	✓	✓
Ship Type FE		✓	✓	
Nationality FE			✓	
Voyage				✓
Observations	17,221	12,149	12,149	17,221
Adjusted R-squared	0.060	0.088	0.088	0.168

Note: The unit of analysis is at a logbook entry. The dependent variable in Panel A is average speed per day measured in knots. The dependent variable in Panel B is the wind speed as reported in the logbooks measured in Beaufort. **The dependent variable** in Panel C is the wind direction measured in degrees. θ_{ij} denotes the angle between the wind and the direction of travel. The regression in Panel A is based on 225,211 observations. The regression in Panel B is based on 40,158 observations. The regression in Panel C is based on 17,221 observations. Data is from NOAA and CLIWOC. **Standard errors** are clustered at the level of the voyage. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 4: Shipping Time to Europe and Market Access

Market Access	(1)	(2)	(3)	(4)
Shipping Time	-4.473^{***}	-5.090^{***}	-5.001^{***}	-5.061^{***}
	(0.389)	(0.438)	(0.365)	(0.343)
Viceroyalty FE $\times$ Decade FE	✓	✓		
Audiencia FE $\times$ Decade FE			✓	✓
Geographic Controls		✓		✓
Mean dep. var.	0.1	0.1	0.1	0.1
Observations	73,282	73,282	73,282	73,282
Adjusted R-squared	0.686	0.697	0.698	0.742

Notes: The unit of analysis is at a $0.5°\times0.5°$ grid-cell. **The dependent variable** is a dummy taking the value 1 if the grid-cell contains a city. **The geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. 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 $\times$ 6,662 = 73,282 observations**. **Standard errors** are clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 5: Shipping Time, Market Access, and City Formation

Population (asinh)	(1)	(2)	(3)	(4)
Panel A: IV				
Market Access	0.406*	0.369	0.392*	0.245*
	(0.222)	(0.233)	(0.214)	(0.131)
Panel B: Reduced Form				
Shipping Time	−1.337*	−1.349	−1.436*	−0.936*
	(0.792)	(0.885)	(0.814)	(0.548)
Panel C: OLS				
Market Access	0.257*	0.234*	0.237*	0.254**
	(0.135)	(0.131)	(0.131)	(0.102)
First stage F	47.1	63.08	99.51	20.66
Viceroyalty FE × Year		✓		
Audiencia FE × Year			✓	✓
Controls				✓
Observations	73,282	73,282	73,282	73,282

Note: The unit of analysis is at a $0.5°\times0.5°$ grid-cell. **The dependent variable** is population size of the grid-cell. 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 geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain *audiencia* fixed-effects. **Standard errors** are clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 6: Event-study Specification

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

Notes: The unit of analysis is at the grid-cell level. The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. 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. **The geographical controls** include distance to the coast (log), elevation, presence of an active mine, terrain ruggedness, and crop suitability. **Standard errors** are clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}\ p < .1$

Table 7: Heterogeneity

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

Note: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **The dependent variable** is a dummy taking the value one if the grid-cell contains a city. The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. All specifications include grid-cell fixed-effects. **The core** denotes the audiencias of Charcas, Lima, and Mexico (1,009 cells $\times 11 = 11,099$ observations), **the periphery** the audiencias of Buenos Aires, Santiago, Caracas, (1,284 cells $\times 11 = 14,124$ observations) and the **semiperiphery** Quito, Santa Fe, Confines, Santo Domingo, Guadalajara, Cuzco (1,534 cells $\times 11 = 16,874$ observations). 2,835 cells do not pertain to an audiencia. **Coastal** denotes the grid cell being less than 100km from the coast. **The geographical controls** contain 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** are clustered at the level of the closest port. $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .1$

Table 8: Coastal Population Density in the Long-Run

	Population 1750		Population 2000		Nightlights		City	
Panel A: Full Sample								
Dist. coast (log)	-0.272^{*}	-0.348^{**}	-0.373^{***}	-0.405^{***}	-0.170^{***}	-0.179^{***}	-0.057^{***}	-0.061^{***}
	(0.159)	(0.158)	(0.076)	(0.077)	(0.041)	(0.041)	(0.015)	(0.015)
Panel B: High Exposure								
Coast dist. (log)	-0.243	-0.159	-0.449^{***}	-0.384^{***}	-0.245^{***}	-0.194^{***}	-0.078^{***}	-0.059^{***}
	(0.207)	(0.159)	(0.103)	(0.090)	(0.059)	(0.049)	(0.022)	(0.018)
Panel C: Low Exposure								
Coast dist. (log)	-0.288^{*}	-0.268^{**}	-0.296^{***}	-0.328^{***}	-0.102^{***}	-0.117^{***}	-0.032^{**}	-0.035^{**}
	(0.149)	(0.115)	(0.060)	(0.060)	(0.038)	(0.042)	(0.013)	(0.014)
Geographic FE	✓	✓	✓	✓	✓	✓	✓	✓
Controls		✓		✓		✓		✓
Observations	3,331	3,331	3,330	3,330	3,331	3,331	3,331	3,331
Adjusted R-squared	0.640	0.659	0.544	0.566	0.390	0.404	0.214	0.222

Notes: The unit of analysis is at a $1°\times1°$ grid-cell. ***Population*** denotes the average population density of the grid-cell in 2000, ***Nightlights*** denotes the average nighlight luminosity, and ***Nightlight City*** is a dummy variable for if the the average nighlight luminosity exceeds 30. ***High Exposure*** denotes above median reduction in remoteness. ***High Exposure*** denotes below median reduction in remoteness. The full sample contains **6,662 observations**. All specifications control for country, *audiencia*, and *viceroyalty* fixed-effects. **The geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. **Standard errors** are clustered at the port-level. $^{***}p < .01$, $^{**}p < .05$, $^{*}\ p < .1$

Table 10: Changes in Shipping Times and Exports to Spanish America

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

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

Table 11: The Reform and Commodity Prices

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

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

Table 12: Heterogeneity by Crop Suitability

City Formation	(1)	(2)	(3)	(4)
T	-0.099^{*}	-0.129^{***}	-0.048	-0.068
T $\times$ Crop suitability	-0.119^{***}	-0.107^{***}	-0.079^{**}	-0.080^{**}
	(0.035)	(0.035)	(0.033)	(0.037)
Viceroyalty FE $\times$ Year	✓	✓		
Audiencia FE $\times$ Year			✓	✓
Geographic Controls		✓		✓
Mean dep. var.	0.1	0.1	0.1	0.1
Observations	73,282	73,282	73,282	73,282
Adjusted R-squared	0.839	0.841	0.846	0.846

Notes: The unit of analysis is at a $0.5° \times 0.5°$ grid-cell. **Crop suitability** is measured as the average suitability for cocoa, coffee, cacao, cotton, tobacco, and sugar cane. **The dependent variable** is a dummy taking the value 1 if the grid-cell contains a city. The dataset is a balanced panel at a 10 year frequency for the period 1710-1810 for 6,662 grid cells. The geographical controls contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. All specification contain grid-cell fixed-effects. The full dataset contains **11** $\times$ **6,662 = 73,282 observations**. **Standard errors** are clustered at the level of the closest port. ***p $<$ .01, **p $<$ .05, * p $<$ .1

Table 13: Shipping Times to Europe and the Slave Trade

Outcome	(1)	(2)	(3)
Panel A: Trans-Atlantic Slave Trade			
Shipping Time	-0.001	-0.092^{**}	0.021
	(0.007)	(0.036)	(0.028)
Panel B: Intra-American Slave Trade			
Shipping Time	-0.010	-0.079^{**}	-0.066^{**}
	(0.007)	(0.031)	(0.027)
Year FE	✓	✓	✓
Port FE		✓	✓
Port $\times$ Trend			✓

Notes: The unit of analysis is the port. **The dependent variable** is the logarithm of number of ships arriving at a port in a given year. Panel A contains **149 observations** while Panel B contains **314 observations**. **Standard errors** are clustered at the port-level. Source: Eltis (2018). ***p $<$ .01, **p $<$ .05, * p $<$ .1

Table 14: Population, Urbanization, Density, and Shipping Times

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

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

Table 15: Rerouting and Transshipment

Outcome and Sample	(1)	(2)	(3)	(4)
Panel A: Rerouting: City formation				
Market Access	0.071^{*}	0.065^{*}	0.063	0.065^{***}
	(0.041)	(0.039)	(0.038)	(0.024)
Panel B: Rerouting: Population				
Market Access	1.382^{***}	1.435^{***}	1.429^{***}	1.172^{***}
	(0.195)	(0.185)	(0.186)	(0.142)
Panel C: Transshipment: City formation				
Market Access	0.112^{***}	0.111^{***}	0.111^{***}	0.126^{***}
	(0.017)	(0.019)	(0.019)	(0.032)
Panel D: Transshipment: Population				
Market Access	1.018^{***}	1.017^{***}	1.011^{***}	1.092^{***}
	(0.093)	(0.112)	(0.099)	(0.115)
Viceroyalty FE × Year		✓		
Audiencia FE × Year		✓	✓	✓
Controls				✓

Notes: The unit of analysis is at a 1°×1° grid-cell. All specifications include *audiencia* fixed effects. The variables are transformed using the inverse hyperbolic sine function. Panel A contains **44,825 observations**. Panel B contains **44,825 observations**. **The geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. **Standard errors** are clustered at the port-level. $^{***}p < .01$, $^{**}p < .05$, * $p < .1$

Table 16: Effects in the frontier

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

Notes: The unit of analysis is at a 1°×1° grid-cell. All specifications include *audiencia* fixed effects. **Panel A** denotes observations below median distance to the closest post-office while **Panel C** denotes observations above median distance. **Panel B** denotes places outside an *audiencia* and **Panel D** denotes places inside an *audiencia*. Panel A and Panel C contain **36,641 observations**. Panel B contains **31,185 observations** and Panel D contains **42,097 observations**. **The geographical controls** contain elevation, crop suitability, the location of active mines, and distance to the coastline, and terrain ruggedness. **Standard errors** are clustered at the port-level. ***p < .01, **p < .05, * p < .1

Table 17: Gravity Equations

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

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

Table 18: Estimating model parameters

	Equation (26)	Equation (27)
Panel A: OLS		
Population$_t$	1.239^{***}	1.054^{***}
	(0.019)	(0.050)
Population$_{t-1}$	-0.116^{***}	-0.324^{***}
	(0.012)	(0.042)
Panel B: IV		
Population$_t$	-0.130^{***}	-0.152
	(0.020)	(0.104)
Population$_{t-1}$	1.289^{***}	0.402
	(0.063)	(0.330)
Origin + Destination FE	✓	✓
F-statistic (effective)	36.58	25.19
Observations	542	542
Adjusted R-squared	0.956	0.799

Notes: The table provides estimates of the contemporanous and lagged agglomeration and amenity parameters of the model. **The instrument** is an indicator variable taking the value one if the reduction in trade costs is above the median. Equation (26) provides estimates of the agglomeration spillovers while Equation (27) provides the amenity spillovers. Trade and migration costs are estimated using origin and destination fixed effect. **The first-stage F-statistic** takes into account clustering following Olea and Pflueger (2013). **Standard errors** are clustered at the level of the closest port. ***p $<$ .01, **p $<$ .05, * p $<$ .1

Table 20: Assessing the Model Performance

Outcome	(1)	(2)	(3)	(4)
Panel A: Levels				
Population$_M$	1.312^{***}	1.288^{***}	1.383^{***}	1.362^{***}
	(0.041)	(0.039)	(0.053)	(0.052)
Panel B: Changes				
Population$_M$	0.197^{**}	0.217^{**}	0.224^{***}	0.230^{***}
	(0.085)	(0.089)	(0.086)	(0.087)
Viceroyalty FE		✓	✓	✓
Audiencia FE			✓	✓
Controls				✓
Adjusted R-squared	0.849	0.862	0.873	0.875

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

Table 21: Main Counterfactual Exercises

Dep. variable: $\tilde{L}$	Δ Shipping Time	Distance to Coast	Core Region
Panel A: Initial Population			
1760:	0.147	-0.019	-0.857
1700:	0.14	-0.016	-0.832
1600:	0.141	-0.009	-0.265
Panel B: Opening year			
1700:	0.005	0.034	0.711
1600:	-0.121	0.023	3.04

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

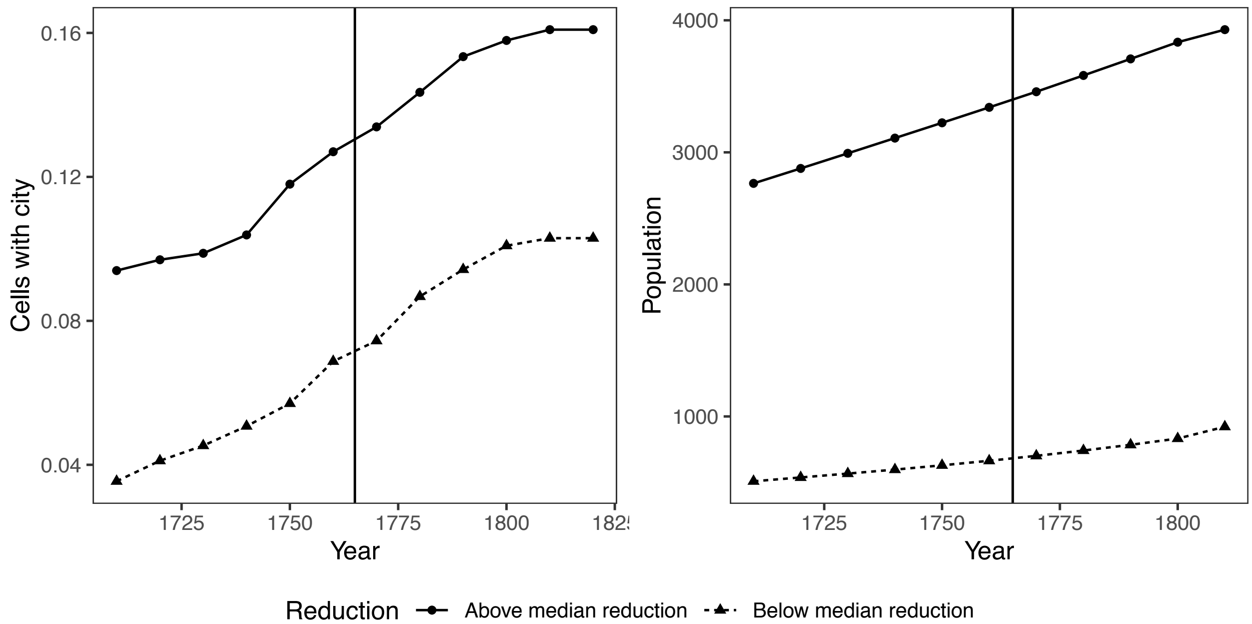

Figure 10: The figures show the share of grid-cells containing cities, the average population, the average urban population, and the average population density for grid-cells according to being above or below the median change in exposure in shipping times during the reform. The averages are calculated for each decade spanning 1710 to 1810.

9 Figures

Figure 11: The figures show the viceroyalty and audiencia borders in 1790 used in the main part of the analysis. Light gray areas show all the areas claimed by the Spanish Empire in 1790. The full lines denote the borders of the viceroyalties while lighter lines denote the borders of the audiencias. The lightest lines denote the coastlines.

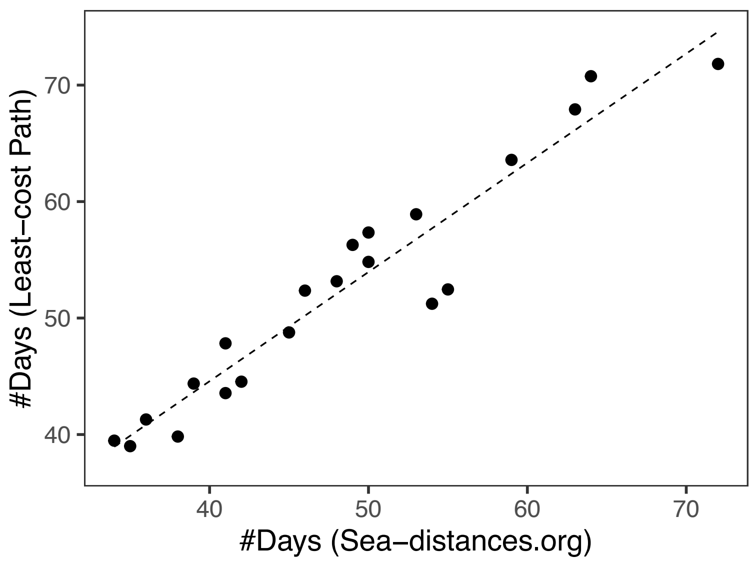

Figure 12: The figures show the share of grid-cells containing cities, the average population, the average urban population, and the average population density for grid-cells according to being above or below the median change in exposure in shipping times during the reform. The averages are calculated for each decade spanning 1710 to 1810.

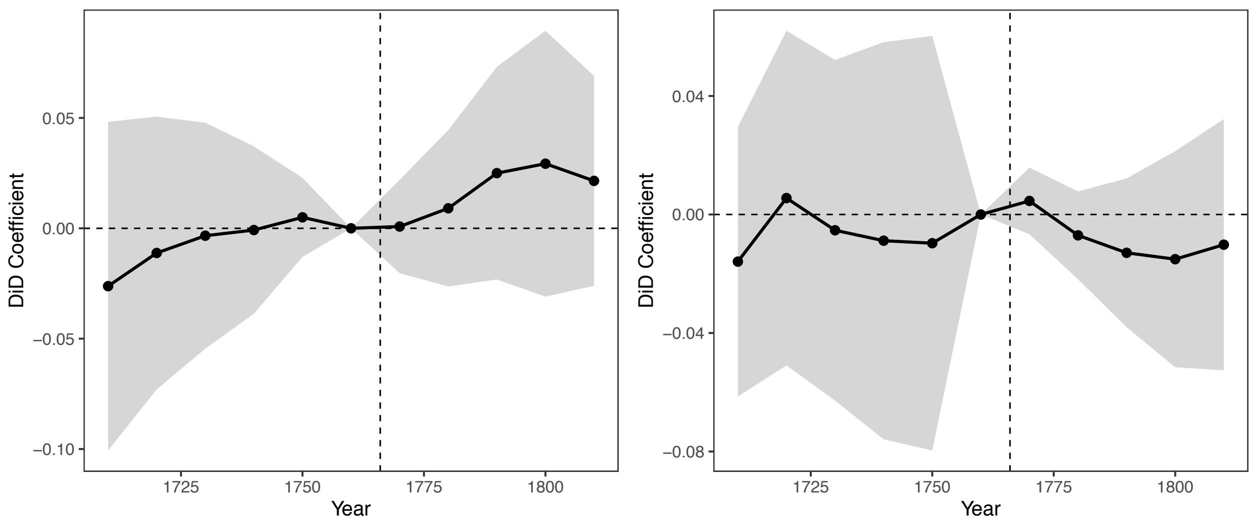

Figure 13: The figures show the share of grid-cells containing cities, the average population, the average urban population, and the average population density for grid-cells according to being above or below the median change in exposure in shipping times during the reform. The averages are calculated for each decade spanning 1710 to 1810.

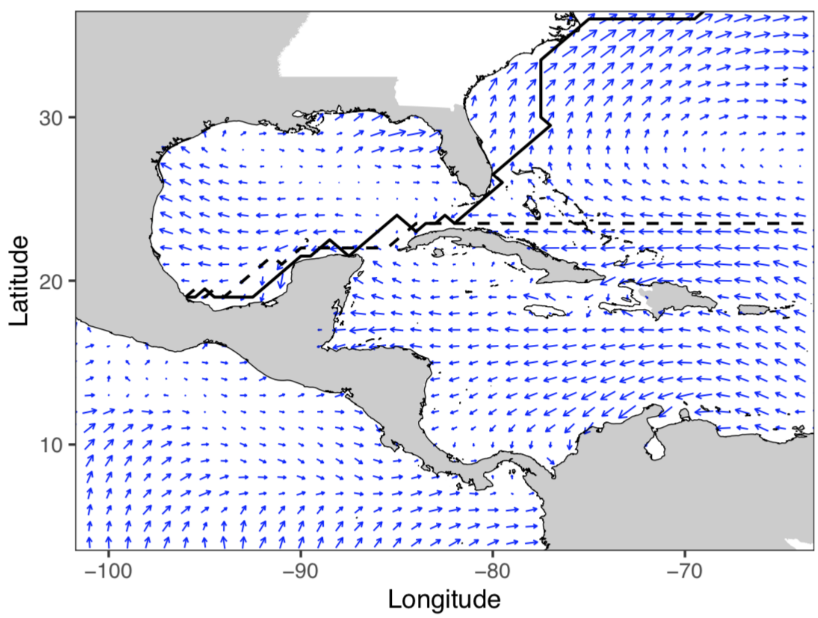

Figure 14: The figure shows the average wind speed and direction for the Caribbean over 2011-2017. The length of each arrow is proportional to the wind speed. The dashed line shows the shortest path from Cádiz to the port of Veracruz while the full line shows the shortest path from Veracruz to Europe (as proxied by the port of Cádiz). The grey areas indicate territory claimed by the Spanish Empire as of 1790. Source: NOAA.

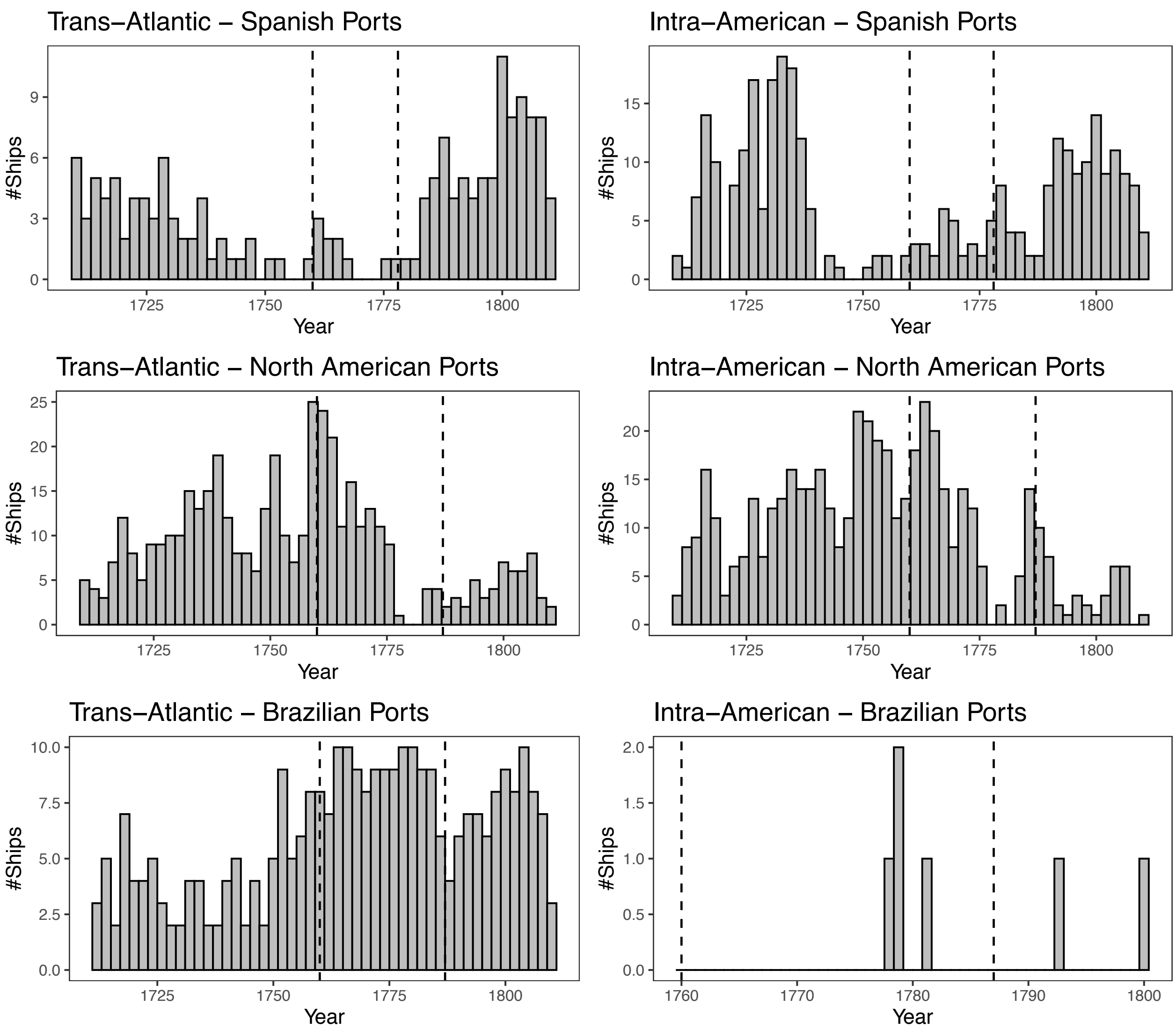

Figure 15: The figures show the number of ships participating in the intra-american and trans-atlantic slave trades arriving at Spanish, North American, and Brazilian ports between 1710 and 1810. The vertical lines denote the years between which most Spanish ports in were opened for long-distance trade. A ship is assigned to a port if the port is the first destination of a particular ship. Source: Eltis (2018).

Online Appendix

A Data Sources

A.1 Cities and Towns

Figure A1: The left map shows the location of settlements in 1710 and 1810 for the settlement types *Poblacion*, *Villa*, *Ciudad*, and *Fuerte*. The black cells are cells which overlap a settlement. The dark lines denote the viceroyalty borders of 1790. Source: HGIS Indias.

Add detailed data description here. . . .

A.2 Potential Vegetation

CHANGE SAGE Potential Vegetation. Global potential vegetation data is from the Center for Sustainability and the Global Environment (SAGE) in the Nelson Institute at the University of Wisconsin-Madison. 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 representative of the world's "potential" vegetation (i.e., vegetation that would most likely exist now in the absence of human activities). See Ramankutty and Foley (1999) for further details. The data is available at https://nelson.wisc.edu/sage/data-and- models/global-potential-vegetation/index.php.

A.3 Agricultural Yield

CHANGE Land Quality Proxy. 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 and white potato). See http://gaez.fao.org/Main.html for the database.

We use the earliest data available (baseline period 1961-1990), with intermediate input level and irrigated water supply. For example, according to the FAO GAEZ data on potential production capacity using low input level and rainfed agriculture (and data derived from it, such as Galor and Özak's (2016) Caloric Suitability Index). I take the maximal calorie amount across all crops available in a region as the final measure of the agricultural yield.

In the next step, each crop is scaled using the historical Food Composition Tables by the FAO (Chatfield, 1953), using the following calorie values per 100 grams for each crop:

- buckwheat: 330
- barley: 332
- chickpea: 345
- foxtail millet: 343
- groundnut: 388
- maize: 356
- oat: 385
- pearl millet: 348
- wetland rice: 357
- rape: 26
- rye: 319
- sunflower: 284

- soybean: 335
- sweet potato: 97
- sorghum: 343
- wheat: 334
- white potato: 70

A.4 Crop Suitability

tba

A.5 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 http://www.worldclim.org/ for the data source. The following variables are included in the analysis:

- wheat: 334
- white potato: 70

A.6 Ruggedness, Slope, and Elevation.

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

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

We measure ruggedness by the average standard deviation of elevation. Both plains will score low in this measure, while mountains and valleys will score high. Elevation, terrain ruggedness, and the slope of the main study area are displayed in the following maps.

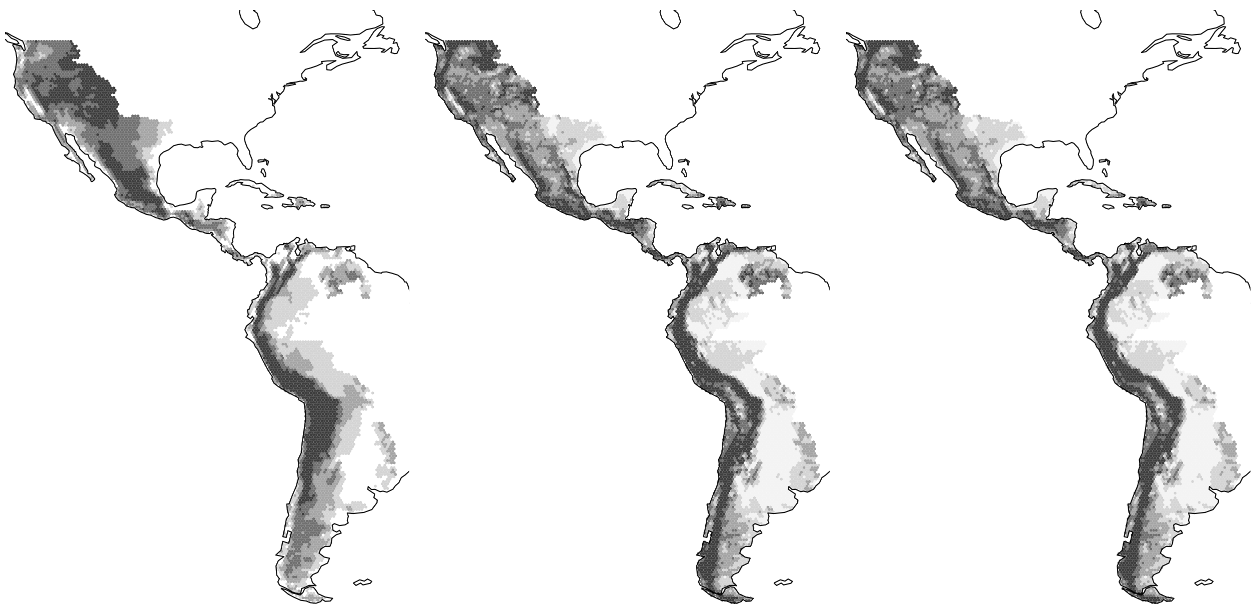

Figure A2: The left figure shows the average movement cost for each grid cell. Darker areas indicate less time consuming travel. The figure in the centre shows the residualized change in remoteness between 1750 and 1800 at the level of 6,662 $0.5° \times 0.5°$ grid-cells. Brighter colors indicate larger reductions. The figure on the left shows the residualized change in market access 1750 and 1800 at the level of 6,662 $0.5° \times 0.5°$ grid-cells. Brighter colors indicate larger increases

A.7 Measures of State Capacity

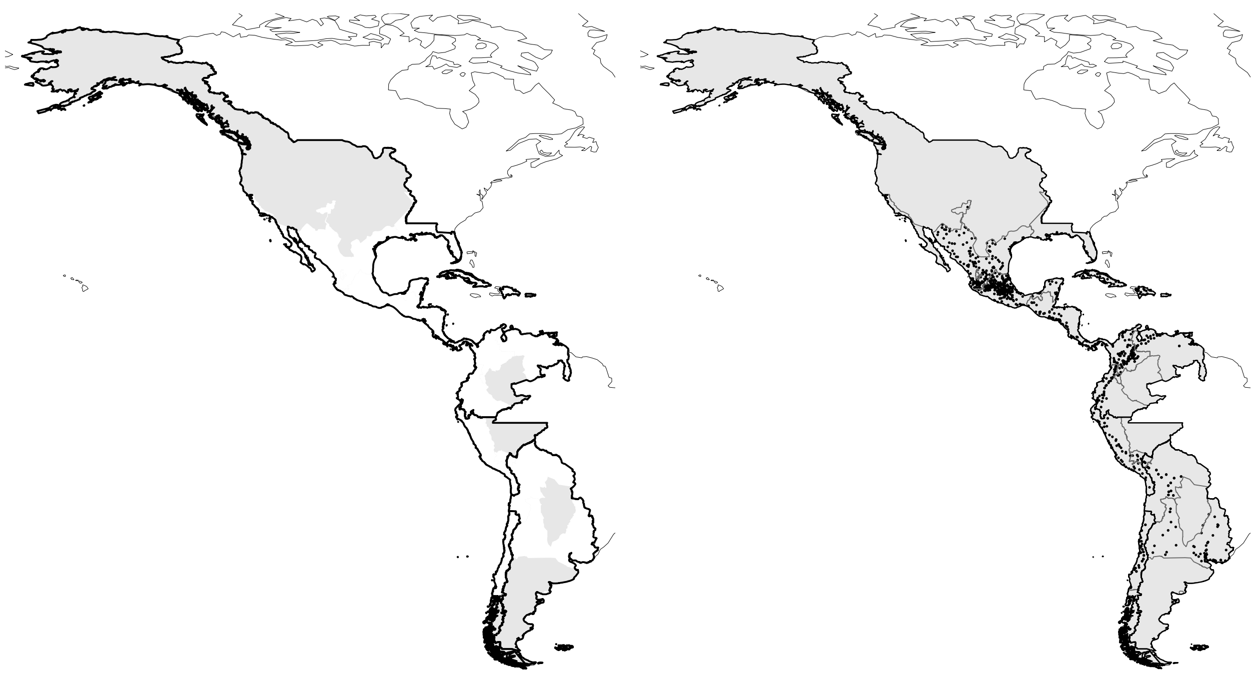

Figure A3: The left map shows the areas pertaining to an *audiencia* in 1790 in white. Areas outside and *audiencia* are colored in grey. The right map shows 897 post offices in Spanish America between 1710 and 1810.

Two measures of state capacity are used in the paper. . . . First, territorial organization is informative about the de-facto power of the Spanish state. This is more apparent in the context of the *audiencia* which tended to cover areas more firmly in Spanish control in the 18th century. Second, I consider the role of post offices which has been extensively used in the literature to proxy for historical state capacity (see for example. . . .). Both these measures of state capacity relate to infrastrucutral power. . . .. (Mann (1986)).

B Further Robustness Checks

B.1 Cross-validating Hyde 3.1 and Census Data

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

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

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

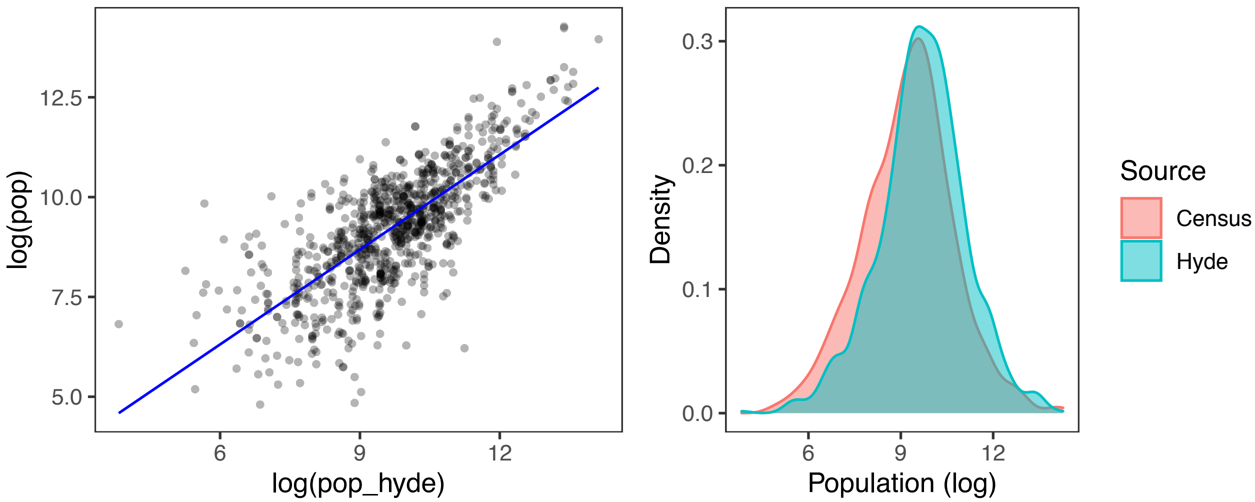

Figure A4: The figure shows the relationship between population counts in census data and in Hyde 3.1. The left figure is a scatter plot of the logarithm of the two variables. The righ figure shows the density plots of the two variables.

C Model Derivations

Consumers problem. The consumers problem is standard and I outline the main steps in this section. The utility function is given by $U_{it} = u_{it} C M_{it}^{\mu} H_i^{1-\mu}$ where M_{it} is a consumption good in region i at time t that is traded, H_i is land in region i which is not traded and time invariant, $C = (\mu(1-\mu))^{-1}$, $u_{it} = \bar{u}_{it} L_{it}^{\beta_1} L_{it-1}^{\beta_2}$. M_{it} is a composite of goods produced in other regions such that,

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

This setup gives rise to the following aggregate demand functions for consumption and land,

$$M_{it} = \frac{\mu w_{it}}{P_i}, \tag{A.2}$$

$$H_i = \frac{(1-\mu)\, w_{it}}{r_{it}}, \tag{A.3}$$

where $P_i = \left(\sum_{j \in R} p_{jit}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ is the price index and r is the price of land. To find the compensated demand function for each variety the household solves the following problem,

$$\max_{\{q_{ijt}\}_{j=R}^{R}} \sum_{j \in R} \left(q_{ijt}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \text{ s.t. } \sum_{j \in R} q_{ijt} p_{ijt} \leq w_{it}, \tag{A.4}$$

which gives the following compensated demand function $q_{ijt} = \frac{w_{it}}{P_{it}}\left(\frac{p_{it}}{P_{it}}\right)^{-\sigma}$. Using the aggregate demand functions gives the indirect utility function presented in the paper,

$$V = \frac{u_{it} w_{it}}{P_{it}^{\mu} r_{it}^{1-\mu}}. \tag{A.5}$$

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 $X_{jt} = w_{jt} L_{jt}$. Using the assumption that there is perfect competition in the market for labor within each region gives the gravity equation for trade,

$$X_{ijt} = \tau_{ijt}^{1-\sigma}\left(\frac{w_{it}}{A_{it}}\right)^{1-\sigma} P_{jt}^{\sigma-1} w_{jt} L_{jt}. \tag{A.6}$$

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

$$V_{ijt} = \frac{V_{jt}}{\mu_{ij}} \epsilon_j, \tag{A.7}$$

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

$$Pr\left(V_{ijt} \geq \{V_{ikt}\}_{\forall k \in R}\right) = \tag{A.8}$$

$$\int_{\mathbb{R}} Pr\left(u \geq \max_{k \in R}\{u_{ik}\}\right) dG(u) = \tag{A.9}$$

$$\int_{\mathbb{R}} \prod_{n=1}^{R} \exp\left\{-\left(\frac{V_{ik}}{\mu_{ik}}\right)^{\theta}\right\} dG(u) = \tag{A.10}$$

$$\frac{\left(V_{ij}/\mu_{ij}\right)^{\theta}}{\left(\sum_{j \in R} V_{ij}/\mu_{ij}\right)^{\theta}}, \tag{A.11}$$

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

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

$$\prod_{n=k}^{R} Pr\left(V_{ik} \leq v\right) = \tag{A.13}$$

$$\exp\left\{-v^{-\theta}\Phi\right\}, \tag{A.14}$$

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

$$\Gamma\left(1-\frac{1}{\theta}\right)\Phi^{\frac{1}{\theta}}, \tag{A.15}$$

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

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

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

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

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

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

Next, using that $P_{jt} = \frac{u_{jt}w_{jt}}{V_{jt}}$ and $u_{jt} = \bar{u}_{jt}L_{jt}^{\beta_1}L_{jt-1}^{\beta_2}$ gives,

$$w_{it}^{\sigma}L_{it}^{1-\alpha_1(\sigma-1)} = \sum_{i\in\Omega} K_{ijt}L_{jt}^{\alpha_1(\sigma-1)}V_{jt}^{1-\sigma}w_{jt}^{1-\sigma}. \tag{A.19}$$

The second condition ensures that all income in location i is spent on imports to location i in each period which is guaranteed by $w_{it}L_{it} = \sum_{j\in R} X_{jit}$. Again using the gravity equation for trade gives the following expression,

$$w_{it}L_{it} = \sum_{j\in R} \tau_{jit}^{1-\sigma}\left(\frac{w_{jt}}{A_{jt}}\right)^{1-\sigma} P_{it}^{\sigma-1} w_{it}L_{it}. \tag{A.20}$$

Again, using that $P_{it} = \frac{u_{it} w_{it}}{V_{it}}$,

$$w_{it}^{\sigma-1} = \sum_{j \in R} \tau_{jit}^{1-\sigma} \left(\frac{w_{jt}}{A_{jt}} \right)^{1-\sigma} u_{it}^{\sigma-1} V_{it}^{1-\sigma}. \tag{A.21}$$

Then using $u_{it} = \bar{u}_{jt} L_{it}^{\beta_1} L_{it-1}^{\beta_2}$ and $A_{jt} = \bar{A}_{jt} L_{jt}^{\alpha_1} L_{jt-1}^{\alpha_2}$ and rearranging gives the final expression,

$$w_{it}^{1-\sigma} L_{it}^{\beta_1(1-\sigma)} V_{it}^{\sigma-1} = \sum_{i \in R} K_{jit} L_{jt}^{\alpha_1(\sigma-1)} w_{jt}^{1-\sigma}. \tag{A.22}$$

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.

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

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,

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

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 $p_{it}^{\sigma-1} = w_{it} / \bar{A}_{it} L_{it}^{\beta_1} L_{it-1}^{\beta_2}$ and then taking the first difference gives,

$$\Delta ln(p_{it}^{\sigma-1}) = (\sigma - 1)\Delta ln(\tilde{w}_i) + \alpha_1(1-\sigma)\Delta ln(L_{it}) + \alpha_2(1-\sigma)\Delta ln(L_{it-1}) + \Delta\epsilon_{it}. \tag{A.25}$$

Using $V_{it} = u_{it} w_{it} / \left(P_{it}^{\mu} r_{it}^{1-\mu} \right)$, $u_{it} = \bar{u} L_{it}^{\beta_1} L_{it-1}^{\beta_2}$, and $r_{it} = (1-\mu)\, w_{it} / H_i$ gives,

$$\begin{aligned} \Delta ln(V_{it}^{\theta}) = \alpha + (\theta - 1)\Delta ln(\tilde{w}_{it}) + \frac{\theta}{\sigma - 1} \mu \Delta ln(P_{it}^{1-\sigma}) + \beta_1 \theta \Delta ln(L_{it}) + \beta_2 \theta \Delta ln(L_{it-1}) + \\ \theta \Delta \bar{u}_{it}. \end{aligned} \tag{A.26}$$

Estimating equations. .....

References

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Mann, Michael. 1986. *The Sources of Social Power: Volume 1, A History of Power from the Beginning to AD 1760*. Cambridge University Press.