Three Essays in Long-term Economic Persistence

Felipe Valencia Caicedo

TESI DOCTORAL UPF / ANY 2015

DIRECTOR DE LA TESI
Hans-Joachim Voth
Departament d'Economia i Empresa

Universitat Pompeu Fabra Barcelona

A mi Sagrada Familia

Acknowledgments

First and foremost I want to thank my supervisor Hans-Joachim Voth, for his guidance and support at UPF and beyond. I also want to thank Oded Galor (Brown) for his advice and continued support throughout the years. My gratitude as well with Marta Reynal-Querol for her constant encouragement and Guy Michaels (LSE) for his detailed and insightful feedback. This thesis owes a lot to my former boss and longtime coauthor William Maloney (World Bank).

Many people have contributed to this thesis in one way or another, while at UPF, during my visit to the the LSE, and at various seminars and conferences in Barcelona, London and around the globe. Mauricio Drelichman (UBC), Luigi Pascali (Warwick) and Giacomo Ponzetto (CREI), were particularly important during the early stages of this project. Nicola Gennaioli (Bocconi), Paola Giuliano (UCLA), Giacomo Ponzetto (CREI), Shanker Satyanath (NYU) and Andrei Shleifer (Harvard) were very instrumental during the job market process. Alexandre Coello de La Rosa introduced me to the intricacies of the Jesuit world. Pablo Astorga (IBEI) kept the Latin American economics conversations flowing and Omar Licandro (UAB) helped implement them.

I thank Antonio Ciccone, Ruben Enikolopov, Christian Fons-Rosen, Albrecht Glitz, Gianmarco León, Stephan Litschig, Alessandro Tarozzi, Ana Tur Prats and Yanos Zylberberg at UPF. I also thank Tim Besley, Jeremiah Dittmar, María Alejandra Irigoín, Ignacio Palacios-Huerta, Steve Pischke, Daniel Sturm and Borge Wietzke at the LSE. Alex Eble, Eduardo Engel, Ömer Özak, Jacopo Ponticelli, Pablo Querubin and Ferdinand Rauch contributed with helpful comments. I have also benefited from conversations and feedback from Daron Acemoglu, Quamrul Ashraf, Ernesto Dal Bó, Pedro dal Bó, Carl-Johan Dalgaard, Melissa Dell, Quoc-Ahn Do, James Fenske, Leopoldo Fergusson, Claudio Ferraz, Lakshmi Iyer, Stelios Michalopoulos, Omer Moav, Gerard Padró i Miguel, James Robinson, Andrés Rosas, Martín Rossi, Rodrigo Soares, Enrico Spolaore, Andrei Shleifer, Juan F. Vargas, Nico Voigtländer, Romain Wacziarg, Leonard Wantchekon, Fabian Waldinger, David Weil, Noam Yuchtman and Fabrizio Zilibotti. The usual disclaimer applies.

I am grateful to UPF and the Catalan Government (FI-DGR) for financial support. Marta Araque, Laura Agustí and Mariona Novoa, *gracias por todo y por tanto*, in helping simplify the intractable Spanish bureaucracy and navigating the job market.

I strived to keep up the 20.152 tradition. Marian Meller, who first welcomed me. Then Andrea Tesei and Hannes Schwandt, Jacopo Ponticelli, along with the visiting Andreas Petrella and Linarello. Now Jagdish Tripathi, passing the torch to the new generations in a globalized office. Alex Eble and Humberto Laudares, thank you for your true friendship, the profession needs more people like you. Mapi thank you for welcoming me to Barcelona. Michael, because the best are no longer with us, *in memoriam*. Daniel Osorio, thank you for your hospitality in London. Brian, Elvia, Pily, Miguel and Zelda made London fun. Bruno and Ciccio, model colleagues and friends. Alain, Andrea, Fer, Fran, Gene, Gio, Jörg, Miguel, Philipp, Tanya, Tom and Vicky, good bye and good luck. Dijana, Emma, Fernando, Hrvoje, Jagdish, Miguel, Oriol, Tomas and Thomas, godspeed.

Last, but certainly not least, this thesis is dedicated to my family and my *seres queridos*, who faced all the tradeoffs. MC this includes you, I am sorry.

Summary

This dissertation investigates economic persistence in the Americas. The first chapter shows the positive long-term economic impact of the Guarani Jesuit Missions in South America. I find that municipalities in Argentina, Paraguay and Brazil with former missionary presence have higher educational and income levels today. Such enduring differences are consistent with cultural transmission mechanisms. The second chapter establishes the within country persistence of economic activity in the New World over the last half millennium. In particular, we show that high pre-colonial density areas tend to be denser today. Furthermore, we document that these historically prosperous areas also tend to have higher incomes today, largely due to agglomeration effects. The third and final chapter argues that differences in innovative capacity, captured by the density of engineers at the dawn of the Second Industrial Revolution, are important to explaining present income differences between Latin and North America, and within the United States.

Resumen

Esta disertación trata sobre persistencia económica en las Américas. El primer capítulo muestra el impacto positivo a largo plazo de las Misiones Jesuitas Guaraníes en Suramérica. Encuentra que las municipalidades en Argentina, Paraguay y Brasil que tuvieron presencia misionera tienen hoy mayores niveles de educación e ingreso. Estas diferencias son consistentes con mecanismos de transmisión cultural. El segundo capítulo establece la persistencia de la actividad económica en el Nuevo Mundo durante los últimos 500 años. Específicamente, demuestra que las áreas con mayor densidad de población pre-colonial son más densamente pobladas ahora. Además muestra que estas áreas históricamente prósperas también tienen mayores ingresos hoy, debido a efectos de aglomeración. El tercer y último capítulo argumenta que las diferencias en capacidad de innovación, medidas utilizando la densidad de ingenieros durante la Segunda Revolución Industrial, son importantes para explicar las diferencias de ingreso entre Latinoamérica y Norteamérica, así como dentro de los Estados Unidos.

Preface

This thesis takes the quest for the deep rooted factors of comparative economic development seriously. The literature on economic persistence or historical development has flourished and become more established in the recent years. The types of questions addressed in this thesis reflect these advances in the overlapping fields of development economics, economic history and economic growth. Though I provide formal summaries of the three articles that constitute this thesis next, this preface places them in broader academic, intellectual and even personal contexts.

The first basic question is whether fortune persists or not in the long run. In the second chapter of this dissertation, with William Maloney we answer this question affirmatively focusing on the Americas at the subnational level. We find that areas that were denser before the arrival of Europeans to the continent are both denser and richer today. This finding is somewhat surprising given the cross-country evidence of a 'Reversal of Fortunes' globally. This article is now forthcoming in the *Economic Journal*.

An obvious follow up question is why is Mexico City (the old Tenochtitlan) poorer today than sparser areas historically such as Connecticut and Massachusetts. The third chapter of this thesis, looks at human capital and technology as the main channels of national and regional development. In particular, we focus on historical investments in advanced human capital, proxied by the stock of engineers at the dawn of the Second Industrial Revolution. We show that places that invested early and heavily in engineering training do better today economically.

The first chapter of this thesis (and my job market paper) combines my research interests on indigenous settlements and historical human capital interventions. In a more micro set up, I examine the case of the Guarani Jesuit Missions in South America. I show that these missions had a positive long-term impact in terms of human capital attainment (of approximately 15 %) and income (of 10 %). To explain these sustained differences I focus on specific cultural mechanisms such as occupational persistence, inter-generational knowledge transmission and indigenous assimilation.

The questions above emerged in conversations with William Maloney when I worked as a Consultant at the World Bank in Washington, DC. These conversations about economic development have now spanned three continents and (hopefully) matured during my graduate training in the US and Europe. For that I am deeply grateful to the advisors, professors and friends mentioned in the acknowledgments.

The focus on persistence also resonates at a personal level. The colloquial *la constancia vence lo que la dicha no alcanza* or its latinized *labore et constantia* have been my motto while at Brown, Yale, UPF and the LSE, and I hope will accompany me as I embark in a new academic and professional adventure at Bonn University.

Abstracts

The Mission: **Human Capital Transmission, Economic Persistence and Culture in South America (Job Market Paper)**

This article examines the long-term consequences of a historical human capital intervention. The Jesuit order founded religious missions amongst the Guarani, in modern-day Argentina, Brazil, and Paraguay. Missionaries instructed indigenous inhabitants in reading, writing and various crafts, before their expulsion in 1767. Using archival records and municipal census data, I demonstrate that educational attainment was and remains higher after 250 years (by about 15 %) in areas of former Jesuit presence. These differences also translate into 10 % higher incomes. The effect of Jesuit missions emerges clearly after comparing them with abandoned Jesuit missions, Franciscan Guarani Missions and using Instrumental Variables strategies. In addition, I collect survey data and conduct behavioral experiments, finding that respondents in missionary areas exhibit higher non-cognitive abilities and collaborative behavior. Such enduring differences are consistent with transmission mechanisms of occupational persistence, intergenerational knowledge transmission and indigenous assimilation. Robustness checks suggest that the results are not driven by migration, urbanization and tourism.

The Persistence of (Subnational) Fortune with William Maloney (Forthcoming: *Economic Journal*)

Using newly collected subnational data, this paper establishes the within country persistence of economic activity in the New World over the last half millennium, a period including the trauma of European colonization, the decimation of native populations, and the imposition of potentially growth inhibiting institutions. High pre-colonial density areas tend to be denser today due to locational fundamentals and agglomeration effects: colonialists established settlements near existing native populations for reasons of labour, trade, knowledge and defence. These areas, identified with pre-colonial prosperity, also tend to have higher incomes today suggesting that at the subnational level, fortune persists.

Engineers, Innovative Capacity and Development in the Americas with William Maloney

Using newly collected national, sub-national and county level data, and historical case studies, this paper argues that differences in innovative capacity, captured by the density of engineers and patents at the dawn of the Second Industrial Revolution, are important to explaining present income differences, and, in particular, the poor performance of Latin America relative to North America. This remains the case after controlling for literacy, other higher order human capital, such as lawyers and physicians, as well as demand side elements that might be confounded with engineering. The analysis then finds that agglomeration, certain geographical fundamentals, and extractive institutions such as slavery affect innovative capacity. However, a large effect associated with being a Spanish colony remains suggesting important inherited factors, particularly through scientific and entrepreneurial traditions.

Contents

Chapter 1

THE MISSION: HUMAN CAPITAL TRANSMISSION, ECONOMIC PERSISTENCE AND CULTURE IN SOUTH AMERICA (JMP)

> "When in 1768 the missions of Paraguay left the hands of the Jesuits, they had arrived at perhaps the *highest degree of civilization* to which it is possible to conduct a young people." "The Jesuits have civilized the [natives], have taught them to be *industrious*, and have succeeded in governing a vast country (...) [making] a virtue of subduing savages by mildness and *instruction*."
>
> Voltaire, 1756 and 1770.[1]

1 Introduction and Motivation

The importance of history in economic development is well-established; historical shocks and "critical junctures" have been shown to influence modern outcomes through geography and natural endowments, legal origins and institutions, genetics, human capital and culture.[2] Although historical persistence of outcomes appears to be strong in many cases, the channels of transmission are less clear. Focusing on extractive institutions, Dell (2010) stresses the negative effect of the *mita* labor system in Latin America, and Nunn and Wantchekon (2011) document the adverse effect of African slavery through decreased trust. Less is known, however, about how other colonial arrangements might have led to *positive* outcomes in the long run. While Europeans often imposed extractive institutions and created exploitative economic relationships (Acemoglu et al. 2001), they also transferred human capital, cultural values and technological know-how (Glaeser et al., 2004), which may have led to beneficial effects in the long run.

In this paper, I demonstrate the important benefits of European missionary activity in South America. Jesuit missionaries travelled to what were essentially the backwaters of the Spanish and Portuguese empires, before being expelled from the continent in 1767. While religious conversion was the official aim of the missions, they also increased human capital formation as a result of schooling children and training adults in various crafts.[3] I focus on the repercussions of the

[1] *Histoire Philosophique et Politique des Indes* (1770) and *Essay on the Customs and the Spirit of the Nations* (1756). In Graham (1901), p. 52. Emphasis added.

[2] The literature on historical persistence has been recently summarized in Nunn (2009 and 2013), and Spolaore and Wacziarg (2013). Seminal papers on these determinants include Diamond (1997), Engerman and Sokoloff (1997), Gallup et al. (1999), La Porta et al. (1998), Acemoglu et al. (2001 and 2002), Ashraf and Galor (2013), Glaeser et al. (2004) and Landes (1998).

[3] Compared to McCleary and Barro (2003 and 2006), I focus less on the direct effects of religion and more on its human capital externalities (Glaeser and Sacerdote, 2008; Becker and Woessmann, 2008 and 2009).

Guarani Jesuit Missions in modern-day Argentina, Brazil and Paraguay. In municipalities where the Jesuits carried out their apostolic efforts, median years of schooling and literacy levels remain markedly higher after almost 250 years. These differences in educational attainment of 10-15% have also translated into higher modern per capita incomes of nearly 10%. To explain such enduring differences, I analyze cultural outcomes and persistence mechanisms. I conduct a household survey and perform lab-in-the-field experiments with indigenous inhabitants in Paraguay to better understand the mechanisms at play. I find that respondents in missionary areas have higher non-cognitive abilities and exhibit more pro-social behavior. I also find that people closer to missionary areas specialize in relatively more skilled labor, moving away from agriculture and towards manufacturing and services.[4]

The literature on persistence and the after-effects of colonialism raises several important questions. First, identification is often challenging because the factors that led to differential treatment are often geographic in nature and can be argued to have independent effects on modern-day outcomes.[5] Other studies simply assume that variation in long-ago samples is plausibly random (Guiso et al. 2008; Voigtländer and Voth 2012). Second, historical shocks are often confounded with national institutional trajectories that have been shown to have a long-lasting effect. Meanwhile, a large literature has stressed the importance of human capital for modern economic growth at the macro level and personal income at the micro level.[6] Yet questions remain about the persistence and transmission mechanisms of human capital shocks, especially during historical times (Waldinger, 2012). Can a one-off human capital intervention have long-lasting effects?

The Jesuit conversion (and education) of the Guarani allows for clean identification of the causal effects of religious missionaries. I exploit the fact that Jesuits were expelled from the Americas in 1767, following political disputes in Europe. This event precludes any direct continuation effect as a result of enduring treatment. The political rupture between the Jesuit order and the Spanish

[4]As has been argued with respect to the Jewish population by Botticini and Eckstein (2005, 2007 and 2012).

[5]The direct effect of geographic factors has been stressed by, among others, Gallup et al. (1999), Rappaport and Sachs (2003), and more recently by Nunn and Puga (2012).

[6]Mankiw et al. (1992), Benhabib and Spiegel (1994), Barro (2001), Glaeser et al. (2004), Heckman (2000), and Hanushek and Woessmann (2008).

Crown was arguably exogenous to the location of proselytizing activities amongst the Guarani. Therefore, before-and-after identification provides an ideal setting for examining the persistence of income, human capital and culture.[7] The early stage of development of the indigenous inhabitants makes the setting unique. To disentangle the national institutional effects from the human capital shock, I focus on fine-grained within country variation in missionary activity in three different countries.[8] The area under study was populated by a single semi-nomadic indigenous tribe, so I can abstract from the direct effects of pre-colonial ethnic tribes (Maloney and Valencia Caicedo, 2012; Michalopoulos and Papaioannou, 2013). The Guarani area has broadly similar geographic and weather characteristics, nonetheless, I control for a host of variables in the estimation. Crucially, I compare outcomes in areas where the Jesuits were active before 1767 with those where they *attempted* to establish missions early on. I also conduct a direct comparison with neighboring Franciscan Guarani Missions, which did not stress education in their conversion.

The virtues and vices of the Jesuit Catholic missions were hotly debated by prominent contemporaries and have been a major topic of study for historians ever since. The Guarani Missions constituted a large social experiment, and at their peak in 1730 involved more than 120,000 indigenous people (see Figure A.1). According to Voltaire (1756), who was a fierce critic of the Church, missions had a positive effect in terms of industriousness and education.[9] Missions were seen as a New World Utopia that stood in stark contrast to European corruption and decay.[10] Even though volumes have been written about the history of the Jesuit Missions of South America, little is known about the long-term economic consequences of these religious institutions. This study aims to address this gap in the literature.

[7] The effect of Protestant missions has also been analyzed by Nunn (2010 and forthcoming) for the African case.

[8] To do so, I employ country and state-fixed effects.

[9] Indeed, Voltaire sent Candide to visit and aid the Jesuits of Paraguay, a praise also shared by Montaigne and Montesquieu.

[10] Other contemporaries and historians such as Palafox (1600-1659) and Popescu (1967) –and even the current Pope– have been more critical of the so-called "Jesuit Republic of Paraguay". Pope Francis, the first Jesuit Pope of the Catholic Church, declared on his official visit to Paraguay: "The truth is that what [the Jesuits] left, with the reductions [missions], are many ruins." Quoted in *La Nación* newspaper, Argentina on November 25, 2013 [author's translation].

To assess the impact of the Guarani Jesuit Missions I assemble a novel data set that combines archival information about the missions with modern outcomes at the municipal level. The geo-coded data set covers the municipalities in the states of Misiones and Corrientes in Argentina, Rio Grande do Sul in Brazil, and Misiones and Itapua in Paraguay (Figures 1 and 2). With this setup I can also study the outcomes of interest in places with different national histories and institutions. In addition to using modern-day and archival data, I collect household survey data from a stratified sample in Southern Paraguay. Combining cultural questions with experiments from the psychology literature, I investigate non-cognitive skills and attitudes in areas with and without a former Jesuit missionary presence (Figure 3).

In order to quantify the Jesuit missionary treatment I use as main variable distance to the nearest mission.[11] I then estimate an econometric model of modern outcomes –such as education and income– based on this measure of missionary presence. I find a positive effect on educational attainment of 15% (.8 median years of schooling) and income of 10%. The human capital effects are greater during historical periods and both effects appear larger at the local level. Nonetheless, the location of the Jesuit Missions can be still be endogenous. Even though I use fixed effects and control for a large set of relevant geographic and weather characteristics, Jesuit missionaries might have chosen favorable locations beyond such observable factors. Hence the positive effects observed might be due to this initial choice and not to the missionary treatment *per se*.[12]

To address the potential endogeneity of missionary placement, I conduct two empirical tests. The first one is a placebo test that looks at missions that were initially founded by the Jesuits but were abandoned early on (before 1659). I can thereby compare places that were initially picked by the Jesuit missionaries with those that actually received the missionary treatment.[13] I find no effect for the missions that were abandoned by the Jesuits early on, which suggests that what mattered in the long run it is what they did and not where they first settled. Second, I conduct a comparison with the neighboring Guarani Franciscan Missions. The comparison is relevant in

[11] Alternatively, I use a dummy variable for whether or not the municipality had a mission.

[12] I quantify this possibility by calculating Altonji ratios (Altonji et al. 2005), which suggest that selection on unobservables would have to be more than 4 times larger than selection on observables to drive the results.

[13] In the spirit of Michaels (2008) and Greenstone et al. (2010).

that both orders wanted to convert souls to Christianity, but Jesuits emphasized education and technical training in their conversion. Contrary to the Jesuit case, I find no positive long-term effect –on either income or education– for Franciscan Guarani Missions.

I also employ an instrumental variables (IV) strategy, where I use as instruments the distance from early exploration routes and distance to Asuncion. The distance from the exploration routes of Mendoza (1535-1537) and Cabeza de Vaca (1541-1542) serves as a proxy for the isolation of the Jesuit missions (in the spirit of Duranton et al. 2014). Asuncion, in turn, served as a base of missionary exploration during the foundational period, but became less relevant for Rio Grande do Sul after the 1750 Treaty of Madrid transferred this territory to Portuguese hands.[14] For this reason and to avoid the direct capital (and Spanish Empire) effects, I use this variable only for the Brazilian subsample of my data. The first-stage results are strongly significant throughout (with F-statistics well above 10), and the coefficients for literacy and income retain their sign and significance –appearing slightly larger– in the IV specifications.

To complete the empirical analysis, I examine cultural outcomes and specific transmission mechanisms that can sustain human capital transmission from the missionary period to today. I find that respondents in missionary areas possess superior non-cognitive abilities, as proxied by higher "Locus of Control" scores.[15] Using well-known experiments from the behavioral literature, I also find that respondents in missionary areas exhibit greater altruism, more positive reciprocity, less risk seeking and more honest behavior. I use priming techniques to further investigate whether these effects are the result of greater religiosity –which appears *not* to be the case.

More generally, I find that municipalities closer to historic missions have changed the sectoral composition of employment, moving away from agriculture and towards manufacturing and services.[16]

[14] This identification strategy is similar to the one employed recently by Becker and Woessmann (2009) using distance to Wittenberg and Dittmar (2011) with distance to Mainz.

[15] This psychological test categorizes a respondent's attitude on a scale that ranges from purely external or low locus of control ("destiny is predetermined") to the exact opposite ("I alone control my own destiny"). For the economic relevance of these measures, see Heckmand and Rubenstein (2001) and Heckman et al. (2006).

[16] Again, this result is consistent with Botticini and Eckstein's (2005, 2007 and 2012) findings for the Jewish population.

In particular, I document that these places still produce more handicrafts such as embroidery, a skill introduced by the Jesuits. People closer to former Jesuit missions also seem to participate more in the labor force and work more hours, consistent with Weber (1978 and 2011). I also find that knowledge –of traditional medicine and myths– was transmitted more from generation to generation in the missionary areas. Unsurprisingly, given their acquired skills, I find that indigenous inhabitants from missionary areas became differentially more assimilated into colonial and modern societies. Additional robustness tests suggest that the missionary results are not driven by migration, urbanization or tourism.

The rest of this paper is organized as follows. Section 2 provides the context in terms of the relevant literature, historical background and geographical setting. Section 3 describes the data and presents the empirical strategy. Section 4 contains the main results on education, income and culture. Section 5 provides empirical extensions and alternative estimations. Section 6 discusses transmission mechanisms and robustness checks. Section 7 concludes.[17]

2 Context

2.1 Related Literature

This article builds on the literature dealing with historical development, which has been recently summarized by Nunn (2009 and 2013), and Spolaore and Wacziarg (2013). The literature has moved away from cross-country studies and towards analyses within countries or using data at the sub-national level (Banerjee and Iyer 2005; Nunn 2008; Bleakley and Lin 2012; Bruhn and Gallego 2012; Naritomi et al. 2012; Dell 2012; Gennaioli et al. 2013; Jha 2013; Michalopoulos and Papaioannou 2013). This piece relates more specifically to the literature on the long-term impact of colonialism and colonial investments (Feyrer and Sacerdote, 2009; Huillery, 2009; Dell 2010; Bruhn and Gallego 2012; Becker et al. 2014; Grosfeld and Zhuravskaya 2014; Jedwab et al. 2014). I contribute to this literature with an exploration of the empirical mechanisms behind economic

[17] The Appendix contains a data section and additional results.

persistence, and the positive long-term effect of a specific colonial institution: religious missions.

Of particular relevance to the current work are studies that emphasize the role of human capital for long-term economic development. Seminal pieces by Benhabib and Spiegel (1994), Mankiw et al. (1992), Barro (2001) and Glaeser et al. (2004) stress the importance of human capital accumulation for growth. Micro evidence from Heckman (2000), and Hanushek and Woessmann (2008) points in the same direction for personal income. Questions remain, however, about the the degree of persistence and channels of transmission of human capital shocks (Waldinger, 2012).

Cultural explanations of economic performance date back to Max Weber's Protestant work ethic hypothesis (Weber, 2011). The importance of cultural norms for economic activity has been restressed by Greif (1993 and 1994) and Putnam et al. (1994). Both the positive (Guiso et al. 2008, Tabellini 2008) and negative (Grosjean 2010; Acemoglu et al., 2011; Voigtländer and Voth 2012; Grosfeld et al. 2013) long-term effects of culture have been documented in the literature. Such historical studies avoid the issue of reverse causality, but cannot disentangle the continuation effect of the phenomena analyzed, be it social capital or anti-Semitism. To avoid this problem I exploit the fact that Jesuits were expelled from the Americas in 1767, due to exogenous reasons. An outstanding empirical question is whether cultural traits are transmitted horizontally or vertically, as in the theoretical models of culture of Cavalli-Sforza and Feldman (1981), Boyd and Richerson (1985), and Bisin and Verdier (2000 and 2001).

Religion is a fundamental aspect of culture. Classic papers on this topic include Iannaccone (1990), and McCleary and Barro (2003 and 2006), and modern re-interpretations include Becker and Woessmann (2008 and 2009), Botticini and Eckstein (2005, 2007 and 2012), Campante and Yanagizawa-Drott (2013), and Cantoni (forthcoming). An emerging literature has explored the long-term effects of nineteenth-century Christian missions in Africa. At the country level, Woodberry (2004 and 2012), and Lankina and Getachew (2012) find a positive effect of Protestant missions on democracy.[18] At the sub-national level, Nunn (2010) finds that missions resulted in

[18] For a more critical view, see Frankema (2012).

higher levels of religiosity, Gallego and Woodberry (2010) and Nunn (forthcoming) find a positive effect on educational attainment, and Cagé and Rueda (2013) on political participation. Acemoglu et al. (2014) use Protestant missions as instruments for education to argue that institutions had a significant impact on long-run development. Within countries, Wantchekon et al. (2013) find positive human capital externalities from religious schools in Benin, and Okoye and Pongou (2014) on school provision in Nigeria.[19] Outside Africa, Mantovanelli (2013) reports a positive effect of Protestant missions on Indian literacy and Ying Bai and Kung (2011), and Chen et al. (2013) on Chinese economic performance.

I contribute to the emerging missionary literature in several ways. By focusing on Africa and excluding Latin America from the analysis the existing papers have essentially neglected an area with one of the most intense missionary presences.[20] I also go further back in time –from the nineteenth to the seventeenth century– and focus on Catholic as opposed to Christian missions.[21] Perhaps more importantly, I address directly the endogeneity of missionary location with a placebo tests and an instrumental variables strategy. I also exploit the 1767 expulsion of the Jesuits, which precludes a direct continuation effect. Finally, I identify novel cultural mechanisms through which missions may have had a persistent effect on income and education.

This paper also contributes to the literature on the historical determinants of schooling. Gallego (2010) argues for the importance of democracy and political decentralization. Rocha et al. (2013), look at the role of European settlement communities in the state of São Paulo, Brazil. Complementary evidence is presented by Summerhill (2010), and de Carvalho Filho and Colistete (2010 and 2011), who also examine the role of slavery and historical inequality in Brazil. Musacchio et al. (2014) look instead at the interaction between political decentralization and commodity booms during the nineteenth century. Though I also focus on the historical determinants of schooling at the sub-national level, I go further back in time, stressing a different determinant and specifying

[19] For similar within-country evidence, see Wietzke (2014) for education in Madagascar and Meier zu Selhausen (2014) for female empowerment in Uganda.

[20] For a notable exception in the case of Mexico, see Waldinger (2013).

[21] See, for instance, McCleary and Pesina (2011) for the case of Guatemalan Christian missions during the early twentieth century.

potential channels of transmission in Argentina, Paraguay and the Brazilian state of Rio Grande do Sul.

Lastly, this paper relates to the literature on technological transfer in a historical setting. Spolaore and Wacziarg (2009), Comin et al. (2010) and Maloney and Valencia Caicedo (2014) demonstrate the very long-term effects of technological shocks. Dittmar (2011) argues that the introduction of the printing press had a positive impact on urban growth in Europe between 1500 and 1600; Hornung (2014) finds a positive effect for the Huguenot diaspora in Prussia; and Squicciarini and Voigtländer (2014) relate industrialization to *Encyclopédie* subscriptions in France. In this paper, I document the differential usage of technologies (e.g., embroidery and accounting) introduced by Jesuit missionaries.

The historiography of the Guarani Jesuit missions is vast and I present only a brief summary here. Primary sources include the *Cartas Anuas* (annual letters) written by such Jesuits Fathers as Ruíz de Montoya, Cardiel and Charlevoix on the state of affairs of the missions. Hernández (1913), Furlong (1955), and more recently Palacios and Zoffoli (1991) and Carbonell de Massy (1992), provide detailed accounts of the history of the Guarani Jesuit Missions. Ganson (2003) and Wilde (2009) offer a revisionist interpretation constructed around Guarani ethno-history. Demographers Maeder (1995), Livi-Bacci and Maeder (2004), and Jackson (2008) find that, despite wars and epidemics, Jesuit Missions had a positive impact on the Guarani population. Alden (1996) gives a comprehensive history of the Society of Jesus in Portugal and the Portuguese Empire, and Sarreal (2014) focuses on the history of Jesuit territories during the eighteenth century. Even so, there is a lack of empirical studies in economics that scrutinize the Guarani Jesuit missions in South America.

2.2 Historical Background

The history of the Jesuits spans volumes, so I provide just a sketch here. The Society of Jesus was founded during the European Counter-Reformation in 1534 at the University of Paris by the

Basque knight St. Ignatius of Loyola *ad maiorem Dei gloriam* [for the greater glory of God]. From the outset it stressed human capital and Papal obedience (Figure 4). It is a relatively new Catholic order when compared to the Order of Saint Benedict (founded in 529), as well as the Franciscan, Dominican and Carmelite Orders (all founded in the 1200s). The Jesuits were then the last major Catholic order to arrive in the Americas through the Spanish and Portuguese empires. Religion was –along with profit making and a desire for adventure– one of the main reasons for embarking to the New World.

The first Jesuits arrived in South America at Salvador de Bahia, modern-day Brazil, in 1549 (Bethell 1984, chapter 14). The Jesuits followed a two-pronged strategy: educating the elites in the major colonial capitals (Mexico City, Lima, Bogota and Quito) while developing indigenous missions in some of the most isolated areas of the Spanish and Portuguese empires (Bethell 1984, chapter 15). The first Jesuit mission in South America was established in Juli in 1565 in modern-day Puno, at the border of Bolivia and Peru. The Jesuits also started missions in Mainas (Peru), Moxos and Chiquitos (Bolivia), Casanare and Orinoco (Colombia and Venezuela), Baja California (Mexico), and California (United States).[22] Outside the Americas, the Jesuits established missions in China, India and Japan in the sixteenth and seventeenth centuries.[23]

Without a doubt, the Guarani missions in modern-day Argentina, Brazil and Paraguay constitute the heart of the Jesuit missionary efforts. The Jesuits arrived in Asuncion, Paraguay, on August 11, 1588.[24] From Asuncion, they explored the surrounding area and established the first Guarani Jesuit Mission in 1609. The Jesuits were not the first to establish religious missions in the Guarani area; the Franciscans established their first Guarani mission in 1580 (Duran Estragó, 1987).[25] The Jesuit foundation was followed by a period of exploration that lasted for fifty years, until 1659 (Figure 4).[26] The Jesuits founded a total of 30 missions or *reducciones* (reductions) in the modern-day territories of Argentina, Brazil and Paraguay (Figure 1 and Table A.1). At their peak,

[22] For an account of the California missions, see Bolton (1917).

[23] Though I focus on the Guarani area, in principle the geographical dispersion of the Jesuit missions makes it possible to test the external validity of my results.

[24] Distance to Asuncion will be analyzed in the Instrumental Variables Section.

[25] The role of the Franciscan Missions will be analyzed empirically.

[26] Missions that were founded but abandoned early by the Jesuits will be studied in the Placebo Section.

the Guarani Jesuit Missions involved more than 100,000 inhabitants (Figure A.1), four times the population of Buenos Aires in 1779.[27] Guarani Jesuit Missions constituted one of "the most original experiments of the spiritual conquest of the New World" (Roa Bastos, in Saguier, 1991, p. 9).

The Jesuit order's focus on human capital cannot be overemphasized. Furlong and Storni (1994) stress the Jesuit contributions to advanced human capital in terms of cartography, ethnography, linguistics, botany, mathematics and medicine, among others. Jesuits were at the technological frontier of the time, and their cultural contributions to both music and the arts are well renowned. They introduced the printing press to Argentina, Brazil and Paraguay, and they even established an astronomical observatory in San Cosme and Damián (Paraguay).[28] It is worth noting that the printing press was not formally introduced into Brazil until the Portuguese court arrival in 1807 (Landes, 1998, p. 134). Jose de San Martín, who would go on to lead the independence movement of the Southern Cone, was born at the Jesuit mission of Yapeyú, in Corrientes, Argentina.

Even though the official aim of the missions was to convert souls to Christianity, the Jesuits taught children (boys *and* girls) how to read and write and carry out basic arithmetic. They also trained adults in masonry, wood carving and embroidery (Gálvez, 1995). This emphasis on education can be seen in Figure A.2, which reproduces a historical blueprint of the emblematic Guarani mission of San Ignacio de Miní, Argentina. Right next to the main square and the church, can be seen the school (*colegio*) for children along with the workshop (*taller*) for adults. For the Guaranis, the missions provided not only educational opportunities but also security and protection. The communities were self-sustaining and thrived raising cattle and producing *yerba mate* (Paraguayan tea).

The expulsion of the Jesuits represents a major event in the history of colonial Latin America. After intense political fights in Europe, the Jesuits were expelled from Spain and Portugal –and from their Latin American colonies– in 1767. Kings Charles III of Spain and Joseph I of Portugal, counselled by the Marquis of Pombal, pressured the (Franciscan) Pope Clement XIV to issue an

[27] Ganson (2003) reports a maximum of 141,182 people in 1732.

[28] Books were printed in the missions of Santa María la Mayor and San Francisco Xavier (Ganson, 2003).

order of expulsion.[29] The order was carried out with surprising efficacy in the Guarani area by Francisco de Paula Bucarelli, the Governor of Buenos Aires. Clement XIV proceeded to dissolve the Jesuit order in 1773. The Jesuits were exiled to Ferdinand the Great's Prussia and Catherine the Great's Russia and the order was not restored until in 1814 by Pope Pius VII. Due to European political fights, the Jesuits were never to return to the Guarani area.

2.3 Geographic Context

The Latin American Jesuit Missions were located in what were essentially frontier lands of the Spanish and Portuguese empires (Bolton, 1917). The case of the Jesuit Guarani lands was no different, located in the border of modern-day Argentina and Brazil, and neighboring the buffer state of Uruguay (Figures 1 and 2). Although quite specific, the area under consideration is not small and is comparable in size to Uruguay or Ecuador.[30] The Spanish Crown viewed these missions as a tool for incorporating people into the empire (Sarreal, 2014). Even though Paraguay was an important territory for the Spanish Empire at the time, the Jesuit Missions were isolated from the colonial capital of Asuncion, which itself numbered 6,451 inhabitants in 1761 (Ganson, 2003).[31] Jesuit missions were also located far away from the state capitals of Corrientes (founded in 1588), Villarica (founded in 1682) and Porto Alegre (founded in 1772). Jesuits missionaries went to an area that remains inaccessible even by modern standars.[32]

The Guarani area was populated by the same indigenous tribe, also known as the *Tupis* in Portuguese. The Guaranis were semi-sedentary, and cultivated manioc root and maize through slash-and-burn agriculture. When the Jesuits arrived, the Guarani were considered to be at a Neolithic stage of development, lacking iron weapons and tools (Ganson, 2003). Hence the colonial human capital intervention took place in a primeval setting. By focusing on the Guarani area I abstract from the direct effects that different pre-colonial ethnic tribes have been shown to have in Africa

[29] The order became effective in 1759 in Portugal and the Portuguese territories and in 1767 in Spain and their Spanish counterparts.

[30] Also similar in size to Italy or the US state of Arizona.

[31] Buenos Aires and São Paulo lay even farther away from the missions.

[32] The remoteness of the missions will be exploited in the IV strategy.

and the Americas (Gennaioli and Rainer 2007; Michalopoulos and Papaioannou, 2013; Maloney and Valencia Caicedo, 2012). The zone is covered by subtropical forests, its climate is humid, and the area contains no major mineral resources (Palacios and Zoffoli, 1991).

3 Data and Empirical Strategy

3.1 Data

I use archival records, government census data and household surveys to run my empirical analyses. To extract usable data from historical sources, I use ArcGIS. An example can be seen in Figure A.3., which shows a historical map of the Jesuit Missions of Paraguay. My data set covers (all municipalities of) five states in three countries (Figure 2); namely, the states of Misiones and Corrientes in Argentina, Rio Grande do Sul in Brazil, and Misiones and Itapua in Paraguay. In total, there are 578 observations, covering around ten million inhabitants, that correspond to the municipal or third level divisions for these countries (*departamentos* in Argentina, *municipios* in Brazil, and *distritos* in Paraguay).

The data for this paper come from three separate sources. First, there is information taken from historical archives on the location, year of foundation, population and general workings of the Guarani Jesuit Missions.[33] Additional historical data come from the National Censuses of Argentina in 1895 and 1914; Brazil in 1890, 1920 and 1940; and Paraguay in 1950.[34] Second, there is an extensive set of geographic and weather controls at a highly disaggregated level from BIOCLIM[35]. Third, there are a series of educational outcomes (median years of schooling and literacy) and income (or poverty) measures from modern censuses for Argentina (2001, 2010), Brazil (2000, 2010) and Paraguay (2002, 2012). Modern data are in turn complemented by a household survey I conducted in Southern Paraguay (Figure 3), as well as by two specialized survey modules on culture from the 2006 Brazilian Municipal Survey and the Paraguay Public

[33] These include the *Archivo de Indias* (Seville), *Archivo General de la Nación* (Buenos Aires), *Archivo Nacional* (Asuncion) and the Roman Jesuit Archives (Vatican).

[34] This is the first national official Census of Paraguay.

[35] http://www.worldclim.org/bioclim

Household Survey of 2012.[36] The specific variables used along with their sources and units are described in detail in the Data Appendix.

Summary statistics for some of the key variables can be found in Table 1, divided into income, education, Jesuit missionary presence, geographic and weather characteristics.[37] Aside from standard measures, I include more sophisticated controls, such as ruggedness and distance to rivers that may have been relevant for missionary settlement. Log income is 5.67 R$, median years of schooling 5.08 and literacy levels border 90%, which are typical values for Latin American developing countries. Summary statistics for the household survey are presented in Table 2, divided into missionary and non-missionary areas.[38] There are no significant differences between the two in terms of demographic characteristics, and some differences in geographic features that I take into account in the estimation. Respondents in missionary areas appear more altruistic and honest, and exhibit a higher (internal) locus of control, differences that I analyze further in the Experimental Evidence section. These data are complemented with a series of outcomes from historical censuses, cultural variables as well as additional demographic, economic and labor characteristics. These data allow for the estimation of heterogeneous effects, the exploration of specific mechanisms of transmission, and the testing for possible confounders.

3.2 Estimating Equations

In order to estimate the effect of the Jesuit Missions on contemporary outcomes, I use the following econometric models:

$$HK_{2000,ij} = \alpha + \beta d(M_{ij}) + \gamma GEO_{ij} + \mu_j + \epsilon_{ij} \tag{1}$$

$$f(Y_{2000,ij}) = \alpha + \beta d(M_{ij}) + \gamma GEO_{ij} + \mu_j + \epsilon_{ij} \tag{2}$$

[36] To the best of my knowledge, no comparable information exists for Argentina at the municipal level for the area studied. Note, for instance, that neither the World Values Survey nor the regional Latinobarometer sample the areas under consideration. It is worth noting that Paraguay as a whole has received little attention in economics. Two notable exceptions being Schechter (2007) and Finan and Schechter (2012).

[37] Some of the variables are not available for all countries, so are complemented with similar indicators, such as income data with poverty measures and median years of schooling with literacy.

[38] For the specific description and units please refer to the Data Appendix.

where HK and Y are human capital and income in municipality i in state / country j in equations 1 and 2, respectively.[39] M measures missionary presence at the municipality level and the d function is either a missionary dummy or distance to the nearest mission in kilometers. Hence the coefficient of interest is β which in the case of a positive effect would be positive in the dummy formulation and negative in the distance to the nearest mission formulation. GEO is a vector of geographic and weather controls with a corresponding vector of coefficients γ. μ captures a country or state-fixed effect, depending on the specification. α is a generic constant and ϵ is an idiosyncratic error term. I use a similar formulation to Equation 1 when I analyze cultural outcomes.

3.3 Estimation

To actually estimate the equations above, I use OLS with fixed effects. Controlling for fixed factors is important for several reasons. Data collection might vary at the country and even the state level. There can also be national institutional differences that are important to take into account in the estimation (Acemoglu et al. 2001 and 2002). I use robust standard errors throughout, except when the number of observations is too small and I jointly report bootstrap standard errors. Given the small number of countries and states I do not cluster errors at this level, but instead conduct robustness tests using spatially adjusted Conley standard errors (results not shown).[40] As an exception, I use OLS and probit specifications with errors clustered at the district level for the individual level data in the cultural section. I report results for both the full and reduced samples at different distance thresholds ($<$400, 200 and 100 kilometers from the nearest mission) in order to reduce the constraint imposed by modern administrative boundaries. The results are preserved and appear stronger at the local level.

3.4 Identification

The causal identification of the missionary effect hinges on several assumptions. First, the historical record suggests that the foundation of the missions proceeded in a relatively haphazard manner.

[39] As is standard, I take the logarithm of income.

[40] In particular, I use alternative cutoffs of .1, .5 and 1 degrees, which reduce the standard errors slightly but leave the general significance levels unchanged.

Hernández (1913) describes as a "coincidence" the entrance of the Jesuit priests to Paraguay. Other historians describe the foundation of San Ignacio de Guazú as an unprecedented "adventure" and the initial establishment of the first missions as "perilous and random" (Astrain, 1996). The remarkable success of some missionaries is contrasted with the failure and even death of some of their contemporaries. Priests like Antonio Ruíz de Montoya, were very successful in founding several missions, while others like Diego de Alfaro and Alfonso Arias died trying. I also control directly for geographic conditions such as lower altitude and proximity to rivers that might have influenced the initial settlement choices.[41] Since Jesuit missionaries might have chosen places with more favorable geographic conditions, it is important to include these variables directly in the estimation. Moreover, being the last Catholic order to arrive to the Americas, the Jesuits had last pick and ended up in peripheral areas of the Portuguese and Spanish empires. This issue will be examined further in the section contrasting Jesuit and Franciscan missionaries. Finally, I use standard econometric techniques such as placebo tests (abandoned missions) and instrumental variables (exploration routes and historical border changes) to confirm the causal effect of the Jesuit missions. I discuss the possible issue of sorting in relation to geography, migration and urbanization throughout the paper. I do not find that selection is driving the Jesuit missionary effect.

4 Main Results

The main results of the paper can be divided into three sections. The first one shows that missionary districts have approximately 15% more years of schooling and higher literacy levels in both modern and historical time periods. The second shows that these differences in education have translated into higher incomes or lower levels of poverty of around 10%. I also present a placebo test (abandoned missions) to tackle the potential endogeneity of missionary location. The third and last section looks at differences in non-cognitive skills and preferences, using experimental evidence.

[41] In the robustness section, I show that the Jesuit areas do not have higher population densities in modern and pre-colonial times.

4.1 Human Capital

4.1.1 Raw Data

Before running any regression, Figure 5 summarizes the spirit of this section. The graph plots modern literacy rates for people aged 15 and older versus distance to the nearest Jesuit mission in kilometers. Municipalities that had missions (orange triangles) cluster at the left hand upper corner with rates above 90%. It appears with the linear trend line that the farther away a municipality is from a historic mission, the lower its literacy level. This unconditional relationship is negative and highly significant with a t-statistic of -4.36. Although literacy rates are relatively high and have converged in modern times, the negative relationship appears substantial. To better quantify this phenomenon I estimate Equation 1 using median years of schooling for Brazil and literacy rates in the merged sample. The pattern observable in the raw data is confirmed in the regressions.

4.1.2 Median Years of Schooling

As a proxy for human capital, I use first Brazilian data on median years of schooling.[42] In order to capture the missionary effect I use distance to the nearest Jesuit mission. The results of estimating Equation 1 using this variable and the distance formulation can be seen in Table 3.[43] The coefficients are negative, strongly significant and stable in the full and localized samples of 400 and 200 kilometers to the nearest mission.[44] With a mean of around 5 years of education, the estimates suggest that moving 100 kilometers closer to a mission increases years of schooling by .6 to .8 years or around 15%. So these magnitudes are economically important, especially when considering that Brazil has a low level of education, even by Latin American standards (Hanushek and Woessmann, 2012). The results are also in the 10% ballpark of educational benefits of the *Bolsa Familia* conditional cash transfer program (Glewwe and Kassouf, 2012).

[42] This information is not avaibable for Argentina or Paraguay.

[43] I control directly for geographic and weather characteristics in the estimation.

[44] For Brazil, less than 400 kilometers covers less than 90% of the sample and less than 200 kilometers about half of the sample.

4.1.3 Literacy

As a second proxy of human capital I use literacy rates, which are reported for the three countries. Merging the data and running the human capital specification with state fixed effects leads to similar conclusions as before. The point estimates are positive and significant for illiteracy rates (Table 3). The coefficients are stable and increase in magnitude in the local sample. With a mean literacy rate of around 90%, the effect estimated suggests a reduction in illiteracy of at least 10% when moving 100 kilometers closer to a mission. Again the missionary effect on education is notable given the different historical and institutional trajectories of Argentina, Brazil and Paraguay.[45] Overall, I find there to be a positive and significant effect of Jesuit Missions on modern human capital, measured as median years of schooling in Brazil and illiteracy for all of the three countries. The education results are comparable and slightly larger than the ones found by Nunn (forthcoming) for Christian missions in Africa.

4.1.4 Intermediate Historical Outcomes

I examine intermediate human capital outcomes for two reasons. First, to see how the effects I find for the modern time period have been accumulated differentially over time. Additionally, the historical data can also be used to identify heterogeneous effects. I focus on the Argentinean Census of 1895 and the Brazilian Census of 1920, though the results also hold for alternative years for these countries and for the Paraguay 1950 Census.[46] In general, I find that Jesuits had an even larger effect on human capital during intermediate historical periods.

Table 4 presents the results for the 1895 Argentinean census. Illiteracy appears consistently higher the farther away the municipality is from a Jesuit mission. The results are not only positive and significant but also larger than before (Column 1).[47] Being 100 kilometers closer to a mission leads to a reduction in illiteracy of 4%. The larger effect might be due to the much lower levels of literacy

[45] For robustness, I also estimate the literacy formulation in the merged sample using distance to the nearest mission for each country (not shown). This leaves the results unchanged only reducing slightly the magnitude of the coefficients.

[46] These are the Argentinean Census of 1914 and the Brazilian Census of 1940.

[47] Due to the small number of observations, I also report bootstrap standard errors.

during this period, which had an average of 23% and a standard deviation of 8%. Alternatively, the missionary educational treatment might have faded away over time, so it is not surprising to see a stronger effect in the past.[48]

In terms of heterogeneity, the results are higher for females than males (Columns 2 and 3). Furthermore, they also appear concentrated among Argentineans as opposed to foreigners (Column 4).[49] This is sensible, as the first were largely the descendants of those who received the missionary treatment, while the second had only recently arrived to the country.[50] The heterogeneous findings are also consistent with a story of vertical cultural transmission (Cavalli-Sforza and Feldman, 1981; Boyd and Richerson 1985; Bisin and Verdier 2000 and 2001) for the historical period.

The results for the 1920 Brazilian census are very similar to the ones just described for Argentina.[51] The effect on literacy is statistically significant and large for the Brazilian population as a whole (Table 4, Column 5) and for different age groups: 7 to 14 years and over 15 years of age (Columns 6 and 7). Results are much larger for the second group. As for Argentina, the effect is also larger historically, in the order of 10%, and again it appears concentrated on Brazilians as opposed to foreigners (Column 8).[52]

Additional results show a large degree of persistence between historical and modern levels of literacy (Figure 6). This is especially true for Argentina, with a slope of .23, but also holds for Brazil, albeit with a higher degree of convergence with a slope of .193. A similar exercise with the 1950 Paraguay data reveals a slope of .217. All relationships are statistically significant at the 1% level. Though striking in itself, this degree of historical persistence is not surprising if one considers the earlier results for the missionary period. Indeed, one interpretation of the intermediate historical

[48] It is well known that literacy levels have converged during modern times (Hanushek and Woessmann, 2012).

[49] These results also hold when using the 1914 census (not shown). Using that census I find additionally that missionary areas have higher levels of educational instruction.

[50] Recall that this was an age of mass migration to Argentina (Droller, 2012). The issue of migration in modern times is explored in the robustness section.

[51] Since the data are reported for different age groups and for incomplete literacy (read not write and vice-versa), I keep here the complete literacy variable instead of using its complement. To make the samples comparable, I restrict the Brazilian sample to municipalities 200 kilometers or closer to a historic mission.

[52] The literacy results also hold for the 1940 census, not shown. This census allows for the estimation of educational instruction as an alternative educational variable.

results is that the missionaries altered the early levels of human capital, generating differences in accumulation that were observable during historical times and are prevalent even today.[53] In the next section I examine whether these educational differences have been translated into differences in income.

4.2 Income and Poverty

4.2.1 Nighttime Satellite Data

A first way to illustrate the impact of the Jesuit Missions on income is through the usage of nighttime satellite data (Henderson et al. 2012).[54] From outer space, the missionary area is depicted in Figure 7, along with municipal level boundaries. As can be observed, many of the light spots associated with higher income correspond to the historical placing of the Jesuit missions. Note that the missions are still in very isolated areas, far away from the main population centers (Figure A.4).[55] I only use the nighttime satellite data for illustrative purposes, due to the availability of more reliable income and poverty measures for the countries studied.[56]

4.2.2 Per Capita Income

The results of estimating Equation 2 using the the distance formulation for income can be seen in Table 5 (first three columns) for Brazil.[57] All specifications include geographic and weather controls. The coefficients appear negative and strongly significant in the full sample (Column 1)

[53] A similar argument has been made by Rocha et al. (2013) for the European colonies in the state of São Paulo, Brazil. As will be seen in the Persistence Mechanisms section, this view is also consistent with Botticini and Eckstein (2005, 2007 and 2012) in that an early human capital shock resulted in long-lasting differences in occupational structures.

[54] I thank Ömer Özak for suggesting this point.

[55] I test directly for this possibility in the robustness checks.

[56] For example, Michalopoulos and Papaioannou (2013) use nighttime satellite data due to the lack of reliable GDP per capita and income measures for the African continent.

[57] I explore alternative formulations in the Appendix. This variable has several advantages over the dummy formulation. First, as a continuous variable it provides a more informative and flexible measure of missionary intensity for municipalities that did not have a mission within their border. Second, it helps to solve the problem that missions might not have had such clearly-defined boundaries over time, cf. Dell (2010), where the *mita* boundaries were strictly drawn and enforced in Bolivia and Peru. Additionally, people might have migrated to nearby towns or vice versa, an issue I explored explicitly in the intermediate historical results and retake in the robustness checks.

and remain robust in the reduced samples (next two Columns). Being 100 kilometers closer to a mission brings a maximum of .3 log points of income per capita.

4.2.3 Poverty: Unsatisfied Basic Needs Index

Because of the lack of income data at the municipal level for Argentina and Paraguay, I study these two countries separately using instead the Unsatisfied Basic Needs (UBN) Index as a multidimensional measure of poverty.[58] The results can be seen in Table 5, using the continuous distance to the nearest mission formulation and country fixed effects.[59] The results appear very similar to the ones for Brazil. The coefficient for distance to the nearest mission now emerges significantly positive (since the dependent variable is now poverty) in Column 4. I further reduce the sample to places 100 kilometers away from a mission.[60] Again the point estimates are stable and effects appear larger at the local level (Column 5). By construction, the poverty index allows for an easier interpretation of the results. In terms of magnitude, as one moves 100 kilometers farther away from a missionary district, the poverty index increases by approximately 10%. The results are also robust to using the household as opposed to the person UBN index, in the last two columns of Table 5. The comparable results for countries with marked historical and institutional differences point toward the strength of the Jesuit effect on income.[61]

To assess the economic importance of the human capital results, I run a specification of income on literacy, instrumented by distance to the nearest Jesuit Mission (not shown). The unconditional estimates are of around 27% while the ones with geographic and weather controls are of around 8%, which is consistent with micro evidence (Psacharopoulos and Patrinos, 2004) as discussed in Acemoglu et al. (2014). The results suggest the importance of controlling for these variables in the

[58]The UBN methodology seeks to determine, with the help of a few simple indicators, if the population's basic needs are being satisfied. The groups that do not reach the minimum threshold are classified as poor. The selected simple indicators are: inadequate housing, housing with critical overcrowding, housing with inadequate services, households with high levels of economic dependence, and households with school-age children not enrolled in school. The UBN index is normalized from 0 to 100.

[59]Again, all specifications control for geographic and weather characteristics.

[60]I use this cutoff for the Argentina and Paraguay sample since less than 200 kilometers covers around 90% of the observations and less than 100 kilometers around 70% of the sample.

[61]I explore alternative specifications in the Appendix.

estimation. But could the observed difference be driven by other factors, beyond these observable characteristics?

4.3 Placebo Test

Jesuit missionaries might have sorted into better places, beyond observable geographic and weather characteristics. In order to address the endogeneity problem of missionary location I conduct a placebo test. In particular, I look at missions that were initially founded but abandoned early on by the Jesuits. This goes to the heart of the question as to whether Jesuits simply picked better places *ex ante*.

4.3.1 Abandoned Missions

The Guarani missions were not the only ones founded by the Jesuits in the Guarani area. Three nearby missionary nuclei were established by the Jesuits in Guayra, Alto Parana and Itatin. These missions all belonged to the exploratory period lasting for 50 years until 1659. In the Guayra region the Jesuits founded Loreto and San Ignacio in 1610; and in Alto Parana they founded the missions of Nuestra Señora de la Natividad de Acaray in 1624 and Santa María la Mayor de Iguazú in 1626. In the Itatin region they founded several reductions the last of which was Yatebó in 1634. These missions were abandoned early on and were not integrated with the rest of the Guarani system of missions (Hernández, 1913).[62] The Guayra foundations lasted from 1610 to 1630 and the Alto Parana nuclei from 1609 to 1638. Itatin foundations were disbanded in 1648 and finally relocated in 1659.

The principal threat to the survival of these missions was their proximity to the Portuguese bands of slave hunters or *bandeirantes* (Ganson, 2003). The *bandeirantes* attacks started in 1611 and intensified from 1628 to 1632.[63] Father Diego de Alfaro was was killed by the Portuguese in 1637 Garruchiños and Alfonson Arias in 1645 in Itatin (Hernández, 1913). The Guarani area

[62] Jesuit Domingo Muriel provides a valuable contemporaneous account of these missions (reprinted in Furlong, 1955).

[63] The effect of the *bandeirantes* will be explored further in the Appendix using an IV strategy. In general, I do not find a direct long-term effect of these raids.

would remain prone to attacks, as evinced by the *bandeira* of Francisco Pedroso Xavier in 1676. The *bandeirantes* were not the only threats to the consolidation of missions, which also depended critically on the survival of priests. The missionaries were working in a context of hardship and low levels of recruitment. In fact, the early years of 1650-1655 are described as the worst in terms of Jesuit recruitment to the New World (Galán García, 1995). At the same time, Jesuit priests faced difficult circunstances and even death in the apostolic front lines, especially during the early exploratory period. In 1628 the Jesuit martyrs Roque González, Alfonso Rodríguez and Juan de Castillo were killed by natives in the area of Ijuí (Hernández, 1913). A similar fate was suffered by Cristovão de Mendoza in Caixas do Sul in 1632 and by Pedro Romero in Santa Barbara in 1645. Such deaths were critical blows to fledging missions, which counted only one or two Jesuit priests.

I retrieve the coordinates for the abandoned missions of Guayra, Alto Parana and Itatin to use them as a placebo test. The rationale of this exercise is that these places were also picked originally but abandoned early by the Jesuits, so they did not receive the full missionary treatment of the Guarani missions. In the absence of a grand plan for the construction of the Jesuit Missions, these abandoned establisments are as close as I can get to unbuilt missions (see for instance, Greenstone et al. 2010 and Michaels 2008).

I find no effects for the abandoned missions, either in terms of education or income. For literacy (Table 6, Columns 1 to 4), some of the coefficients are significant separately but appear now with the opposite (positive) sign. When estimated jointly, they lose significance or do not appear with a consistent sign. As can be seen in the last four Columns of Table 6, the coefficients for income for the missions of Alto Parana, Guayra and Itatin are not significant either separately or jointly.[64] The results do not support the hypothesis that the *bandeirantes* had a negative and long-lasting effect in these areas.[65] The findings in this section suggest that it was not just the original placement of missions but the actual development of the missionary activities for centuries which

[64]The Guarani Jesuit distance results are robust to the inclusion of these abandoned missions (not shown).

[65]To test for this I possibility I run a specification with direct distance to Villarica, which was attacked repeteadly by the *bandeirantes*.

had an effect in the long-term.[66] Endogeneity issues aside, did the Jesuit missionary treatment lead to differences in other outcomes besides human capital and income? To answer this question I present evidence from a household survey.

4.4 Experimental Evidence

Formal education is not the only aspect of human capital formation that can impact economic outcomes in a major way (Heckman and Rubenstein 2001 and Heckman et al. 2006). Non-cognitive skills may have similarly benefitted from the Jesuit "intervention" and norms of cooperation may have changed in a differential fashion. In order to take a more in-depth look at individual level behavior and attitudes in the missionary area, I conducted a household-level survey in Southern Paraguay (Figure 3).[67] The survey covered all the eight Paraguayan Jesuit missionary districts (in blue) and sampled 12 comparable districts (red dots) in the states of Misiones, Itapúa, Caazapá, Guayrá and Alto Paraná.[68] Within the twenty villages, 28 household heads were randomly selected to complete the interviews.[69] The survey focuses on cultural questions, following recent contributions by Falk et al. (2014), as well as standard questions from the World Values Survey and the regional Latinobarometer equivalent.[70]

As a measure of non-cognitive skills I use the Rotter Locus of Control (Heckman et al., 2006). This psychological test categorizes a respondent's attitude on a scale going from purely external (low) locus of control ("destiny is predetermined") to the exact opposite ("I alone control my own destiny"). There is a significant difference between average responses in Jesuit missionary and non-missionary districts (Figure 8). Not only is the whole distribution shifted to the right (internal

[66] Another way to explore this issue is to look at the intensity of treatment effects of Jesuit Missions, which I present in the Appendix of the paper.

[67] I gratefully acknowledge the financial support from Zurich University for this project. I also thank Gharad Bryan, Rosemarie Nagel and Laura Schechter for very helpful comments. This is the first tranche of a project that plans to cover also the Jesuit missionary areas in Argentina and eventually Brazil.

[68] Comparable districts were selected on the basis of their population and income. The survey was carried on by E+E Economía y Estadísticas para el Desarrollo, a local Paraguayan consulting firm.

[69] First blocks were randomly selected using maps from each of the districts. Starting from a randomly chosen household, the enumerator proceeded to interview the third house of each block going counter-clockwise. Depending on the size of the block three to four households were selected in each block. All participants were rewarded with a notebook of 1 dollar value for their participation.

[70] The actual text of the survey is available upon request.

locus of control) for the Jesuit districts, but the difference is statistically significant at the 5% level (Table 7, Column 1). Standard errors are now clustered at the district level.

Another goal of the survey was to determine whether there were significant differences in terms of preferences and social norms between the missionary and non-missionary areas. To this end, I conduct standard games from the psychology and experimental economics literature including dictator and trust games, as well as questions on time discounting and risk preferences.[71] The results of these exercises are presented in Table 7. Residents in Jesuit missionary areas are markedly more altruistic (Column 2) in a hypothetical game of allocating 1 million Guaranis (220 Dollars or two week's wages). I also find that these respondents are more willing to allocate money received in a trust game, a measure of positive reciprocity, in Column 3.[72] There seem to be no significant differences in terms of time discounting (Column 4), but less willingness to take risks.[73] This can be seen in the higher certainty equivalence required from a 50-50 lottery of 0 or 1 million Guaranis (Column 5).[74]

I also conduct a cheating game with the respondents, in the spirit of Hanna and Wang (2013) and Lowes et al. (2014). In the game individuals tossed a fair coin nine times. They were told *ex ante* to count the number of heads they will get and that with five or more heads they would obtain an extra compensation for their participation (a box of tea , a traditional staple food with a one dollar value).[75] In the sample as a whole, there is evidence of dishonesty –359 people (64%) claim to have obtained 5 or more heads versus 201 that report 4 or less.[76] There are also important differences between the missionary and non-missionary areas (Table 7, Column 6). In the latter, more people seem to be lying, claiming that they obtained more than 4 heads.

[71]For the specific questions please see the Data Appendix.

[72]Results are robust to using the 5,000 transfer for a total of 25,000 Guaranis to be redistributed.

[73]Note that some of the responses are bounded to correspond with the wording of the question, leading to a decrease in the number of observations.

[74]Results are robust to using constructed measures of risk preferences (lover, neutral and averse) from this answer.

[75]In particular, respondents were told that they would receive as compensation a notebook (of one dollar value) and depending on the response from this game an additional box of tea (also of one dollar value).

[76]This familiar pattern is consistent with the findings of Fischbacher and Föllmi-Heusi (2013). As is standard, we do not know for a fact whether people cheated in this experiment, only through the deviations from an even split. We also made sure that enumerators did not observe or record the outcome of this section, leaving the respondents to write their own responses.

The survey strongly suggests that long-term benefits of missionary activity are not limited to higher levels of formal education. In addition, there is substantial evidence that inhabitants in areas where Jesuit missions existed are more honest, trust each other more, and reward each other for cooperative behavior to a greater extent. They are also more risk-averse. One obvious question to ask is if this is possibly driven by persistent levels of religiosity, along the lines of the "Big Gods" argument (Norenzayan 2013; McKay et al. 2014). To examine this mechanism further, I use religious priming to examine if it affects collaborative behavior.

Respondents were asked about their religious beliefs and religious practice as part of the survey. This question was administered either right before or right after the experimental section, based on random assignment. There appear to be no significant differences in terms of preferences (results not shown). Only the coefficient for certainty equivalence is positive significant at the 10% level, but the magnitude is five times smaller than before. There are no significant differences in the cheating game either. It does not seem that religious priming is driving pro-social behavior. Or put diffently, that the differences in responses are due to fundamental or structural differences and not to very short-term interventions.

5 Empirical Extensions

In this section I present empirical extensions and alternative estimations of the main results described so far. First, I compare Jesuit with Franciscan Guarani Missions, which did not stress education in their conversion. I also present instrumental variables strategies as an alternative to tackle the potential endogeneity of missionary location. The IV results are broadly consistent with the OLS estimates.

5.1 Franciscan Guarani Missions

The study of Franciscan Guarani Missions allows for the comparison between two Catholic orders with a different focus in a similar area. Was it the establishment of missions in the Guarani area or the focus that they had which led to differential outcomes in the long run? The comparison with the Franciscan Guarani Missions is a relevant one, as many of the elements that led to their location—such as indigenous availability, favorable climatic and geographic conditions—were common to the Jesuit Missions. Ultimately, both Catholic orders wanted to maximize the number of souls converted to Christianity. However, the Franciscans did not stress human capital formation and technical training in their conversion.

Jesuits were not the first to establish religious missions in the Guarani area (Figure 4). The first Guarani Franciscan Missions were established between 1580 and 1615 by Fathers Bolaños and Alonso, while the first Guarani Jesuit Mission appeared in 1609 (Durán Estragó, 1987). By choosing first, Franciscans located themselves further north and closer to the existing population centers, presumably ending up in better locations. I study the early missions of Altos founded in 1580, Itá in 1585, Yaguarón in 1586; Atyrá, Guarambaré, Tobatí and Ypané from 1580 to 1600, Caazapá in 1606, and Yuty in 1611. I use the exact location and the available historical population data for these Franciscan Guarani Missions.

One way to see the differences between Jesuit and Franciscan Guarani Missions is by using contemporary population data. Figure 9 shows the mean population in both sets of missions from 1640 to 1760. Though the data series is incomplete, the divergence between Jesuit and Franciscan missions is apparent (Maeder, 1995).[77] Starting from a similar base of around 1,500 people, Jesuit Missions reached almost three times that number at their peak in 1730. By comparison, Franciscan missions remained fairly stable in terms of population, declining from 1720 onward. In a Malthusian regime, these differences in population can be interpreted as early differences in income (Galor and Weil 2000; Ashraf and Galor 2011; Galor 2011).

Second, I test directly whether Franciscan missionaries had the same effects as Jesuits in the long term, by re-estimating the human capital and income equations, using instead distance to the nearest Franciscan mission. The results, or lack thereof, can be seen in Table 8. I find no effect for

[77] Even when they were devoted to similar activities (cattle raising and *yerba mate* cultivation), the Jesuits proved more effective (Maeder, 1995).

either modern literacy or income (Columns 1 and 2). Franciscans might have picked geographically advantageous places, but the effect of their missionary treatment does not appear to be long-lasting. In a horserace between the missions from the two orders I find that the beneficial effect on education and income is preserved for the Jesuits and appears now negative for the Franciscans (Columns 3 and 4). Even though the two variables are highly correlated, so it is hard to take these results at face value, it is still worthwhile to analyze what could be driving the disparities.

First there is a difference in terms of focus. As has been argued before, from the outset there was a clear emphasis on human capital formation and technical training on the part of the Jesuits, a difference that prevails today. The mendicant orders, to which the Franciscans belonged, were characterized since their inception by tending for the sick and the poor, charity and reducing inequality. "The Jesuit order, in contrast [to the Mendicant orders], was not defined by its commitment to poverty and to the poor." Waldinger (2013, p. 2). In the last two columns of Table 8 I examine this possibility.[78] Areas closer to Franciscan missions do not seem to have lower levels of inequality relative to the Jesuit areas (Column 5). The same is true for health, proxied by mortality (Column 6). If anything, the Jesuit areas do better in these regards. It is the Jesuit focus on human capital, which appears to have had a beneficial role in the long run. [79]

5.2 Instrumental Variables

An alternative way to address the potential endogeneity of Jesuit missionary placement is to use standard instrumental variable techniques (Angrist and Pischke, 2008). The idea is to find a source

[78] To see how the mendicant character of some Catholic orders actually benefited human capital formation in the case of Mexico, see Waldinger (2013). Another distinction between the two scenarios is that the Jesuits focused more on elite education in Mexico relative to Paraguay, where the missions took the lion's share of their apostolic efforts.

[79] Other differences between the Franciscan and Jesuit Missions have been documented in the historical literature. Institutionally, Franciscans were more open towards the colonial labor system of *encomienda*, while Jesuits were more successful in obtaining lower labor tributes and taxes from the Spanish Crown (Salinas, 2010). An exception being the Jesuit Mission of San Ignacio de Guazú which was located closer to the Franciscan Missions and experienced the *encomienda* labor regime. Also, by choosing first, Franciscans located themselves further north and closer to the existing population centers, which made it harder for them to resist the Spanish colonial encroachment. For instance, indigenous people from these missions were used to execute local works (Salinas, 2010). The isolation of the Jesuit Missions in what were essentially frontier lands made it harder for the Spaniards to use the natives for such activities, protecting and benefiting them in the long term.

of variation that is correlated with the initial placing of the missions, but that does not affect the outcomes of interest directly. In this section I present two such candidates: original exploration routes and distance to Asuncion. I provide some historical background to justify these choices and examine their corresponding exclusion restrictions.

5.2.1 Exploration Routes

As has been stressed before, Jesuit missions were located in remote areas of the Spanish and Portuguese colonies that remain relatively isolated even today. The aim of this section is to capture a measure of isolation that can be used to proxy for missionary location. One such candidate is distance from early exploration routes (Figure 10). Historical exploration routes such as Lewis and Clark's in the US have been recently used as instruments for highway development (Duranton and Turner 2012; Duranton et al. 2014). For the missionary area the equivalent are the expeditions of Pedro de Mendoza (1535-1537) and Alvar Nuñez Cabeza de Vaca (1541-1542).

Under the aegis of the Spanish Crown, Pedro de Mendoza explored the Río de la Plata (River Plate) region of South America (Figure 10). Sailing from Spain and the Canary islands and following the delta of the River Plate, he founded the city of Buenos Aires in 1535 (Figure 4). Mendoza became the first Governor of the Río de la Plata region, but died shortly thereafter from syphilis in 1539 (Chipman, 2014). From Buenos Aires, lieutenant governor Juan de Ayolas sailed almost 1,000 kilometers up the Paraná River and founded the fort of Corpus Chirsti in 1536. Similarly, interim governor Domingo de Irala founded Nuestra Señora Santa María de la Asunción (Asuncion) in 1541.[80]

Alvar Núñez Cabeza de Vaca, who became famous for his conquest of Florida and the Gulf of Mexico, also played an important role in the exploration of South America (Chipman, 2014). Cabeza de Vaca was given permission to explore the Río de la Plata region in 1540 (Figure 10). He started off in the island of Santa Caterina (modern/day Brazil) and instead of sailing to Buenos Aires took the fateful decision to traverse the interior and walk barefoot more than 1,200 kilometers

[80] Distance to Asuncion will be explored as an alternative instrument in the next section.

to Asuncion. After four and a half months of traversing "a trackless wilderness filled with cannibals, impassable rivers, jungles and poisonous snakes" (Chipman, 2014, P. 54) he arrived to Asuncion the morning of March 11, 1542.

The rationale of the instrumental strategy is to proxy for the remoteness of the Jesuit missions using distance from the expedition routes (negative first stage). These routes served to found the initial cities, whereas the missionary area remained relatively unexplored. At the same time, the exact path of the expeditions was somehow arbitrary. The results of instrumenting missionary location with distance to the exploration routes can be seen in Table 9. The first stage is negative and significant (F-statistic well above 10). The second stage results are positive for illiteracy (Column 1) and negative in the income formulation (Column 5), as before. The magnitudes are similar for education and slightly larger for income.

5.2.2 Distance to Asuncion

As was mentioned in the historical context, the first Jesuits arrived in Asuncion on the 11th of August of 1588 (Figure 4). From that base, Fathers Manuel Ortega and Thomas Fields started their evangelical expedition in the territory of Guayra. Subsequent expeditions explored the area controlled by the Guarani, leading to the foundation of the first mission of San Ignacio Guazú in 1609. Asuncion would remain an exploratory base throughout the missionary period (Figure 11). Still, it is important not to overemphasize the importance of Asuncion, which had a population of 6,451 in 1761, twenty times less than the Jesuit Missions (Ganson, 2003).

In 1750, less than twenty years before the expulsion of the Jesuits, the Treaty of Madrid changed the Spanish and Portuguese borders in South America. This treaty replaced the Tordesillas Treaty of 1494, largely leaving the territory of Brazil in its current form.[81] In the missionary area, the modern state of Rio Grande do Sul passed to Portuguese hands along with the seven missions (also known in Portuguese as the *sete povos*) of São Borja, São Luiz Gonzaga, São Nicolau, São Miguel,

[81] The San Idelfonso Treaty of 1777 would confirm the 1750 boundaries. The Tordesillas treaty will be used as an alternative instrument in the Appendix.

São Lourenço Martir, São Joao and Santo Angelo. The center of influence for this region shifted abruptly from the Spanish to the Portuguese empire, diminishing the importance of Asuncion as a colonial capital. My working assumption is that this city is even less relevant for Rio Grande do Sul in modern times, but that it was influential in the historical placing of the Jesuit Missions.[82]

I instrument distance to the nearest Jesuit Mission using distance from Asuncion, only for the Brazilian subsample of the data (Figure 11). This identification strategy is similar to the one employed by Becker and Woessmann (2009) with distance to Wittenberg and Dittmar (2011) with distance to Mainz. I exclude the states in Paraguay given the importance of the national capital and Argentina, which remained part of the Spanish Empire after the borders were changed in 1750, until it became independent in 1810. For robustness, I control directly for distance to São Paulo, which became the new pole of influence for the region. The results of this instrumental variables exercise can be found in Table 9. The first stage is very robust (F-statistic > 10). The instrumented coefficients appear significantly positive for illiteracy (Column 2) and negative for income (Column 6). The coefficients for education appear slightly larger and the ones for income have a similar magnitude to the OLS results.

By and large, the instrumental variable results confirm the OLS results for income and education. Taken together with the placebo results, they suggest a causal effect of the Jesuit Missions on income and education. The results for exploration routes and the distance to Asuncion specifications are broadly similar though slightly larger in magnitude than the OLS results. It does not seem that this is caused by weak instruments or by the difference in samples. Beyond measurement error, this might be due to differences between average and local treatment effects due to heterogeneous effects (Imbens and Angrist, 1994 and Heckman, 1997). In the Appendix, I extend the IV analysis using distance to the Tordesillas line as an alternative instrument.[83] Beyond identification, what transmission mechanisms can be driving the observed differences?

[82]Despite being a neighbor, Paraguay is not among the main trading partners of Brazil and its trade share (exports plus imports) was less than 2% in 2010.

[83]I look at alternative estimations and intensity of treatment effects in the Appendix.

6 Persistence Mechanisms

This section presents particular occupational and cultural mechanisms that can be behind the persistent human capital and income differences observed. Guiso et a. (2006) define culture as "those customary beliefs and values that ethnic, religious, and social groups transmit fairly unchanged from generation to generation" and Nunn (2012) argues that "culture is an important mechanism that helps explain why historical shocks can have persistent impacts." Theoretically, historical and cultural factors can affect modern outcomes through path dependence in models of multiple equilibria (Nunn, 2007 and Guiso et al. 2008).[84] Models dealing explicitly with cultural diffusion have been developed by Bisin and Verdier (2000), Doepke and Zilibotti (2008) and Mokyr (2010), among others. Empirical contributions include Fernández (2010), Alesina et al. (2013) and Atkin (2014). I focus here on the persistence of occupational structures, inter-generational knowledge transmission and indigenous assimilation. To this end I use information from two specialized surveys: the Brazilian Cultural Module of the 2006 Municipal Survey and the Cultural Module of the 2011 Paraguayan Household Survey.[85] My setting is also unique in that I can essentially shut down the genetic mechanism. Naturally, the Jesuits did not intermarry: "Jesuits were never known to take Indian women as their concubines" (Ganson, 2003, p. 78). and the period from the missionary intervention to today is also too short to entail significant genetic changes.

6.1 Occupational Persistence

An important mechanism of transmission comes from the long-lasting transformation of occupational structures. In the spirit of Botticini and Eckstein's studies (2005, 2007 and 2012) the idea is that individuals that attended religious missions, receiving instruction and technical training, moved away from agriculture to start a proto-artisan class. Three pieces of empirical evidence point in this direction.

[84] Though in his model Nunn focuses on the impact of slavery in Africa, his distinction between equilibria with productive and unproductive activities due to colonial policies is still relevant in this context.

[85] Special thanks to Yolanda Barrios, Norma Medina and Zulma Sosa from the Paraguayan statistical office for sharing these data.

First, the Brazilian cultural survey asks specifically about the prevalence of handicraft activities. Embroidery was one of the activities in which the Jesuit missionaries trained the natives. Father Antonio Sepp, S.J., (1655-1773) describes in his letters the role of the workshops and how he instructed the natives to copy Dutch lace and embroidery (Amable, 1996, p. 58). In the state of Rio Grande do Sul the most important handicraft today is precisely embroidery, which results are presented in Table 10.[86] Surprisingly, hundreds of years after the Jesuit expulsion, missionary areas report more prevalence of this activity (Column 1). The empirical results are robust to the inclusion of geographic controls and larger at the local level (not shown). More generally, in the missions, "Full-time craftsmen included blacksmiths, carpenters, statuary artisans, gilders, silversmiths, tailors, hat makers, and bronze fabricators such as bell makers" (Crocitti, 2002, p. 9).[87] The long term effect of technical training is consistent with Botticini and Eckstein (2005, 2007, and 2012), where early human capital accumulation helped to consolidate a Jewish merchant and artisan class. A complementary interpretation is that embroidery could serve as a proxy for non-cognitive skills such as patience, consistent with the experimental evidence. [88]

I also examine the broader occupational structure of Paraguay. Because the data is at the individual level, I employ a probit specification with state fixed effects and errors clustered at the district level. In Table 10, it is evident that the areas closer to Jesuit Missions have moved away from agriculture to manufacturing and commerce (Columns 2 to 4). This structural transformation towards more productive activities is notable in an area that continues to be predominantly rural. There is an inextricable link between human capital investment decisions and occupational choices, as in Doepke and Zilibotti (2008).[89]

One last interesting source of variation in labor patterns can be observed in Figure 12. The figure plots the number of people working 15 to 39 hours a week. It appears that those closer to the

[86] The results also hold for other handicrafts.

[87] It will not come as a surprise then that these inhabitants assimilated better.

[88] I thank Joachim Voth for suggesting this point.

[89] I thank Fabrizio Zilibotti for suggesting this point. This is also consistent with the mechanism expounded before, where the portable skills transmitted to the natives might have helped to consolidate an artisan class.

missions are working more, consistent with Weberian cultural explanations.[90] I find supportive econometric results for labor force participation in Brazil. It appears that more people participate in the labor force in general (Table 10, Column 5) and that this effect is concentrated among females relative to males (Columns 6 and 7). This relates back to Max Weber's famous Protestant hypothesis. According to Weber this same ethic was found, "as early as St. Benedict [480-547], more so for the Cistercians [1098], and, finally, most decisively, for the Jesuits [1534]." (Weber, 2011, p. 130). For recent evidence comparing the thrift of these Catholic orders, see Barnebeck Andersen et al. (2013) for the Cistercian order in England and Akcomak et al. (2013) for the Brethren of the Common life in the Netherlands. Though Catholic, the Jesuits can be thought of as having the Puritan work ethic Weber underscored. In fact, he noted "The gradual rationalization of asceticism into an exclusively disciplinary method reached its apex in the Jesuit order." (Weber, 1978, p. 1172).[91]

6.2 Knowledge Transmission

As a specific element of cultural persistence I look directly at inter-generational knowledge transmission. This type of transmission is crucial for sustaining the persistent nature of the results shown. Though information on this topic is often neglected in standard surveys, such questions were included in the Cultural Module of the 2011 Paraguayan Household Survey. The results of this exercise can be found in Table 11.[92] First, I find that people in missionary areas report more knowledge of both traditional medicine and folktales (Columns 1 and 3). More importantly, they also declare having received this knowledge from their parents (2 and 4).[93] So the empirical evidence confirms inter-generational knowledge transmission as one of the cultural mechanisms behind the persistent outcomes observed.

[90] The relationship is statistically significant at the 1% level. A similar pattern can be observed for Paraguay, not reported.

[91] "Just as it constituted the goal of the exercitia [religious exercises] of St. Ignatius [of Loyola, 1491-1556] and the highest forms of rational monastic virtues in general, this active self-control constituted also Puritanism's defining practical ideal of life." (Weber, 2011, p. 130)

[92] I use again a probit specification with clustered standard errors at the district level.

[93] It also seems that this traditional knowledge was transmitted in Spanish (results not shown), suggesting the role of differential indigenous assimilation, a mechanism I explore further in the empirical extensions section.

I also examine skills and cultural activities that are specifically related to Jesuit interventions. In particular I look at accounting, which was taught in the religious missions (Crocitti, 2002).[94] The practice of accounting emerges more emphatically in missionary areas (Table 11, Column 5). A similar result can be seen for the literacy practice of keeping a diary (Column 6) and the more general cultural habit of visiting a library (Column 7).[95] It appears that areas closer to missions have higher levels of transmitted native knowledge and imported skills. The importance of such knowledge transmission mechanisms has been stressed recently by Wantchekon et al. (2013). The long-lasting prevalence of these portable skills is also consistent with inter-generational and vertical models of transmission (Cavalli-Sforza and Feldman, 1981, Boyd and Richerson 1985, Bisin and Verdier, 2000 and 2001).

Overall, the results in this section point towards transmission mechanisms that might be driving the persistent differences in income and human capital. I see the results of occupational persistence and inter-generational knowledge transmission as cultural markers that can help to further identify the missionary treatment. I do not argue that embroidery is driving modern growth in these areas, but instead take the view that this particular skill is part of the broader technological package transferred to the indigenous people by the Jesuits. The technological transfer is even more remarkable considering that there were only one to two Jesuit fathers per mission. Ultimately, the persistence of knowledge is instrumental to understanding how income, and especially human capital, might have taken divergent paths for hundreds of years. But did these differences in know-how translated into better social integration?

6.3 Indigenous Assimilation

One last way to analyze long-term cultural behavior is to look directly at indigenous assimilation (Diaz-Cayeros and Jha, 2012). Presumably, indigenous inhabitants that attended religious missions had an easier time assimilating into the colonial society when the Jesuits left, due to the skilled

[94] For a detailed account of the role of accounting in the Guarani Jesuit Missions, see Blumers (1992).

[95] I obtain similar results for visits to a museum.

training they acquired. An early indication of this mechanism can be observed in the 1890 Census.[96] In Table 12 we can see that people reported more mixed marriages (general mixed and *caboclo:* European and indigenous) in places closer to religious missions (Columns 1 and 2).[97] No such question was asked in later censuses. Interestingly, they also report being more Catholic, albeit from a very high base of 93% (Column 3).[98]

The prevalence of indigenous people in the missionary area can also be observed up until today. Column 4 in Table 12 reports results for Brazil. In 2010, more people report being indigenous the closer they are to a mission. This is interesting, since in Latin America areas with higher modern indigenous population density have been associated with lower levels of income.[99] A similar pattern can be found for Paraguay, when focusing on language. Guarani is one of the two official languages of Paraguay, along with Spanish, in itself a remarkable testament to the survival of the aboriginal tribes. In fact, linguists point directly to the religious missions for the survival of Guarani (Engelbretch and Ortiz, 1983). For empirical purposes, this also means that data on the prevalence of Guarani is recorded by the Paraguayan statistical office. The results using this data can be seen in Table 12, Columns 5 to 7.[100] It appears that there are less people speaking Guarani in the missionary areas and more people speaking Spanish. Furthermore, there are more people who report speaking *both* languages in these areas, again suggesting a differential process of assimilation.[101]

From early records of mixed marriages to contemporary data on indigenous population in Brazil and indigenous languages in Paraguay, it appears that indigenous people assimilated more in the missionary areas from colonial times up until the present day. Which other channels or mechanisms of transmission can be ruled out?

[96] Given the small number of observations, I include a reduced set of geographic controls.

[97] This mixing could affect the genetic composition of the population, though I still find more people that self-identify as Guarani in this area.

[98] I find similar results for modern data, not reported.

[99] The role of European population and development has been discussed in Acemoglu et al. 2002, Easterly and Levine, 2012, Putterman and Weil 2010, Chanda et al. 2014, and Valencia Caicedo and Maloney 2014.

[100] Because the data is again at the individual level, I employ a probit specification and cluster the errors at the district level. I also include state fixed effects for Paraguay, which leaves the results unaffected.

[101] These results also hold using data from the 1950 census. The colloquial combination of Spanish and Guarani is termed Yopará.

6.4 Robustness Checks

In this last section, I present complementary evidence for the Jesuit effect on modern income and human capital as the main channel of transmission. I do so by exploring alternative channels and analyzing heterogeneous effects. In particular, I rule out possible confounders such as population density, migration, health and tourism.

6.4.1 A. Population Density

Perhaps one of the most obvious alternative channels of transmission of the missionary effect is population density.[102] The religious entities might just have initiated future urban agglomerations, as in Becker at al. (2010). The results of this exercise can be found in Table 13. I find, if anything, that places close to the Jesuit Missions are less dense today. The coefficient is positive and significant for the full sample (Column 1) and insignificant for the more localized sample (Column 2).[103] These results do not come as a surprise when collated with the historical record, since Jesuit missionaries went to peripheral areas isolated from existing population centers. Even though the Jesuit Missions thrived historically, by no means did these places become modern metropolises (as can be seen in Figure A.4). I also explore the possible prior role of pre-colonial population density in Column 3.[104] Data come from Maloney and Valencia Caicedo (2012) and are only available at the state level. I do not find that the states where Guarani Jesuit missions were located are denser relative to their Argentinean, Brazilian and Paraguayan counterparts. The results suggest that the Jesuits affected the people they treated more than the places they visited.

6.4.2 Migration

Although the issue of migration has been addressed before in the paper, this section focuses specifically on this possible confounder. Migration informed the empirical strategy and, in particular, the usage of the more continuous nearest distance formulation. Historically, missions grew through natural reproduction rather than immigration (Livi-Bacci and Maeder, 2004). In the interme-

[102] As has been argued for Bai and Kai-sing Kung (2011) for China.
[103] I obtain similar results for even more reduced samples.
[104] I thank Nicola Gennaioli for suggesting this point.

diate historical results it also appeared that the human capital effect was concentrated among Argentinians and Brazilians as opposed to foreigners, but does this finding hold also for modern times?

To answer this question, I divide the Brazilian sample into municipalities with high and low mobility, namely, where people declare that they are residents or not of that municipality. Table 13 presents the results for these subsamples. It appears that the human capital results are concentrated among residents (Column 4). The results for non-residents are insignificant and smaller in magnitude (Column 5). It does not appear that people are sorting themselves into the missionary locations in modern times. If anything, there might have been historical outmigration from the area, so the results I find could be underestimates.

6.4.3 Health

I study here health as a human capital investment complementary to education.[105] The data availability is restricted to Brazilian municipalities. I use standard indicators such as mortality under 5 years of age and infant mortality, as well as a multidimensional health index.[106]I find negative and significant coefficients for the health index suggesting better health outcomes in these areas (Column 6). Moving 100 kilometers away from a mission is enough to go from a high to a fair level of health development, a sizable downgrade. Similarly, I find positive and significant coefficients for the mortality measures, indicating worse indicators the farther away from the missionary areas (results not shown).

6.4.4 Tourism

Another possible confounder of the Jesuit missionary results can be tourism. These areas might simply receive more visitors and this could explain their relative prosperity. To test for this confounder, I use data from the Cultural Module of the Brazilian Municipal Survey (2006). The

[105]The role of health was already explored in the Franciscan comparison section.

[106]The IFDM (Indice FIRJAN de Desenvolvimento Municipal) is the Brazilian counterpart of the UN Health Development Index (HDI). The health index includes items such as the number of prenatal visits and deaths due to ill-defined and avoidable causes.

survey asks about the prevalence of tourism-related activities in the area. Results can be found in Column 7. I find no effect on tourism when using distance to the nearest Jesuit mission. The coefficient is slightly positive (opposite sign) and insignificant. The results are not surprising given the relative isolation and inaccessibility of the places studied.

Taken together, the results in this section point towards the robustness of the missionary effect. They give additional evidence for education as the main channel of transmission for different subsamples. The results also help to rule out the possible role of confounders.

7 Conclusion

Going back to Voltaire and the controversy over the Guarani Jesuit Missions, though it is hard to measure mildness, I do find significant long-lasting effects of these religious institutions on education and income. I find a positive and significant effect of on median years of schooling and literacy, and even larger magnitudes for intermediate historical time periods. Places that are closer to historic missionary districts have incomes that are 10% higher today. The effects are larger at the local level and robust to the inclusion of geographic controls. A placebo test and instrumental variables techniques, suggest that these effects are causal. The impact is specific to missions from the Jesuit versus the Franciscan order, which did not focus on human capital and technical training. Inhabitants of former Jesuit missionary areas have higher non-cognitive abilities and exhibit more pro-social behavior. Moreover, the enduring differences are consistent with specific cultural mechanisms of occupational persistence, inter-generational knowledge transmission and indigenous assimilation. Additional robustness tests suggest that the missionary results are not being driven by migration, urbanization or tourism.

Are the observed differences important? I interpret the differences of around 10% as substantial, yet plausible. My results are consistent with those of Nunn (forthcoming) for nineteenth-century Christian missions in Africa and similar in magnitude to well-established conditional cash tranfer programs such as *Bolsa Familia*. It is remarkable that these effects are still observable centuries after the Jesuit expulsion and are present in countries with different institutional trajectories. To analyze the economic importance of my results, I run a specification of income on literacy, instrumented by distance to the nearest Jesuit Mission. [107] I find estimates on the order of 8%, a value consistent with micro evidence in general and the particular estimates for Argentina, Brazil and Paraguay (Psacharopoulos and Patrinos, 2004). In terms of policy, being aware of these observed differences could aid governments to better target and cater education and labor-training programs.

More broadly, the case of the Guarani Jesuit Missions serves as a microcosm to study important economic questions. I find not only an important degree of economic persistence, in line with the recent literature, but also broad channels and specific transmission mechanisms through which this persistence is enacted. In particular, I demonstrate how human capital differences can emerge in the long term leading to persistent differences in educational, economic and behavioral outcomes.[108] Futhermore, I document specific cultural and occupational mechanisms that can sustain these differences. The evidence in this regard suggests the salience of vertical cultural transmission.

Overall, the findings in this paper underscore the importance of particular historical events for long-term development and growth (Nunn, 2009 and 2013). I believe that such historical accidents can be instrumental in answering policy-relevant questions for which few counterfactuals exist today. This type of research can help us uncover deep-rooted factors of development. Far from advocating historical determinism, a thorough understanding of these historical forces and their implied constraints offers the opportunity to make development policies more targeted and effective.

[107] I view this simply as a benchmarking exercise, as the potential endogeneity of missionary location has already been discussed throughout the paper. Additionally, missions might have impacted modern outcomes through other channels besides formal human capital, like culture.

[108] Future research could further examine the behavior of individuals and firms in situ.

References

Acemoglu, D., Gallego, F.A., & Robinson, J.A. (2014): "Institutions, Human Capital and Development." NBER Working Paper No. 19933. Cambridge, MA.

Acemoglu, D. Hassan, T.A. and Robinson, J.A. (2011): "Social Structure and Development: A Legacy of the Holocaust in Russia." 126.2, 895–946.

Acemoglu, D., Johnson, S., & Robinson, J.A. (2001): "The Colonial Origins of Comparative Development: An Empirical Investigation." *American Economic Review*, 91.5, 1369-1401.

Acemoglu, D., Johnson, S., & Robinson, J.A. (2002): "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution." *Quarterly Journal of Economics*, 117.4, 1231-1294.

Acemoglu, D., & Robinson, J.A. (2012)*: Why Nations Fail: The Origins of Power, Prosperity, and Poverty.* New York: Crown Business.

Akcomak, S., Webbink, D. & ter Weel, B. (2013): "Why Did the Netherlands Develop so Early? The Legacy of the Brethren of the Common Life." CPB Discussion Paper, 228.

Alden, D. (1996): *The Making of an Enterprise: the Society of Jesus in Portugal, its Empire, and Beyond, 1540-1750.* Stanford, CA: Stanford University Press.

Alesina, A., Paola Giuliano, P., & Nunn, N. (2013): "On the Origins of Gender Roles: Women and the Plough." *Quarterly Journal of Economics*, 128.2, 469-530.

Altonji, J., Elder, T., & Taber, C. (2005): "Selection on Observed and Unobserved Variables: Assessing the Effectiveness of Catholic Schools." *Journal of Political Economy*, 113.1, 151-184.

Amable, M.A., (1996): *Historia Misionera: una perspectiva integradora.* Asuncion: Ediciones Montoya.

Angrist, J.D., & Pischke, J-S. (2008): *Mostly Harmless Econometrics: An Empiricist's Companion.* Princeton, NJ: Princeton University Press.

Ashraf, Q., & Galor, O. (2011): "Dynamics and Stagnation in the Malthusian Epoch." *The American Economic Review*, 101.5., 2003-2041.

Ashraf, Q., & Galor, O. (2013): "The 'Out-of-Africa' Hypothesis, Human Genetic Diversity, and Comparative Economic Development." *American Economic Review*, 103.1, 1–46.

Astrain, A. (1996): J*esuitas, Guaraníes y encomenderos.* Ed. Bartomeu Melià. Asuncion: Centro de Estudios paraguayos, Antonio Guasch.

Atkin, D. (2014): "The Caloric Costs of Culture: Evidence from Indian Migrants." Yale University, manuscript.

Bai, Y., & Kai-sing Kung, J. (2011): "Diffusing Knowledge while Spreading God's Message: Protestantism and Economic Prosperity in China, 1840–1920." Hong Kong University of Science and Technology, manuscript.

Banerjee, A., & Iyer, L. (2005): "History, Institutions, and Economic Performance: The Legacy of Colonial Land Tenure Systems in India." *American Economic Review*, 95.4, 1190-1213.

Barnebeck Andersen, T., Bentzen, J., Dalgaard , C-J. & Sharp, P. (2013): "Pre-reformation roots of the protestant ethic." CAGE Online Working Paper Series No. 42. University of Warwick.

Barro, R.J., (2001): "Human capital and growth." *American Economic Review*, 91.2, 12-17.

Becker, S.O., Boeckh, K., Hainz. & Woessmann, L. (2014). "The Empire Is Dead, Long Live the Empire! Long-Run Persistence of Trust and Corruption in the Bureaucracy." *Economic Journal*, 1468-0297.

Becker, S.O., Cinnirella, F., & Woessmann, L. (2010). "The trade-off between fertility and education: evidence from before the demographic transition." *Journal of Economic Growth*, 15.3, 177-204.

Becker, S.O., & Woessmann, L. (2008). "Luther and the Girls: Religious Denomination and the Female Education Gap in Nineteenth Century Prussia." *The Scandinavian Journal of Economics*, 110.4, 777-805.

Becker, S.O. & Woessmann, L. (2009): "Was Weber Wrong? A Human Capital Theory of Protestant Economic History." *Quarterly Journal of Economics*, 124.22: 531-596.

Bellows, J. & Miguel, E. (2009). "War and local collective action in Sierra Leone." *Journal of Public Economics*, 93.11–12, 1144-1157.

Benhabib, J., & Spiegel, M.M. (1994): "The role of human capital in economic development evidence from aggregate cross-country data." *Journal of Monetary Economics*. 34.2, 143-173.

Bethell, L., ed. (1994): "The Cambridge History of Latin America." Vol. 2. Cambridge: Cambridge University Press.

Bisin, A., & Verdier, T. (2000): "Beyond The Melting Pot: Cultural Transmission, Marriage, And The Evolution Of Ethnic And Religious Traits." *Quarterly Journal of Economics*, 66.3, 955-988.

Bisin, A. & Verdier, T. (2001): "The economics of cultural transmission and the dynamics of preferences." *Journal of Economic Theory*, 97.2, 298-319.

Bleakley, H., & Lin, J. (2012): "Portage and path dependence." *Quarterly Journal of Economics*, 127.2, 587.

Blumers, T. (1992): La contabilidad en las reducciones Guaraníes. Asunción: Centro de Estudios Antropológicos, Universidad Católica.

Bolton, H.E., (1917): "The mission as a frontier institution in the Spanish-American colonies." *The American Historical Review*, 23.1,42-61.

Botticini, M. & Eckstein, Z. (2007): "From Farmers to Merchants, Conversions and Diaspora: Human Capital and Jewish History." *Journal of the European Economic Association*, 5.5, 885-926.

Botticini, M. & Eckstein, Z. (2005): "Jewish Occupational Selection: Education, Restrictions, or Minorities?" *The Journal of Economic History*, 65.4, 922-948.

Botticini, M. & Eckstein, Z. (2012): *The Chosen Few: How Education Shaped Jewish History*. Princeton, NJ: Princeton University Press.

Boyd, R. & Richerson, P.J. (1985): *Culture and the Evolutionary Process*. Chicago: University of Chicago Press.

Bruhn, M. & Gallego, F.A. (2012) "Good, Bad, and Ugly Colonial Activities: Do They Matter for Economic Development?" *Review of Economics and Statistics*, 94.2, 433-461

Cagé, J., & Rueda, V. (2013): "The Long Term Effects of the Printing Press in Sub Saharan Africa." Sciences Po, manuscript.

Campante, F. R., and Yanagizawa-Drott., D.H. “Does Religion Affect Economic Growth and Happiness? Evidence from Ramadan.” NBER Working Paper No. 19768. Cambridge, MA.

Cantoni, D. (forthcoming) “The Economic Effects of the Protestant Reformation: Testing the Weber Hypothesis in the German Lands.” *Journal of the European Economic Association.*

Carbonell de Massy, R. (1992) *Estrategias de desarrollo rural en los pueblos Guaraníes.* Barcelona: Antoni Bosch.

Cavalli-Sforza, L. & Feldman, M. (1981): *Cultural Transmission and Evolution: A Quantitative Approach.* Princeton, NJ: Princeton University Press.

Chanda, A., C. Cook, J. & Putterman, L. (2014): “Persistence of Fortune: Accounting for Population Movements, There Was No Post-Columbian Reversal.” *American Economic Journal: Macroeconomics*, 6.3, 1-28.

Chen, Y., Wang, H. & Yan, S. (2013): “The Long-Term Effects of Christian Activities in China.” Peking University, manuscript.

Chipman, D. Álvar Núñez Cabeza de Vaca (2014): *The 'Great Pedestrian' of North and South America.* Austin, TX: Texas University Press.

Comin, D., Easterly, W. & Gong, E. (2010): “Was the Wealth of Nations Determined in 1000 BC?” *American Economic Journal: Macroeconomics*, 2.3, 65-97.

Crocitti, J.J. (2002): “The internal economic organization of the Jesuit missions among the Guarani.” *International Social Science Review*, 77.1-2, 3–15.

de Carvalho Filho, I., & Colistete, R.P. (2010): “Education performance: was it all determined 100 years ago? Evidence from São Paulo, Brazil.” MPRA Paper No. 24494. Munich.

de Carvalho Filho, I., & Monasterio, L., (2011): “Immigration and the Origins of Regional Inequality: Government-sponsored European Migration to Southern Brazil before World War I.” *Regional Science and Urban Economics*, 42.5, 794-807.

Dell, M. (2012): “Path Dependence in Development: Evidence from the Mexican Revolution.” Harvard University, mimeograph.

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

Diamond, J. (1997): Guns, germs, and steel: the fates of human societies. New York: WW Norton & Company: 14.

Diaz-Cayeros, A., & Jha, S.. (2012): “Global Trade, Contracts and Poverty Alleviation in Indigenous Communities: Cochineal in Mexico.” Stanford University, manuscript.

Dittmar, J.E. (2011): “Information technology and economic change: the impact of the printing press.” *Quarterly Journal of Economics*, 126.3, 1133-1172.

Doepke, M., & Zilibotti, F. (2008): “Occupational Choice and the Spirit of Capitalism.” *Quarterly Journal of Economics*, 123.2, 747-793.

Droller, F. (2012): “Migration and Long-run Economic Development: Evidence from Settlements in the Pampas.” Brown University, mimeograph.

Durán Estragó, M. (1987): *Presencia franciscana en el Paraguay.* Asunción: Universidad Católica.

Duranton, G. & Turner, M.A. (2012). “Urban Growth and Transportation.” *Review of Economic Studies*, 79, 1407–1440.

Duranton, G., Morrow, P.M. & Turner, M.A. (2014). “Roads and Trade: Evidence from the US.” *Review of Economic Studies*, 81, 681–724.

Easterly, W., & Levine, R. (2012): "The European Origins of Economic Development." NBER Working Paper No. 18162. Cambridge, MA.

Engelbretch, G. & Ortiz, L. (1983): "Guarani Literacy in Paraguay." *International Journal of the Sociology of Language*, 42, 53-67.

Engerman, S.L., & Sokoloff, K.L. (1997): "Factor endowments, institutions, and differential paths of growth among new world economies." In: *How Latin America Fell Behind*, 260-304.

Falk, A., Becker, A., Dohmen, T., Huffman, D., & Sunde, U. (2012). "An experimentally validated preference module." University of Bonn, mimeograph.

Feyrer, J., & Sacerdote, B. (2009): "Colonialism and modern income: islands as natural experiments." *The Review of Economics and Statistics*, 91.2, 245-262.

Fernández, R. (2010): "Does culture matter?" NBER Working Paper No. 16277. Cambridge, MA.

Finan, F. & Schechter, L. (2012): "Vote-Buying and Reciprocity." *Econometrica*, 80.2, 863-881.

Fischbacher, U. & Föllmi-Heusi, F. (2013) "Lies in Disguise—an Experimental Study on Cheating." *Journal of the European Economic Association.* 11.3, 525-547.

Frankema, E.HP. (2012): "The origins of formal education in sub-Saharan Africa: was British rule more benign?" *European Review of Economic History*, 16.4, 335-355.

Furlong, C.G, & Muriel, D. (1955): *Domingo Muriel, A. J., Y Su Relación De Las Misiones (1766).* Buenos Aires: Librería del Plata.

Furlong, G., & Storni, F. (1994): *Los jesuitas y la cultura rioplatense*. Buenos Aires: Biblos.

Galán García, A. (1995): *El Oficio de Indias de los jesuitas en Sevilla, 1566-1767.* Sevilla: Fondo de Cultura de Sevilla.

Gallego, F.A. (2010): "Historical origins of schooling: The role of democracy and political decentralization." *The Review of Economics and Statistics*, 92.2, 228-243.

Gallego, F.A., & Woodberry, R. (2010): "Christian missionaries and education in former African colonies: How competition mattered." *Journal of African Economies*, 19.3, 294-329.

Gallup, J.L., Sachs, J.D., & Mellinger, A.D. (1999): "Geography and economic development." *International Regional Science Review*, 22.2, 179-232.

Galor, O. (2011): Unified Growth Theory. Princeton, NJ: Princeton University Press.

Galor, O., & Weil, D.N. (2000): "Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond." *American Economic Review*, 90.4, 806-828.

Gálvez, L. (1995): *Guaraníes y Jesuitas: De la tierra sin mal al paraíso*. Buenos Aires: Sudamericana.

Ganson, B.A. (2003): *The Guaraní under Spanish rule in the Río de la Plata.* Stanford, CA: Stanford University Press.

Gennaioli, N., et al. (2013): "Human Capital and Regional Development." *Quarterly Journal of Economics*, 128.1, 105-164.

Gennaioli, N., & Rainer, I. (2007): "The modern impact of precolonial centralization in Africa." *Journal of Economic Growth*, 12.3, 185-234.

Glaeser, E. L., La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2004): "Do institutions cause growth?" *Journal of Economic Growth*, 9.3, 271-303.

Glaeser, E. L., & Sacerdote, B. (2008): "Education and Religion." *Journal of Human Capital*, 2.2, 188-215.

Graham, R. B. C. (1901): *A vanished Arcadia: being some account of the Jesuits in Paraguay, 1607 to 1767.* London: William Heinemann.

Greenstone, M., Hornbeck, R. & Moretti, E. (2010): "Identifying agglomeration spillovers: Evidence from winners and losers of large plant openings." *Journal of Political Economy*, 118.3, 536-598.

Greif, A. (1993): "Contract enforceability and economic institutions in early trade: The Maghribi traders' coalition." *The American Economic Review*, 83.3, 525-548.

Greif, A. (1994): "Cultural beliefs and the organization of society: A historical and theoretical reflection on collectivist and individualist societies." *Journal of Political Economy*, 102.5, 912-950.

Grosfeld, I., Rodnyansky, A. & Zhuravskaya, E. (2013): "Persistent Antimarket Culture: A Legacy of the Pale of Settlement after the Holocaust." *American Economic Journal: Economic Policy*, 5.3, 189-226.

Grosfeld, I., & Zhuravskaya, E. (2013): "Persistent effects of empires: Evidence from the partitions of Poland." Paris School of Economics, Manuscript.

Grosjean, P. (2010): "A History of Violence: The 'Culture of Honor' as a Determinant of Homicide in the US South." UNSW Australia Business School, Manuscript.

Guiso, L., Sapienza, P., & Zingales, L. (2008): "Long term persistence." NBER Working Paper No. 14278. Cambridge, MA.

Hanushek, E.A., & Woessmann, L. (2008): "The role of cognitive skills in economic development." *Journal of Economic Literature*, 46.3, 607-668.

Hanna, R. & Wang, S. "Dishonesty and Selection into Public Service." NBER Working Paper No. 14278. Cambridge, MA.

Hanushek, E.A., & Woessmann, L. (2012): "Schooling, educational achievement, and the Latin American growth puzzle." *Journal of Development Economics*, 99.2, 497-512.

Heckman, J. (1997): Instrumental variables: A study of implicit behavioral assumptions used in making program evaluations. Journal of Human Resources, 441-462.

Heckman, J.J. (2000): "Policies to foster human capital." *Research in Economics*, 54.1,3-56.

Heckman, J.J., & Rubinstein, Y. (2001): "The importance of noncognitive skills: Lessons from the GED testing program." *American Economic Review*, 91.2, 145-149.

Heckman, J.J., Stixrud, J., & Urzua, S. (2006): "The Effects of Cognitive and Noncognitive Abilities on Labour Market Outcomes and Social Behavior." *Journal of Labor Economics*, 24.3, 411-482.

Henderson, J. V., Storeygard, A. and Weil., D.N. (2012): "Measuring economic growth from outer space." *American Economic Review*, 102.2, 994-1028.

Hernández, P.J. (1913): *Misiones Del Paraguay: Organización Social De Las Doctrinas Guaraníes De La Compañía De Jesús.* Barcelona: G. Gili.

Hornung, E. (2014): "Immigration and the diffusion of technology: The Huguenot diaspora in Prussia." *American Economic Review*, 104.1, 84-122.

Huillery, E. (2009): "History matters: The long-term impact of colonial public investments in French West Africa." *American Economic Journal: Applied Economics*, 1.2, 176-215.

Iannaccone, L.R. (1990): "Religious practice: A human capital approach." J*ournal for the Scientific Study of Religion*, 29.3, 297-314.

Imbens, G.W., & Angrist, J.D. (1994): "Identification and estimation of local average treatment effects." *Econometrica*, 62.2, 467-475.

Jackson, R.H. (2008): "The population and vital rates of the Jesuit missions of Paraguay, 1700–1767." *Journal of Interdisciplinary History*, 38.3, 401-431.

Jedwab, R., Kerby, E., & Moradi, A. (2014): "History, Path Dependence and Development: Evidence from Colonial Railroads, Settlers and Cities in Kenya." George Washingotn University, Manuscript.

Jha, S. (2013): "Trade, Institutions, and Ethnic Tolerance: Evidence from South Asia." *American Political Science Review*. 107.4, 806-832.

Landes, D.S. (1998): *The Wealth and Poverty of Nations: Why Some Countries are so Rich and Some so Poor*. New York, NY: W.W Noton.

Lankina, T., & Getachew, L. (2012): "Mission or Empire, Word or Sword? The Human Capital Legacy in Postcolonial Democratic Development." *American Journal of Political Science*, 56.2, 465-483.

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1998): "Law and Finance." *Journal of Political Economy*, 106.6, 1113-1155.

Livi-Bacci, M., & Maeder, E.J. (2004): "The Missions of Paraguay: the demography of an Experiment." *Journal of Interdisciplinary History*, 35.2, 185-224.

Lowes, S., Nunn, N., Robinson, J.A. & Weigel, J. "The Evolution of Culture and Institutions: Evidence from the Kuba Kingdom." Harvard University, manuscript.

Maeder, E.J.A. (1995): "Asimetría demográfica ente las reducciones franciscanas y jesuíticas de guaraníes." *Revista Complutense de Historia de América*. 21, 71-83.

Maloney, W. F. & Valencia Caicedo, F. (2012): "The Persistence of (Subnational) Fortune: Geography, Agglomeration, and Institutions in the New World." Policy Research Working Paper 6187. World Bank.

Maloney, W.F., & Valencia Caicedo, F. (2014): "Engineers, Innovative Capacity and Development in the Americas." Policy Research Working Paper 6814. World Bank.

Mankiw, N.G., Romer, D. & Weil, D.N. (1992): "A contribution to the empirics of economic growth." *Quarterly Journal of Economics*, 107.2, 407-437.

Mantovanelli, F. (2013): "The Protestant Legacy: Missions and Literacy in India." Boston College, Manuscript.

McCleary, R.M., & Barro, R. (2003): "Religion and Economic Growth Across Countries." *American Sociological Review*, 68.5, 760-781.

McCleary, R.M., & Barro, R.J. (2006): "Religion and Economy." *Journal of Economic Perspectives*, 20.2, 49-72.

McKay, R., Efferson. C., Whitehouse H. & Fehr, E. (2010): "Wrath of God: religious primes and punishment" *Proceedings of the Royal Society B: Biological Sciences.* 278.1713, 1858-63

McCleary, R.M., & Pesina, J. (2011): "Religious Competition, Protestant Syncretization, and Conversion in Guatemala since the 1880s." Harvard University, manuscript.

Meier zu Selhausen, F. (2014): "Missionaries and female empowerment in colonial Uganda: New evidence from Protestant marriage registers, 1880–1945." *Economic History of Developing Regions*, 29.1, 1-39.

Michaels, G. (2008): "The effect of trade on the demand for skill: Evidence from the interstate highway system." *The Review of Economics and Statistics*, 90.4, 683-701.

Michalopoulos, S., & Papaioannou, E. (2013): "Pre-Colonial Ethnic Institutions and Contemporary African Development." *Econometrica*, 81.1, 113-152.

Mokyr, J. (2010).: "Entrepreneurship and the industrial revolution in Britain." In: *The Invention of Enterprise: Entrepreneurship from Ancient Mesopotamia to Modern Times*, 183-210.

Musacchio, A., Martinez, A. & Viarengo, M. (2014): "Colonial Institutions, Commodity Booms, and the Diffusion of Elementary Education in Brazil, 1889-1930." NBER Working Paper No. 20029. Cambridge, MA.

Naritomi, J., Soares, R.R. & Assunção, J.J. (2012): "Institutional development and colonial heritage within Brazil." *The Journal of Economic History*, 72.2, 393-422.

Norenzayan, A. (2014). *Big Gods*. Princeton, NJ: Princeton University Press.

Nunn, N. (2007): "Historical legacies: A model linking Africa's past to its current underdevelopment." *Journal of Development Economics*, 83.1, 157-175.

Nunn, N. (2008): "The Long-Term Effects of Africa's Slave Trades." *Quarterly Journal of Economics*, 123.1, 139-176.

Nunn, N. (2009): "The Importance of History for Economic Development." *Annual Review of Economics*, 1.1, 65-92.

Nunn, N. (2010): "Religious Conversion in Colonial Africa." *American Economic Review, Papers & Proceedings*. 100.2, 147-52.

Nunn, N. (2012): "Culture and the historical process." *Economic History of Developing Regions*, 27.1, 108-126.

Nunn, N. (2013): "Historical Development." In: Aghion P., Durlauf S. *Handbook of Economic Growth*. Vol. 2. North-Holland.

Nunn N. (forthcoming): "Gender and Missionary Influence in Colonial Africa." In: Akyeampong E, Bates R, Nunn N, Robinson J.A. *African Development in Historical Perspective*: Cambridge: Cambridge University Press.

Nunn, N., & Puga, D. (2012): "Ruggedness: The blessing of bad geography in Africa." *Review of Economics and Statistics*, 94.1, 20-36.

Nunn, N., & Wantchekon, L. (2011): "The Slave Trade and the Origins of Mistrust in Africa." *American Economic Review*, 101.7, 3221-52.

Okoye, D. and Pongou, R. (2014): "Historical Missionary Activity, Schooling, and the Reversal of Fortunes: Evidence from Nigeria." MPRA Paper No. 58052. Munich.

Oster, E. (2013): "Unobservable Selection and Coefficient Stability: Theory and Validation." NBER Working Paper No. 19054. Cambridge, MA.

Palacios, S. & Zoffoli. E. (1991): *Gloria y Tragedia de las Misiones Guaraníes*. Bilbao: Ediciones Mensajero.

Popescu, O. (1967): *El sistema económico en las misiones jesuíticas: un vasto experimento de desarrollo indoamericano*. Barcelona: Ariel.

Psacharopoulos, G., & Patrinos, H.A. (2004): "Returns to investment in education: a further update." *Education Economics,* 12.2, 111-134.

Putnam, R.D., Leonardi, R. & Nanetti, R.Y. (1994): *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton, NJ: Princeton University Press.

Putterman, L., & Weil, D.N. (2010): "Post-1500 Population Flows and the Long Run Determinants of Economic Growth and Inequality." *Quarterly Journal of Economics*, 125.4, 1627-1682.

Rappaport, J., & Sachs, J.D. (2003): "The United States as a coastal nation." *Journal of Economic Growth*, 8.1, 5-46.

Rocha, R., Ferraz, C. & Soares, R.R. (2013): "Human Capital and Development: The Legacy of European Settlements in Brazil." PUC Rio, manuscript.

Saguier, R.B., ed. (1991): *Tentación de la utopía: las misiones jesuíticas del Paraguay.* Virginia: Tusquets.

Salinas, M.L. (2010): "Vida y trabajo en la misión, jesuitas y franciscanos en las misiones del Paraguay en perspectiva comparada: Siglo XVII." In: Fronteiras e Indentidades. XIII Jornadas Internacionales sobre Missoes Jesuíticas. Dourados, Brazil.

Sarreal, J. (2014): *The Guaraní and Their Missions: A Socioeconomic History.* Stanford, CA: Stanford University Press.

Schechter, L. (2007): "Theft, gift-giving, and trustworthiness: Honesty is its own reward in rural Paraguay." *American Economic Review*, 97.5, 1560-1582.

Spolaore, E., & Wacziarg, R. (2013): "How Deep Are the Roots of Economic Development?" *Journal of Economic Literature*, 51.2, 325-69.

Spolaore, E., & Wacziarg, R. (2009): "The Diffusion of Development." *Quarterly Journal of Economics*, 124.2, 469-529.

Squicciarini, M.P., & Voigtländer, N. (2014): "Human Capital and Industrialization: Theory and Evidence from 18th Century Encyclopédie Subscriptions." UCLA Anderson, manuscript.

Summerhill, W. (2010): "Colonial institutions, slavery, inequality, and development: evidence from São Paulo, Brazil." MPRA Paper No. 22162. Munich.

Tabellini, G. (2008): "Presidential address institutions and culture." *Journal of the European Economic Association*, 6.2-3, 255-294.

Voigtländer, N., & Voth, H-J. (2012): "Persecution Perpetuated: The Medieval Origins of anti-Semitic Violence in Nazi Germany." *Quarterly Journal of Economics*, 127.3, 1339-1392.

Voltaire, (1756): *Essay on the Customs and the Spirit of the Nations.* Paris.

Voltaire, (1770): *Histoire Philosophique et Politique des Indes (1770).* Amsterdam.

Waldinger, F. (2012): "Bombs, Brains, and Science: The Role of Human and Physical Capital for the Creation of Scientific Knowledge." CAGE Online Working Paper Series 78. University of Warwick.

Waldinger, M. (2013): "Colonial Missionaries and Long Run Development in Mexico." LSE, manuscript.

Wantchekon, L., Natalija N., & Klašnja, M. (2013): "Education and Human Capital Externalities: Evidence from Colonial Benin." Princeton University, manuscript.

Weber, M. (1978): *Economy and Society.* Berkeley: University of California Press.

Weber, M. (2011): *The Protestant Ethic and the Spirit of Capitalism.* Oxford: Oxford University Press.

Wietzke, F.B. (2014): Universal primary education, private schooling and interreligious inequality: The case of Madagascar. LSE, manuscript.

Wilde, G. (2009): Religión y poder en las misiones de guaraníes. Buenos Aires: SB.

Woodberry, R.D. (2012): "The missionary roots of liberal democracy."*American Political Science Review,* 106.2, 244-274.

Woodberry, R.D. (2004): "The shadow of empire: Christian missions, colonial policy, and democracy in postcolonial societies." University of North Carolina at Chapel Hill, mimeograph.

World Bank (2008): *Reshaping Economic Geography.* World Development Report. Washington, DC.

I. Data Appendix

In this section I provide more detailed information about the variables, units and souces used in the paper.

A. Income and Poverty

Income: Data for Brazil comes from the *Instituto Brasileiro de Geografia e Estatística* (IBGE) and can be accessed through IPEA.[109] The data measures total annual income in 2000 in contemporary Brazilian R$. As is standard, I take the natural logarithm of this number.[110] Comparable data for Paraguay are available from the World Bank (2008) World Development Report on Reshaping Economic Geography. The data are for mean per capita income in 2005 US dollars; for details please see Maloney and Valencia Caicedo (2012).

Poverty: Since income data are not available at the municipality level for Argentina, I instead use comparable poverty data on the Unsatisfied Basic Needs (UBN) index measured for both households and individuals. The data for Argentina are from the *Instituto Nacional de Estadística y Censos* (INDEC)for 2001.[111] Similar data for Paraguay comes from the *Dirección General de Estadística, Encuestas y Censos* (DGEEC) and is for 2002.[112]

Nighttime Satellite Images: For illustrative purposes, I use the nighttime satellite data from the F18-2010 mission, available at http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html. This data has been used as a proxy for income in Henderson et al. (2012), and Michalopoulos and Papaioannou (2013).

B. Human Capital

Literacy: Literacy (and illiteracy) rates are measured in percentages of the relevant population. Data for Brazil are also from the IBGE is for people aged 15 or 25 and above in 2000. Data for Paraguay come from DGEEC and are for people aged ten years and above in 2002. Literacy data for Argentina are again from INDEC for people aged ten years and above in 2001.

Median Years of Schooling: Brazil's IBGE reports data on median years of schooling for people 25 aged years and above in 2000. No similar information is reported for Argentina or Paraguay.

[109] http://www.ibge.gov.br/home/ and http://www.ipeadata.gov.br/

[110] Highly correlated data for municipal level GDP are also available and used for robustness only, as they tend to be less reliable than income measures at this level of disaggregation.

[111] http://www.indec.mecon.ar/

[112] http://www.dgeec.gov.py/

C. Missionary Presence

Missionary Dummy: is the simplest measure and takes the value of 1 for the municipality that had a mission historically and 0 otherwise. This coarse measure assumes that the boundaries of the missions were strict and is mostly used for descriptive purposes.

Missionary Distance: This more continuous variable denotes the closest distance between a municipality's centroid and a historical mission. It is measured in kilometers and calculated using STATA and ArcGIS. This measure is more informative and flexible with respect to missionary boundaries. A similar measure is used to study the effect of Franciscan Missions.

Missionary Population: For most of the thirty Jesuit Missions I was able to obtain historic information on the indigenous population from the Archivo General de Indias and the Roman Jesuit Archive (Vatican). Though incomplete, the records cover the period from 1650 to 1790, giving a rough picture of the contemporary conditions of the religious establishments (see Figure A.1). This measure can also be used to capture intensity of treatment effects. Comparable information is also available for some Franciscan missions.

Year of Foundation: Similarly, I obtain the year of foundation of Guarani Jesuit Missions, which can be used to calculate the number of years they was active and capture the intensity of treatment.

Mission Moved: Lastly, I construct a dummy variable taking the value of 1 if the Mission moved and 0 otherwise, again to capture the intensity of treatment effect.

D. Geographic and Weather Controls

Area: Total area in squared kilometers taken from IBGE (2010) for Brazil, and calculated with ArcGIS for Argentina and Paraguay.

Altitude: Elevation measured in meters over sea level originally available at very high resolution from WorldClim and processed using ArcGIS.[113] Similar data are also available from IBGE (2000) for Brazil and used alternatively for robustness. Recorded separately in the household survey.

Latitude and Longitude: Measured in decimal degrees for the municipal centroid and taken from IPEA (2000) for Brazil, and calculated with ArcGIS for Argentina and Paraguay. Recorded separately in the household survey.

Temperature: Annual mean temperature measured in °C x 10 available originally at very high resolution (around 1 kilometer grid cells) from BIOCLIM (BIO12) and processed using ArcGIS.[114] Alternative comparable data are also available for Brazil from IPEA based on the Climate Research Unit of University of East Anglia (CRU-UEA) project.

[113] http://worldclim.com/
[114] http://www.worldclim.org/bioclim

Rainfall: Annual precipitation in millimeters also available from BIOCLIM (BIO1) converted using ArcGIS. Alternative data are also available for Brazil from IPEA based on the CRU-UEA project.

Ruggedness: Terrain ruggedness index in millimeters, originally available from Nunn and Puga 2012) at high-resolution (30 x 30 arc-seconds) and later processed using ArcGIS.[115]

Slope: Similar to ruggedness, in thousandths of a percentage point, also originally from Nunn and Puga (2012) at the grid cell level and processed with ArcGIS.

Distance to River: Distance to the nearest river in decimal degrees is calculated using ArcGIS with the waterways shape file for South America.[116]

Distance to Coast: Distance to the nearest coast in decimal degrees is also calculated using ArcGIS using the world coastline shape file.[117]

Coastal Dummy: Alternatively, a simple dummy taking the value of 1 for a municipality that has direct access to the coast and 0 if landlocked, also calculated using ArcGIS.[118]

E. Historical Outcomes

Historical Literacy: Literacy and illiteracy rates are measured in percentages over the relevant population. Data for Argentina comes from the 1895 and 1914 censuses.[119] Data for Brazil is from the 1920 and 1940 censuses and data for Paraguay from the 1950 census.[120] The municipal level data provides information for different age groups and for males and females separately. Data for Argentina (1895 and 1914) and Brazil (1920) further distinguish between native and foreign literacy rates, allowing for the exploration of heterogeneous effects.

Religion: The religion of the respondent is first recorded in the 1890 Brazilian Census. The Brazilian IBGE also reports the religion of the respondent for modern times.

Mixed Marriage: Data on the partner's race (white, mixed, caboclo and mestizo) are available from the 1890 Brazilian Census.

Language: Since Paraguay is a bilingual country, the 1950 Paraguayan census records the language of the respondent: Guarani, Spanish or both.

[115] http://diegopuga.org/data/rugged/
[116] Available, among others at: http://mapcruzin.com/
[117] See: http://openstreetmapdata.com/data/coastlines
[118] The standard agricultural suitability (FAO-GAEZ or University of Wisconsin SAGE) data is available at the 5-minute grid cell resolution, which is coarser than the municipality level data used in this paper.
[119] The 1869 Argentina Census does not report literacy.
[120] The 1890 Brazil Census does not report literacy. I thank Vicky Fouka for sharing her Rio Grande do Sul historical literacy data.

F. Cultural and Experimental Variables

Altruism: From the household survey, in Guaranis, respondents were asked to imagine they received 1 million Guaranis and then asked how much of that amount they would donate to charity.

Positive Reciprocity: From a hypothetical trust game, in which an initial amount of 10,000 (about 2 dollars) is allocated to each individual. Any quantity transferred to the other person is multiplied by 3. Then the other person has to decide the allocation of the total amount: 10,000 plus the amount transferred multiplied times three. The answer for this exercise corresponds to the case in which the other person has transferred his / her full amount, for a total of 40,000 Guaranis to be redistributed. Answers were also recorded for 0 and 5,000 transfers for a total of 10,000 and 25,000 Guaranis to be redistributed.

Time Discounting: From the household survey, corresponds to the ypothetical answer (in Guaranis) to the payment expected to receive in 12 months in exchange for a payment of 1,000,000 Guaranis today.

Certainty Equivalence: From the household survey, corresponds to the hypothetical answer (in Guaranis) to the the certain payment the respondent would prefer to a 50-50 lottery of 0 or 1 million Guaranis. Can be used to construct measures of risk preferences (lover, neutral and averse).

Cheating Game: From the household survey, number of heads, when participants were prompted to toss a fair coin nine times and record the number of heads. In addition, they were informed that with 5 or more heads they will obtain an extra compensation for their participation (a box of tea, a traditional staple food with a one dollar value, aside from a notebook also of one dollar value).

Rotter Locus of Control: From the household survey, short version of Rotter (1954) psychological test going from low values (external control, minimum of 24) to high values (internal control, maximum of 48).

Handicrafts: The Brazilian Municipal Survey of 2006 records very detailed information on handicraft production, most importantly, embroidery.

Knowledge Transmission: The Paraguayan Cultural Module of 2011 contains very specific information about traditional knowledge of medicine and folktales, including inter-generational transmission and language of transmission.

Language: The main language of the respondent (Spanish, Guarani, both or other) was asked in Paraguay in the 2012 Household Survey.

Race: The percentage of indigenous population is reported by the IBGE for Brazil in 2010.

G. Individual Controls and Additional Data

Age: Individual control, from the household survey, in years.

Male: Individual control, from the household survey, 1 for males and 0 for females.

Race: Individual control, from the household survey, categorical variable for indigenous, mestizo, white, black and mulatto.

Marital Status: Individual control, from the household survey, categorical variable for single, married, in concubinage, divorced and widowed.

Siblings: Individual control, from the household survey, dummy variable 1 for yes 0 otherwise.

Children: Individual control, from the household survey, dummy variable 1 for yes 0 otherwise.

Immigrant Status: Individual control, from the household survey, dummy variable 1 for born in Paraguay 0 otherwise.

Population Density: Population counts are taken from the 2001 census for Argentina, the 2000 Brazilian census and the 2002 Paraguayan census, and area is as reported previously.

Pre-colonial Population Density: Number of indigenous people per square kilometer, taken from and described in detail in Maloney and Valencia Caicedo (2012).

Migration: Data on migration and resident status are reported for Brazil by the IBGE in 2010.

Hours Worked: Total number of hours worked for people 10 and older is taken from the 2010 Brazilian Census and the 2012 Paraguayan Household Survey.

Labor Force Participation: Labor force participation is available for Brazil through IPEA for 2000.

Occupation: From the Paraguayan Household Survey of 2012, I collect information on occupations including agriculture, manufacturing, commerce and services.

Inequality: A Theil index on income is available for Brazil from IPEA for 2000 and for Paraguay from the World Bank (2008).

Health: A series of health variables including mortality under 5, infant mortality, number of doctors, and Health Development Indexes are available for Brazil from IPEA for 2000.

Tourism: Data on the prevalence of touristic activities come from the Brazilian Municipal Survey of 2006.

II. Additional Results: Alternative Estimation Estrategies

I present in this section complementary empirical results. They include a alternative specifications for income, an intensity of treatment robustness specification and a new instrument.

B. Alternative Specifications

As a first pass of the income data I look at the impact of missions on income in Brazil using dummy variables. In this first specification, a municipality receives a value of 1 if it had a Jesuit mission in the past and 0 otherwise. This coarse measure assumes that the boundaries of the missions were strict and is mostly used for descriptive purposes.[121] The missionary effect on logarithm of income appears positive, large and statistically significant at different distance thresholds (Figure A.5). This is true both for the full sample at around .8 log points as well as for progressively smaller samples (starting with 500 kilometers to the nearest mission in 100 decreases). The coefficients appear stable in magnitude and relatively larger at the local level. Because missionary presence might just be capturing different geographic and weather characteristics, I control for these variables directly in Figure A.6. Although now smaller in magnitude, at around .6 log points, the results are largely unchanged. The coefficients are again positive and significant, stable and larger at the local level. The results suggest that geographic conditions have a positive and significant effect, but that there is still an important role for the missionary treatment.

To formally assess the role of observable variables and unobservable characteristics, I calculate Altonji ratios (Altonji et al. 2005; Bellows and Miguel, 2009).[122] The intuition of this exercise is to see how large the selection in unobservables would need to be relative to observables in order for it to drive the results observed. For the full sample the ratio is 4.15 (Altonji et al. 2005 report 3.55) meaning that selection in unobservables would need to be that much higher to drive the results.[123] Technically, for this result to hold the R-squared of the regressions should be approaching the maximum R-squared (Oster, 2013). In this case the R-squared increases from around .3 to (a very

[121] The missionary area covers around one million of the total ten million inhabitants in the sample.
[122] For a similar application in a historical context, see Nunn and Wantchekon (2011).
[123] I compare here the first estimates from Figures 4 and 5.

high) .66 in the localized sample. Although the results from this exercise are reassuring, I employ other strategies to deal with endogeneity in the paper.

I explore here other non-linear formulations, beyond the dummy variable and distance to the nearest mission specifications.[124] The first is a log-log rather than a log-linear specification. As can be seen in the first two Columns of Table A.2, this variation leaves the results largely unchanged. The coefficients are negative, significant and stable. If anything, they appear larger in the reduced sample. An alternative formulation uses concentric distance rings as opposed to continuous distance. This measure is a combination of the dummy and the distance formulation used previously. Namely, I use a dummy to ascertain whether the municipalities lie within 100 kilometers from a mission, in concentric increments of 100 kilometers up until 500 kilometers.[125] The results of this formulation, in Table A.2, again lead to the familiar pattern. Places closer to missions are richer today. This holds both in the full (Columns 3 and 4) and reduced (Column 5) samples. Lastly, I estimate a quantile regression, which shows that the missionary effect works not only at the mean but also at the median level of the sample (Columns 6 and 7).[126] Again, the results are larger at the local level. Taken together, the results using alternative formulations show the robustness of the Jesuit results for income.

B. Robustness: Intensity of Treatment

As has been discussed throughout the paper, the results presented are robust to alternative definitions, variables and formulations. In this section I focus instead on the intensity of missionary treatment. To do so, I estimate alternative econometric specifications with interaction effects.[127] In particular, I exploit historical information on the year of foundation, indigenous population and a dummy variable for whether the mission moved or not. Instead of only using distance to the

[124] I also experiment with Conley standard errors, that take into account spatial auto-correlation, which leaves the results (not shown) unchanged.
[125] From 500 to 600 is the excluded category.
[126] This formulation also allows for testing robustness for outliers. As is standard, I use bootstrapped standard errors in this formulation. Quantile results for education (not shown) reveal large treatment effects for median and below median literacy levels.
[127] I thank Pedro dal Bó and Esteban Aucejo for suggesting these formulations.

nearest mission as in Equation 2, I interact this variable with the year of foundation and or the mean of the indigenous missionary population. For all formulations I use information on the nearest mission as well as geographic and weather results. The results of this empirical exercise can be seen in Table A.3. In the Distance X Year of Foundation formulation in the first Column, the log coefficient is negative and significant, reflecting that not only distance to the nearest mission, but also how many years it was active, was important. The results are positive and significant when I use instead the mean of indigenous population divided by distance, again in logs (Column 2). So not only the number of years, but also the quantity of people treated appears as important. Combining this information, I estimate a model with population interacted with years of missionary activity normalized by distance. Once again the log coefficient is positive and statistically significant (Column 3). I also interact distance to the nearest mission with distance to the nearest river, as a proxy for isolation or market access, finding a negative effect (Column 4). Lastly, I explore whether missions that moved during some point in their history have a differential effect.[128] I find using a dummy variable that indeed such movers had less of an impact (significant at the 10%) in the long-run (Column 5). Taken together, the results in this section show that the intensity of the Jesuit treatment also mattered in terms of years of exposure and population size.

C. Distance to Tordesillas

As an alternative instrument, I use an earlier even border change than the 1750 Treaty of Madrid. On the June 7, 1494, two years after the Discovery of the Americas, the Spaniards and the Portuguese signed the treaty of Tordesillas to delimit their empires in the New World. The Tordesillas line followed the meridian 370 leagues from the Cape Verde islands (46°30´ W of Greenwich), determining that any new territory east of the line would be Spanish and anything West of it would be Portuguese (Figure A.7). Of course this left Spain with all the newly-found Caribbean islands. The demarcation of the line preceded the discovery of South America during the third voyage of Christopher Columbus in 1498. As a result, a significant territory of South America was left under Portuguese jurisdiction and colonized accordingly.

[128] Approximately half of the missions moved at some point in their history.

The Tordesillas line also had important implications for the Jesuit Missions. As was discussed in the placebo section, proximity to the Portuguese territories represented a generalized threat from the slave hunting *bandeirantes*. In the Spanish Empire the New Laws issued by Charles V in 1542 aimed to protect the indigenous inhabitants from colonial exploitation. The laws (and their enforcement) on the Portuguese side were more lenient in this regard.[129] As a result, the *bandeirantes* would often raid the Spanish territories, capture indigenous slaves and return to their Portuguese bases.[130] This meant that missions that were located farther away from the line had a higher probability of survival.

I take here as instrument for the location of the Jesuit Missions the (horizontal) distance from the Tordesillas line. In particular, I hypothesize that the probability of survival of a mission is inversely proportional to the distance from the Tordesillas line. This is all conditional on being to the left of the line, as can be seen in Figure A.7, so I abstract from the actual consequences of being on a particular side of it. I include country fixed effects, and control for geographic and weather characteristics. The assumption is that distance to Tordesillas influenced the location of the missions, but does not affect the outcomes of interest directly. As was seen in the placebo section, I find no direct effect of the attacks in the long run.[131] The results can be seen in Table 9. Again the first stage is very strong. The instrumented coefficient for missionary distance emerges positive and significant for illiteracy (Column 3) and negative and significant for income (Column 7), as in the previous estimates.

To further explore the robustness of the instrumental variable results, I combine all instruments in Columns 4 and 8 of Table 9. I restrict the sample to the Brazilian municipalities, to be able to use the distance to Asuncion instrument. The sign and significance is preserved both for the education and income results. I cannot reject Hausman tests for income and education with the three instruments.[132] Results are robust to estimation with both 2SLS and LIML.

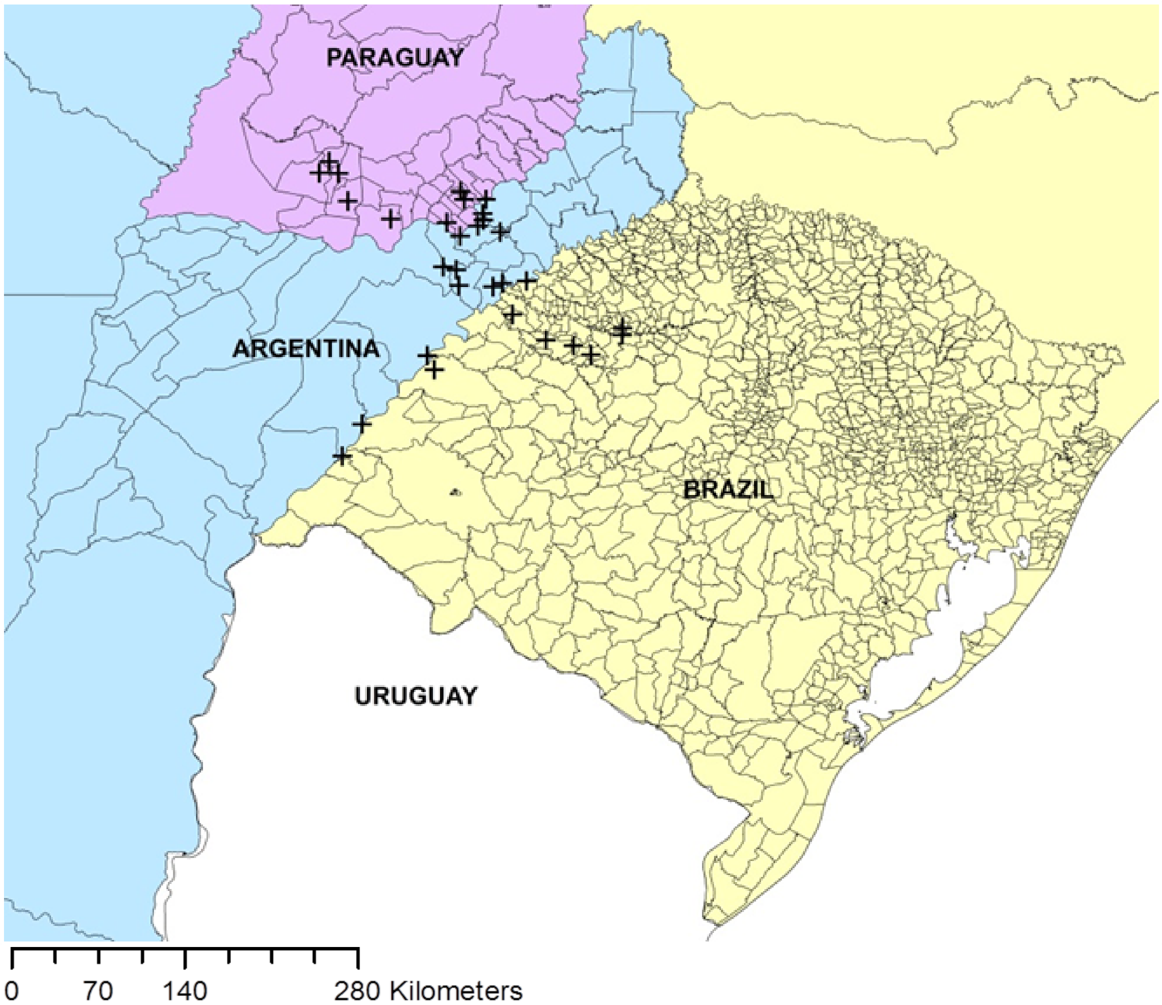
[129] In the Spanish Americas, the New Laws were complemented by the Alfaro Ordnances of 1612 (Ganson, 2003).
[130] As can be seen dramatically in Roland Joffé's The Mission.
[131] I control again for the direct distance to São Paulo, leaving the results essentially unchanged.
[132] Of course, this hinges on the assumption of the estimates with one instrument, in this case distance to Asuncion, being consistent.

Figures

Figure 1. Location of the Guarani Jesuit Missions in Latin America

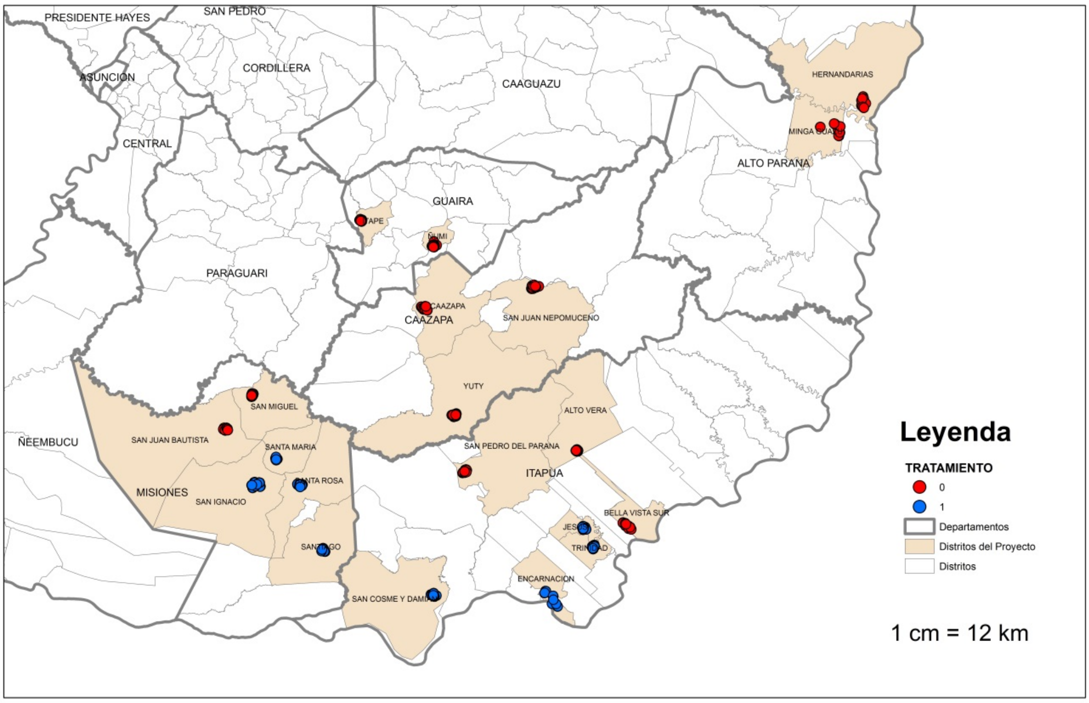
Note: The map shows the location of the Guarani Jesuit Missions, along with state level boundaries for Argentina, Brazil and Paraguay, and national level boundaries for the rest of Latin American countries.

Figure 2. Location of the Guarani Jesuit Missions in Argentina, Brazil and Paraguay



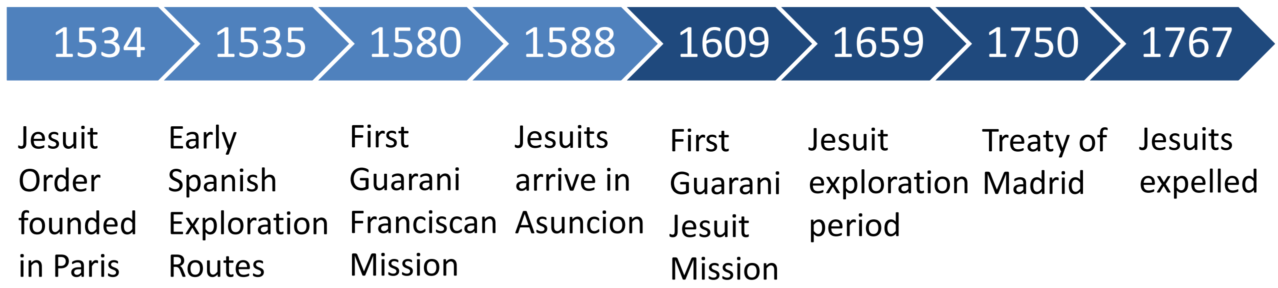
Note: The map shows the exact location of the Guarani Jesuit Missions, along with municipal level boundaries for the states of Corrientes and Misiones (Argentina), Itapua and Misiones (Paraguay) and Rio Grande do Sul (Brazil), and state boundaries for other states in Argentina, Brazil and Paraguay.

Figure 3. Household Survey Map: Southern Paraguay



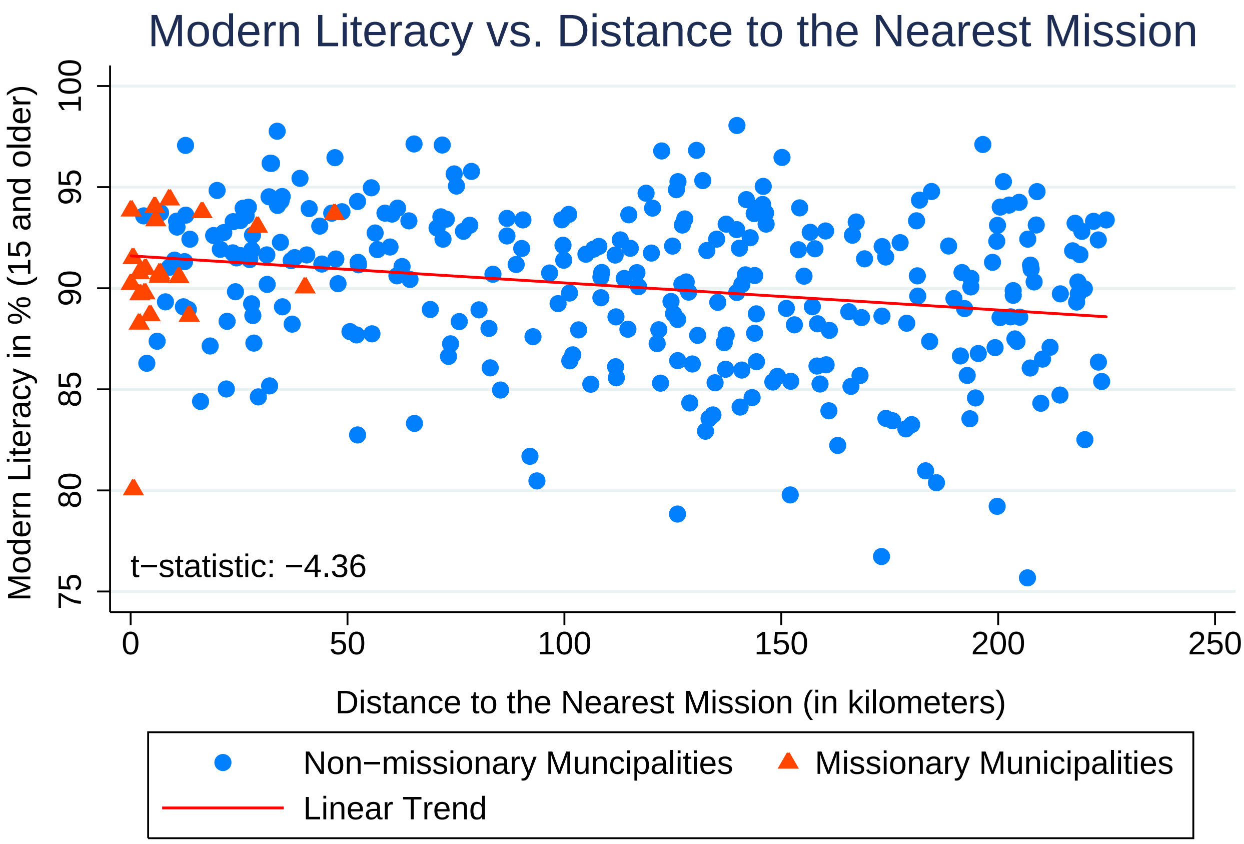
Note: The map depicts the survey areas with non-missionary districts (in red) and missionary districts (in blue) along with district boundaries for Southern Paraguay.

Figure 4. Historical Timeline



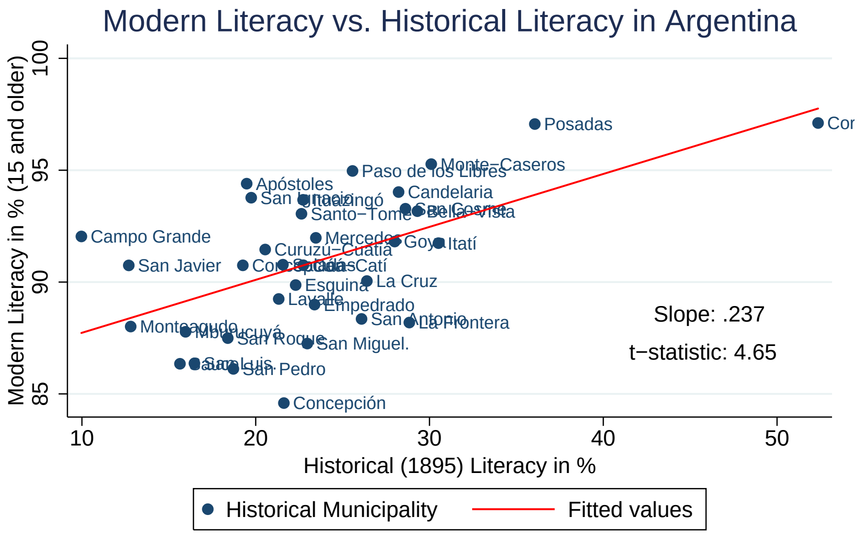
Note: The figure depicts the key historical events studied in the paper, the darker shade of blue depicts the 150 years of Jesuit missionary intervetion.

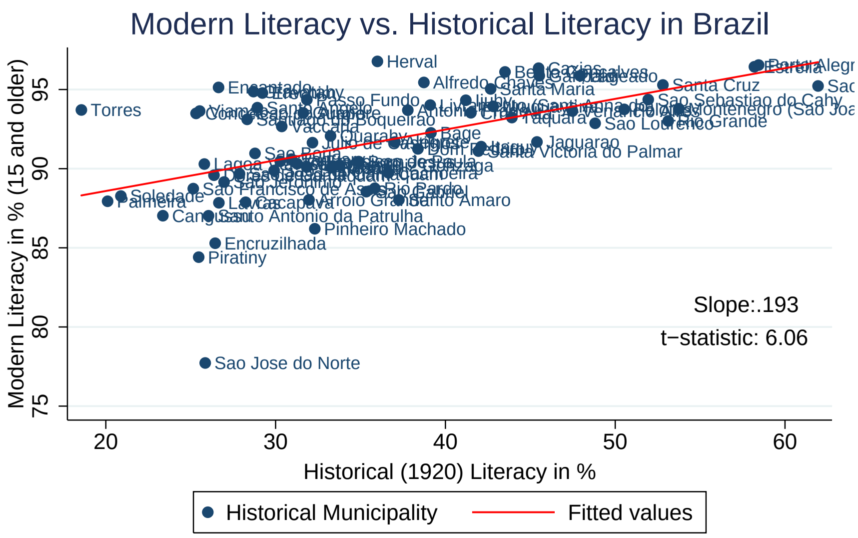
Figure 5. Literacy vs. Missionary Distance: Unconditional Plot

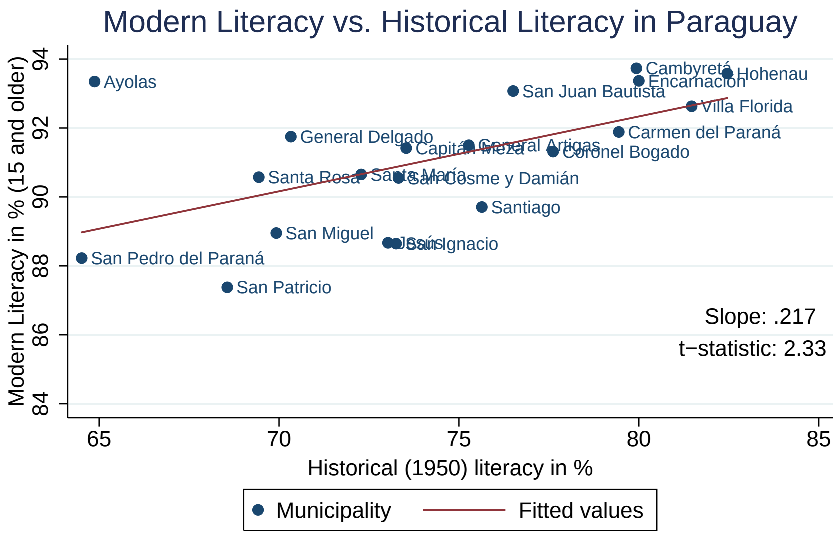


Note: Unconditional plot of 2000 literacy in percentages for people aged 15 and older in Argentina, Brazil and Paraguay versus distance of the municipality centroid in kilometers to the nearest Jesuit mission. Orange triangles represent missionary municipalities and blue dots non-missionary ones. The red line is a linear trend. The sample is restricted to a 225 kilometers distance threshold.

Figure 6. Modern vs. Historical Literacy in Argentina, Brazil and Paraguay: Unconditional Plots

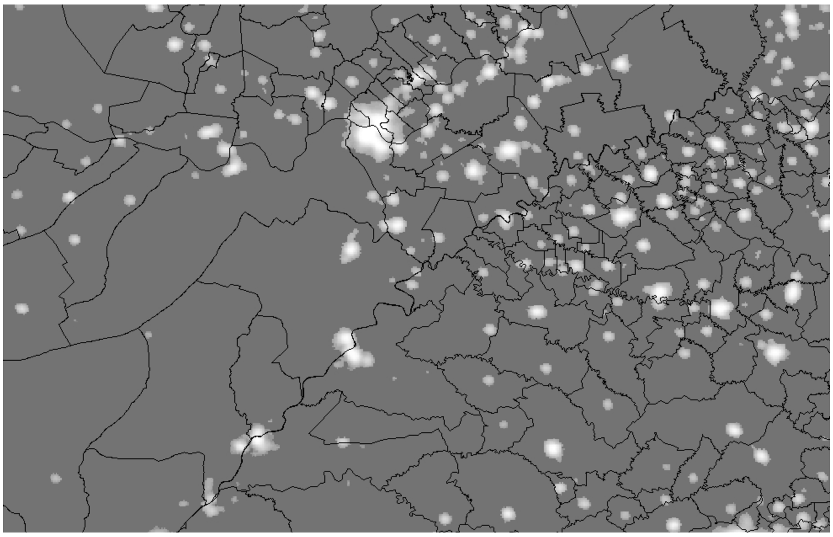


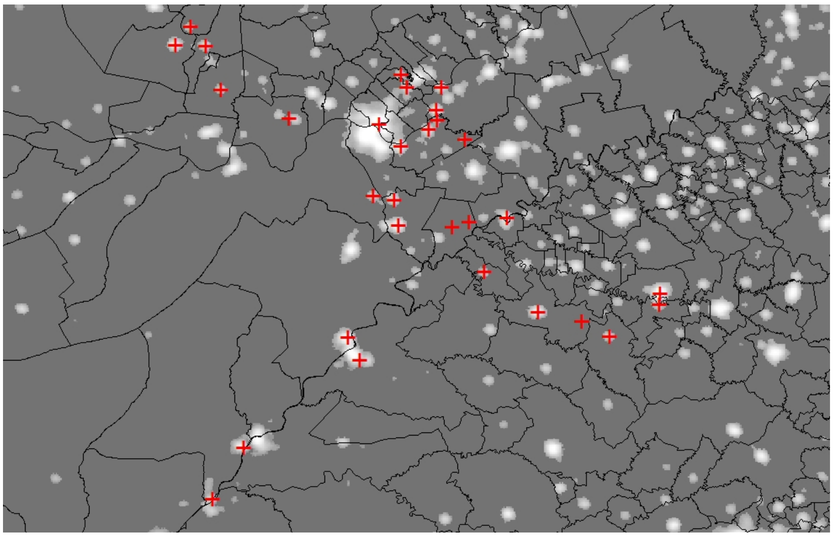




Note: Unconditional plots of 2000 literacy in percentages for people aged 15 years and older in Argentina and Brazil on 1895 literacy in percentages in Argentina, 1920 in Brazil, and 1950 in Paraguay. Blue dots represent municipalities with historical names and red lines are linear trends.

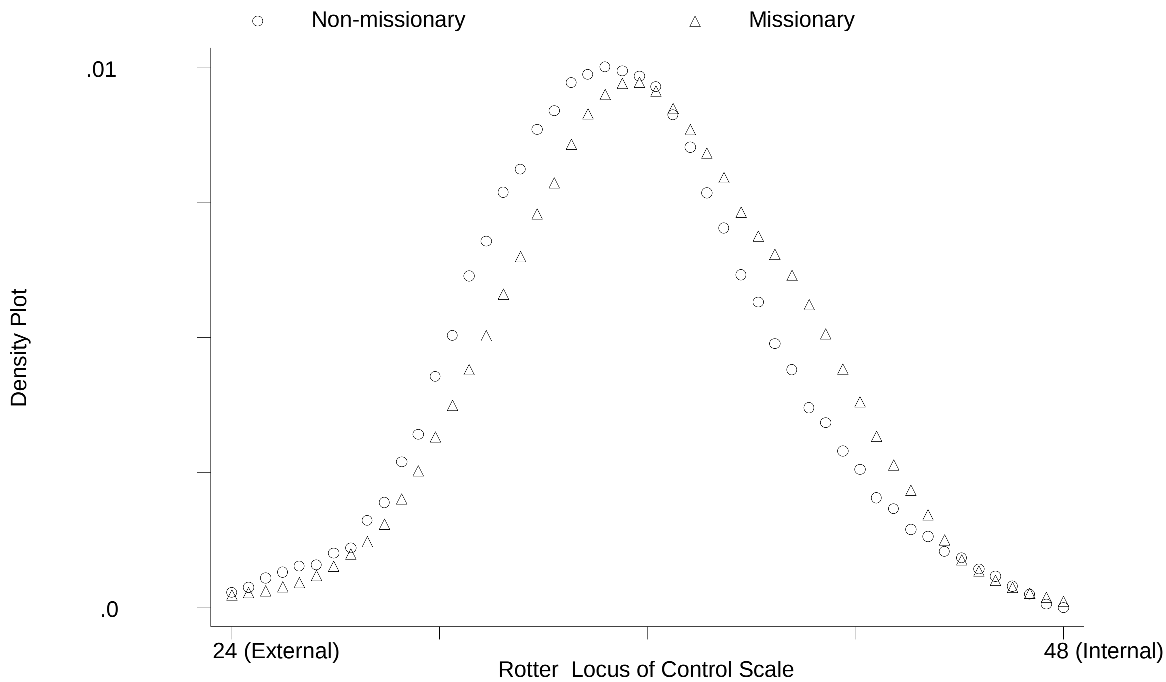
Figure 7. Nighttime Satellite Maps of the Guarani Jesuit Missionary Area





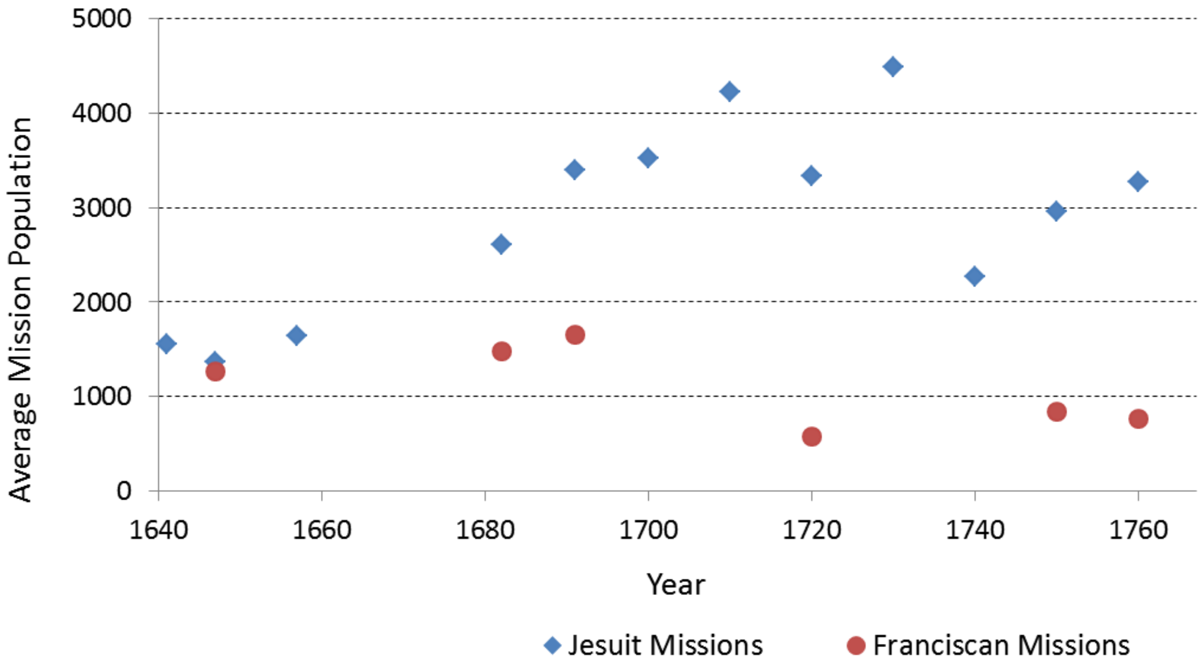
Note: The maps depict the nighttime satellite images (F18-2010) of the Guarani Jesuit missionary area along with municipal level boundaries for the states of Corrientes and Misiones (Argentina), Itapua and Misiones (Paraguay) and Rio Grande do Sul (Brazil), without and with the location of the Guarani Jesuit Missions (red crosses).

Figure 8. Missionary Effect on Rotter Locus of Control Scale



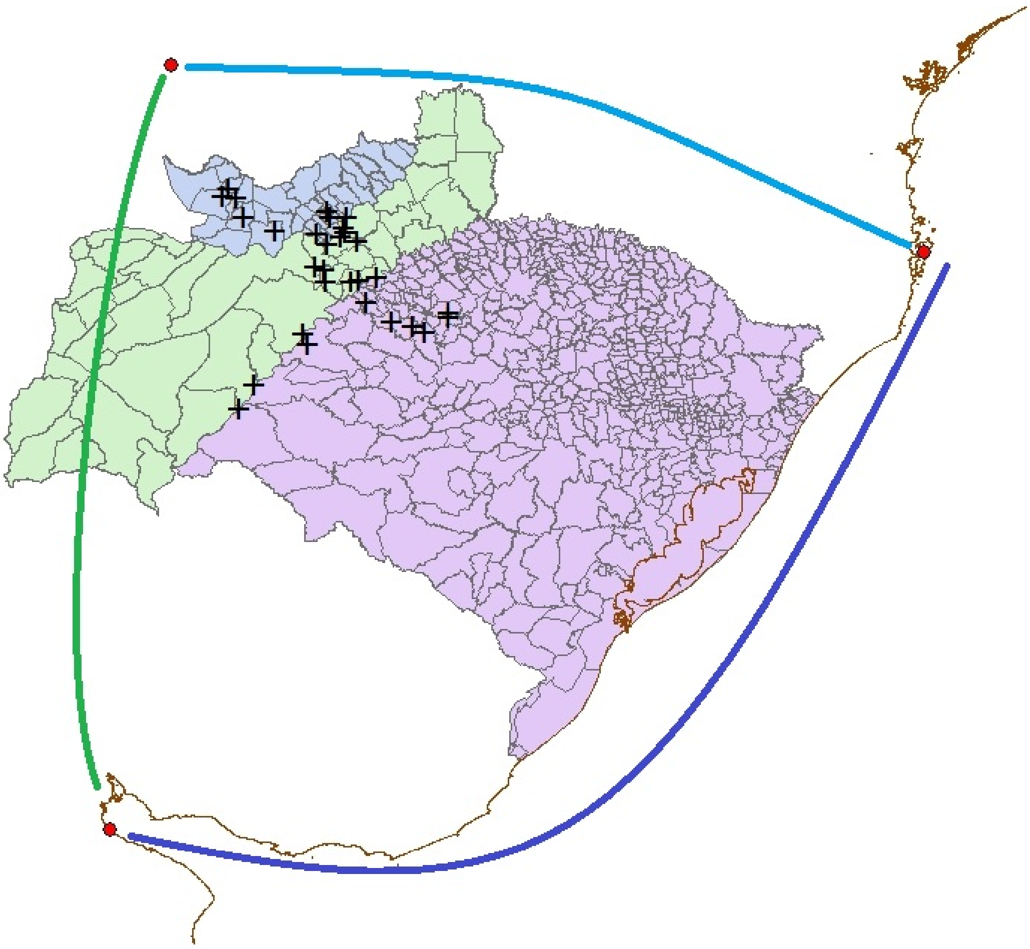
Note: The figure depicts a density plot of the Rotter Locus of Control Scale (going from low values of external control to high values of internal control), separating between non-missionary areas (in circles) and missionary areas (in triangles)

Figure 9. Historical Population of Jesuit and Franciscan Guarani Missions (1640-1760)



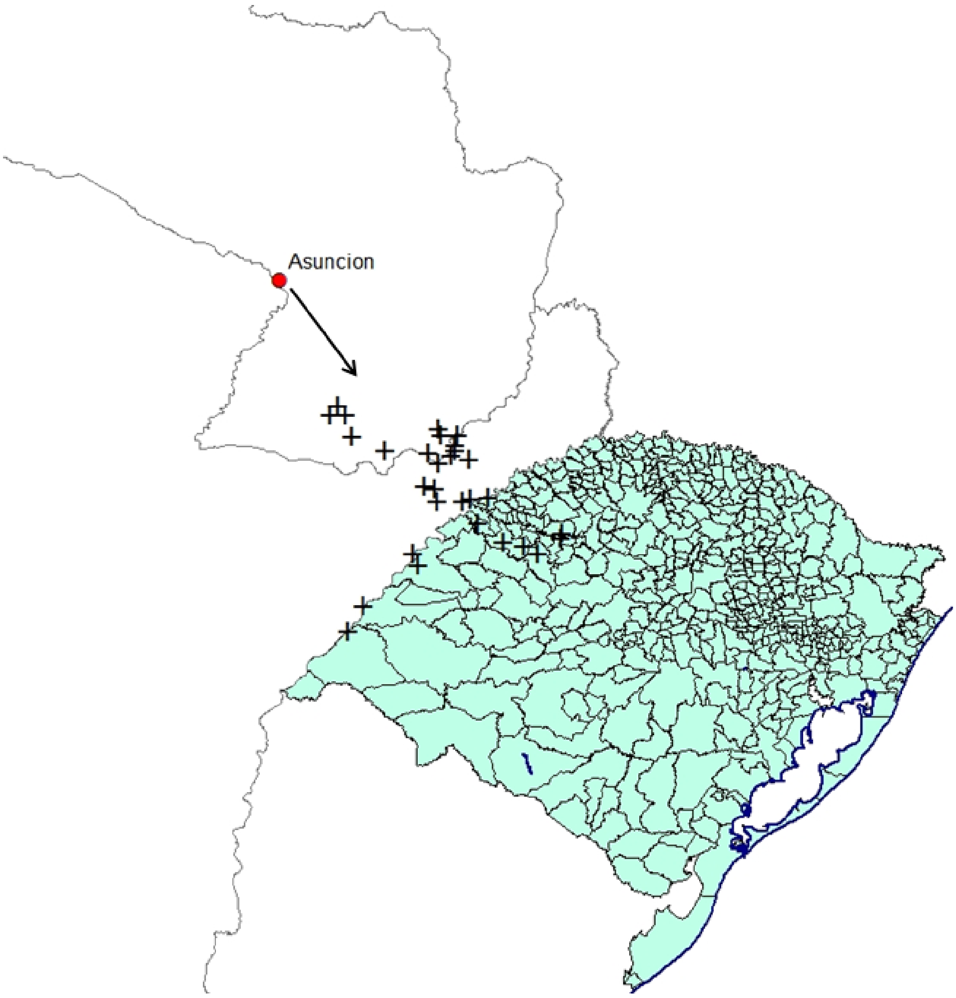
Note: This graph plots average mission population for Jesuit (blue diamonds) and Franciscan (red dots) Missions from 1640 to 1760.

Figure 10. Map of the Guarani Jesuit Area along with Exploration Routes



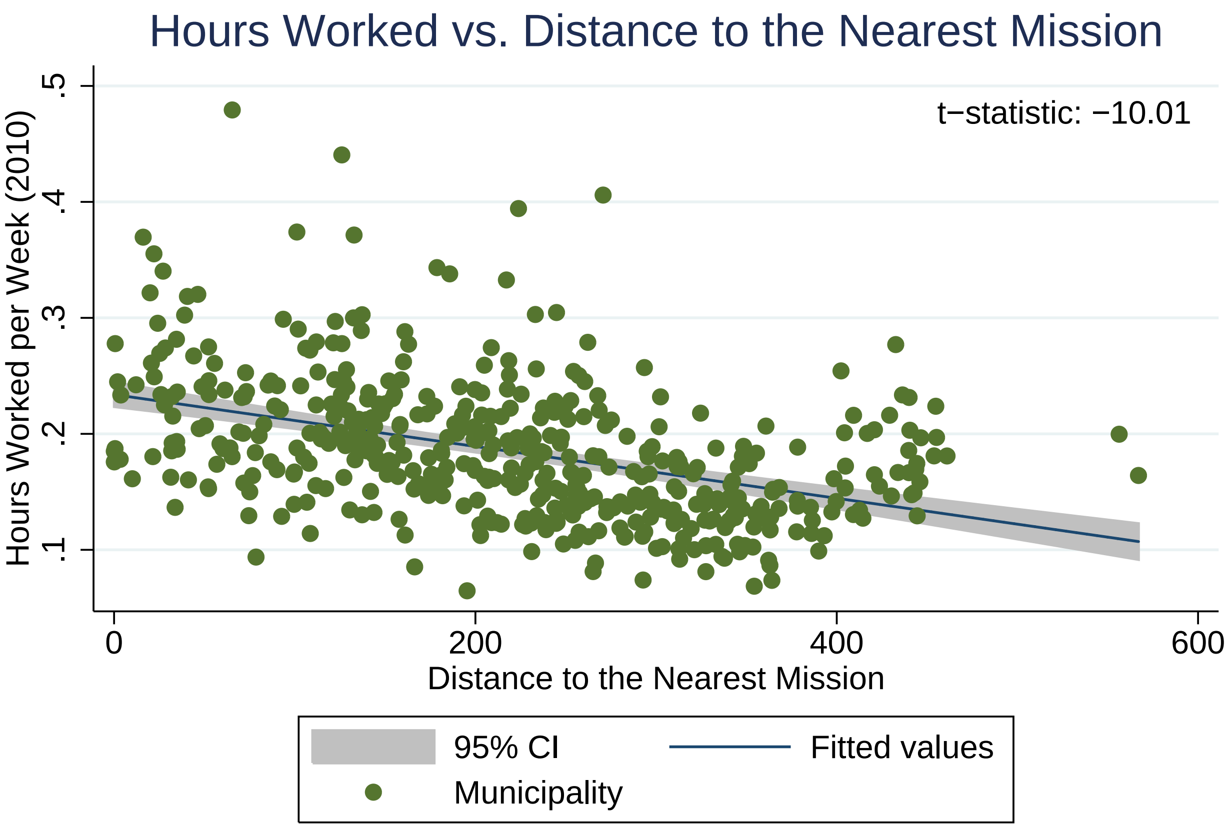
Note: The map shows the location of the Guarani Jesuit missions along with municipal level boundaries for the states of Misiones and Corrientes (Argentina), Misiones and Itapua (Paraguay) and Rio Grande do Sul (Brazil). The lines mark the expeditions by Pedro de Mendoza, Alvar Nuñez Cabeza de Vaca, Juan de Ayolas and Domingo de Irala. The red points demarcate Asuncion, Buenos Aires and Santa Caterina.

Figure 11. Map of Rio Grande do Sul with the Direction of the Jesuit Missions from Asuncion



Note: The map shows the location of Asuncion, the Guarani Jesuit Missions, along with municipal level boundaries for the state of Rio Grande do Sul (Brazil), and national level boundaries for Argentina and Paraguay.

Figure 12. Hours Worked vs. Missionary Distance: Brazil



Note: Unconditional plot of percentage of people reporting working 15 to 39 hours in Brazil in 2010 versus distance to the nearest Jesuit mission in kilometers. Municipalities in green circles, blue linear fit with gray 95% confidence bands.

Tables

Table 1. Summary Statistics: Municipal Level Data (Argentina, Brazil and Paraguay)

CATEGORY	VARIABLES	N	Mean	SD	Min	Max
INCOME	Ln Income	506	5.7	0.9	4.4	9.2
	Individual Poverty Index	82	43.4	13.5	20.8	75.9
	Household Poverty Index	82	42.5	16.5	17.7	77.0
EDUCATION	Median Years of Education	467	5.1	0.8	3.3	9.0
	Literacy	549	90.9	4.0	75.7	98.4
	Illiteracy	549	9.1	1.6	4.0	24.3
MISSION	Mission Dummy	578	0.04	0.19	0.00	1.00
	Distance to the Nearest Mission	549	196	123	0	567
GEO CONTROLS	Latitude	549	-28.7	1.2	-33.7	-25.9
	Longitude	549	-53.2	1.9	-59.3	-49.7
	Area	578	717	1215	28	9588
	Temperature	577	191	13	146	226
	Altitude	577	326	226	3	1157
	Rainfall	577	1625	189	1050	1995
	Ruggedness	577	52469	40858	6335	173076
	Slope	577	1456	1183	32	6739
	Distance to River	577	0.2	0.3	0.0	1.3
	Distance to Coast	577	2.5	1.7	0.0	7.0
	Landlocked	578	0.96	0.20	0.00	1.00

Note: For specific descriptions and sources, please refer to the Data Appendix.

Table 2. Summary Statistics: Household Survey (Paraguay, 2014)

VARIABLES	Non-Missionary			Missionary			Total		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age	336	45.99	15.37	224	47.46	15.72	560	46.58	15.51
Sex	336	0.27	0.45	224	0.28	0.45	560	0.28	0.45
Marital Status	336	2.34	1.14	224	2.50	1.14	560	2.41	1.14
Number of Siblings	335	1.22	1.04	220	1.18	0.94	555	1.21	1.00
Number of Children	336	1.60	1.62	224	1.40	1.36	560	1.52	1.52
Immigrant Status	36	1.06	0.54	224	1.07	0.58	560	1.06	0.56
Latitude	336	-26.29	0.52	224	-27.07	0.19	560	-26.60	0.57
Longitude	336	-56.05	0.75	224	-56.40	0.53	560	-56.19	0.69
Altitude	325	170.49	60.10	205	153.67	37.88	530	163.99	53.22
Altruism	333	313619	235268	218	433051	871819	551	360871	580268
Time Discounting	328	2209787	3033609	220	2479591	3410979	548	2318102	3190168
Certainty Equivalence	321	522274	703136	212	499293	210533	533	513133	561329
Positive Reciprocity	329	17041	7190	217	17862	4697	546	17367	6326
Cheating Game	331	5.07	1.65	218	4.87	1.50	549	4.99	1.59
Rotter Locus of Control	336	35.29	4.05	224	36.11	4.10	560	35.61	4.09

Note: For specific descriptions and sources, please refer to the Data Appendix.

Table 3. Missionary Effect on Modern Education: Brazil, Argentina and Paraguay

	1	2	3	4	5	6
	Med. Years Edu.	Med. Years Edu.	Med. Years Edu.	Illiteracy	Illiteracy	Illiteracy
	Brazil	Brazil	Brazil	ARG BRA PAR	ARG BRA PAR	ARG BRA PAR
	Full	<400 kms	<200 kms	Full	<400 kms	<200 kms
Mission Distance	**-0.00665*** **	**-0.00797*** **	**-0.00444** **	**0.0112** **	**0.00942***	**0.0253*** **
	(0.002)	**(0.002)**	**(0.002)**	**(0.005)**	**(0.005)**	**(0.007)**
Constant	44.10***	58.62***	18.39	-53.74*	-85.83**	-3.996
	(10.30)	(10.16)	(16.49)	(32.50)	(34.49)	(34.18)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Fixed Effects	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**
Observations	427	400	187	548	514	281
R-squared	0.172	0.189	0.231	0.073	0.101	0.133

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers (Equation 1). The dependent variable is median years of schooling in Brazil in Columns 1 to 3 and illiteracy for people aged 15 years and older in 2000 in percentages for Argentina, Brazil and Paraguay in Columns 4 to 8. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS with state fixed effects in Columns 4 to . The results are for the full, $<$400 and $<$200 kilometers from the nearest Jesuit mission samples. Robust standard errors in parentheses *** p$<$.01, ** p$<$.05, *p$<$.1

Table 4. Missionary Effect on Historical Education: Argentina (1895) and Brazil (1920)

	1	2	3	4	5	6	7	8
	Illiteracy Total	Illiteracy Males	Illiteracy Females	Illiteracy Foreigners	Literacy Total	Literacy 7-14 years	Literacy 15+ years	Literacy Foreigners
	ARG 1895	ARG 1895	ARG 1895	ARG 1895	BRA 1920	BRA 1920	BRA 1920	BRA 1920
	Full	Full	Full	Full	<200 kms	<200 kms	<200 kms	<200 kms
Mission Distance	**0.0414*** **	**0.0580*** **	**0.0982*** **	**-0.0329*** **	**-0.115** **	**-0.0311*** **	**-0.0834** **	**-0.0542**
Robust SE	**(0.0150)**	**(0.0124)**	**(0.0179)**	**(0.0068)**	**(0.0388)**	**(0.0086)**	**(0.0347)**	**(0.1050)**
Bootstrap SE	**(0.0159)**	**(0.0125)**	**(0.0186)**	**(0.0073)**	**(0.0677)**	**(0.0154)**	**(0.0405)**	**(0.1340)**
Constant	12.91***	18.77***	20.85***	10.29***	796.3***	215.3**	571.5**	1,034*
	(2.15)	(2.04)	(3.30)	(1.14)	(220.30)	(71.10)	(190.10)	(509.40)
GEO Controls	**NO**	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**	**YES**
Observations	32	33	34	33	18	18	18	18
R-squared	0.189	0.338	0.317	0.264	0.553	0.43	0.568	0.36

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers (Equation 1). The dependent variable is illiteracy in percentages in Argentina in 1895 in Columns 1 to 4 and in Brazil in 1920 in Columns 5 to 8. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS. The results are for the full sample for Argentina and the <200 kilometers from the nearest Jesuit mission sample for Brazil. Robust and bootstrap standard errors in parentheses *** p<.01, ** p<.05, *p<.1

Table 5. Missionary Effect on Modern Income and Poverty: Brazil, Argentina and Paraguay

	1	2	3	4	5	6	7
	Ln Income	Ln Income	Ln Income	Individual Poverty Index	Individual Poverty Index	Household Poverty Index	Household Poverty Index
	Brazil Full	Brazil <400 kms	Brazil <200 kms	ARG & PAR Full	ARG & PAR <100 kms	ARG & PAR Full	ARG & PAR <100 kms
Mission Distance	**-0.00291*** **	**-0.00319*** **	**-0.00189** **	**0.0938** **	**0.147** **	**0.0801** **	**0.129** **
	(0.001)	**(0.001)**	**(0.001)**	**(0.005)**	**(0.004)**	**(0.004)**	**(0.006)**
Constant	18.85***	22.15***	12.42**	40.64	-148.6**	100.3	-25.05
	(3.223)	(3.831)	(6.265)	(50.090)	(3.689)	(67.020)	(17.940)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Fixed Effects	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**	**YES**
Observations	427	400	187	81	59	81	59
R-squared	0.253	0.28	0.21	0.202	0.208	0.175	0.16

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers (Equation 2). The dependent variable is the logarithm of income per capita in 2000 in Brazil in columns 1 to 3, Unsatisfied Basic Needs (UBN) Poverty Index in Argentina and Paraguay at the individual level in Columns 4 and 5, and the household level in Columns 6 and 7. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS with state fixed effects in Columns 4 to 7. The results are for the full, <400, <200 and <100 kilometers from the nearest Jesuit mission samples. Robust standard errors in parentheses *** $p<.01$, ** $p<.05$, *$p<.1$

Table 6. Placebo Effect of Abandoned Jesuit Missions on Modern Income and Education

	1	2	3	4	5	6	7	8
	Literacy	Literacy	Literacy	Literacy	Ln Income	Ln Income	Ln Income	Ln Income
	ARG BRA PAR	ARG BRA PAR	ARG BRA PAR	ARG BRA PAR	BRA & PAR	BRA & PAR	BRA & PAR	BRA & PAR
Alto Parana Mission Distance	**0.0120*** **			**0.013**	**0.000317**			**0.011**
	(0.004)			**(0.024)**	**(0.001)**			**(0.007)**
Guayra Mission Distance		**0.00298**		**-0.0384*** **		**-0.00129**		**-0.00403**
		(0.008)		**(0.013)**		**(0.003)**		**(0.004)**
Itatin Misision Distance			**0.0253*** **	**0.0298**			**-0.000122**	**-0.0189**
			(0.008)	**(0.044)**			**(0.003)**	**(0.015)**
Constant	115.1***	112.0**	113.9***	-29.06	-11.10	-15.93	-10.87	-22.88
	(25.22)	(43.49)	(25.02)	(52.58)	(7.92)	(13.62)	(7.83)	(16.44)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	548	548	548	548	506	506	506	506
R-squared	0.078	0.065	0.081	0.095	0.398	0.399	0.398	0.401

Note: The table shows the coefficient of distance to the nearest abandoned mission in kilometers. The dependent variables are literacy for people aged 15 years and older in 2000 in percentages for Argentina, Brazil and Paraguay and the logarithm of income in 2000 for Brazil and Paraguay and, full sample throughout. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS with state fixed effects. Robust standard errors in parentheses *** $p<.01$, ** $p<.05$, *$p<.1$

Table 7. Missionary Effect on Non-cognitive Skills and Preferences

	1	2	3	4	5	6
	Rotter Scale	Altruism (Allocation)	Positive Reciprocity	Time Discounting	Certainty Equivalence	Cheating Game
	PAR 2014	PAR 2014	PAR 2014	PAR 2014	PAR 2014	PAR 2014
Jesuit Mission Dummy	**0.860****	**88,225****	**1,790*****	**22,382**	**154,401*****	**-0.309***
	(0.38)	**(33314)**	**(685.30)**	**(104382)**	**(31782)**	**(0.18)**
Constant	73.74***	617,445	37,331	1,474,000***	35,430	-2.712
	(21)	(1735000)	(34147)	(409897)	(1075000)	(2.37)
Individual Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	497	516	481	438	475	489
R-squared	0.04	0.03	0.03	0.018	0.189	0.012

Note: The table shows the coefficient a Jesuit missionary dummy. The dependent variables are Rotter Locus of Control scale, monetary value responses in Guaranis in Colummns 2 to 5 and number of heads in Column 6. Individual controls include age, gender, race, marital status, number of siblings and place of birth. Geographic controls include altitude, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS with state fixed effects. Standard errors clustered at the district level in parentheses *** p<.01, ** p<.05, *p<.1

Table 8. Franciscan and Jesuit Missionary Effect on Modern Income and Education

	1	2	3	4	5	6
	Literacy	Ln Income	Literacy	Ln Income	Theil Index	Mortality
	ARG BRA PAR	BRA & PAR	ARG BRA PAR	BRA & PAR	BRA & PAR	BRA & PAR
Franciscan Mission Distance	**0.00772**	**-0.00010**	**0.0342*** **	**0.00356*** **	**-0.126*** **	**-0.0296**
	(0.008)	**(0.001)**	**(0.011)**	**(0.001)**	**(0.038)**	**(0.029)**
Jesuit Mission Distance			**-0.0214*** **	**-0.00356*** **	**0.0603*** **	**0.0417*** **
			(0.006)	**(0.001)**	**(0.023)**	**(0.014)**
Constant	77.89**	0.862	91.76**	6.317	0.03	-73.32
	(30.82)	(3.54)	(41.53)	(3.87)	(133.00)	(96.460)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**NO**
Observations	548	506	548	506	506	467
R-squared	0.067	0.872	0.082	0.879	0.448	0.107

Note: The table shows the coefficient of distance to the nearest Franciscan and Jesuit missions in kilometers. The dependent variables are literacy for people aged 15 years and older in 2000 in percentages for Argentina, Brazil and Paraguay; the logarithm of income in 2000 for Brazil and Paraguay; and a Theil inequality index for income in Brazil and Paraguay in 2000, full sample throughout. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS with state fixed effects. Robust standard errors in parentheses *** p<.01, ** p<.05, *p<.1

Table 9. Instrumental Variables Effect of Jesuit Missions on Modern Income and Education

	1	2	3	4	5	6	7	8
	Illiteracy	Illiteracy	Illiteracy	Illiteracy	Ln Income	Ln Income	Ln Income	Ln Income
	Explorers IV	Asuncion IV	Tordesillas IV	All IV	Explorers IV	Asuncion IV	Tordesillas IV	All IV
	ARG BRA PAR	Brazil	ARG BRA PAR	Brazil	BRA & PAR	Brazil	BRA & PAR	Brazil
Mission Distance	**0.0140****	**0.0215****	**0.0524****	**0.0255*****	**-0.00337*****	**-0.00199*****	**-0.00771****	**).00231*****
	(0.006)	**(0.011)**	**(0.024)**	**(0.009)**	**(0.001)**	**(0.001)**	**(0.003)**	**(0.001)**
Constant	-52.60*	-97.75	-91.32**	-260.5***	18.97***	10.61**	29.67***	10.40
	(30.77)	(64.43)	(44.76)	(78.30)	(5.33)	(4.15)	(8.76)	(13.74)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Fixed Effects	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**	**YES**	**NO**
First Stage F-statistic	162.6	98.8	320.8	624.0	320.8	98.8	32.4	624.0
Observations	548	467	548	467	506	467	506	467
R-Squared	0.058	0.143	0.075	0.145	0.874	0.262	0.356	0.262

Note: The table shows the instrumented coefficient of distance to the nearest Jesuit mission in kilometers. The instrumental variables are distance to the Exploration route, Asuncion and Tordesillas Line. The dependent variables are illiteracy for people aged 15 years and older in 2000 in percentages for Argentina, Brazil and Paraguay and the logarithm of income in 2000 for Brazil and Paraguay, full sample throughout. Geographic controls include distance to São Paulo, distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by two step least squares with state fixed effects (except in 2 and 6). Robust standard errors in parentheses *** p<.01, ** p<.05, *p<.1

Table 10. Missionary Effect on Handicrafts, Labor Force Participation and Occupational Structure in Brazil and Paraguay

	1	2	3	4	5	6	7
	Handicrafts Embroidery	Employment Agriculture	Employment Manufacturing	Employment Commerce	Labor Force Part. Total	Labor Force Part. Male	Labor Force Part. Female
	Brazil 2006	Paraguay 2012	Paraguay 2012	Paraguay 2012	Brazil 2012	Brazil 2012	Brazil 2012
Mission Distance	**-0.00215***	**0.0141****	**-0.0175*****	**-0.0143*****	**-0.0120*****	**-0.00926*****	**-0.0151*****
	(0.001)	**(0.007)**	**(0.006)**	**(0.005)**	**(0.003)**	**(0.002)**	**(0.005)**
Constant	3.732	-29.69**	12.76	20.33***	67.78***	78.96***	56.50***
	(3.37)	(13.00)	(8.96)	(6.11)	(0.90)	(0.63)	(1.24)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**NO**	**NO**	**NO**
Fixed Effects	**NO**	**YES**	**YES**	**YES**	**NO**	**NO**	**NO**
Observations	427	1928	1928	1928	467	467	467
R-Squared	0.0263	0.1092	0.0459	0.0518	0.023	0.027	0.019

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers. The dependent variables are the prevalence of embroidery in percentages in Brazil in 2006 in Columns 1 and 2 for the full and <200 kilometers from the nearest Jesuit mission samples; general, male and female labor force participation in percentages in Brazil in 2012 in Columns 3 to 5; and percentage of the population working in Agriculture, Manufacturing and Commerce in Paraguay in 2012 in Columns 6 to 8, full sample throughout. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS in Columns 1 to 4 and for a Probit model in Columns 5 to 7 with state fixed effects and errors clustered at the district level. Robust and clustered standard errors in parentheses *** p<.01, ** p<.05, *p<.1

Table 11. Missionary Effect on Inter-generational Knowledge Transmission and Skills in Paraguay

	1	2	3	4	5	6	7
	Medicine Knowledge	Medicine Transmission	Tales Knowledge	Tales Transmission	Accounting Practice	Diary Usage	Library Visits
	PAR 2011	PAR 2011	PAR 2011	PAR 2011	PAR 2011	PAR 2011	PAR 2011
Mission Distance	**-0.00546****	**-0.00523****	**-0.00757*****	**-0.00582*****	**-0.00791****	**-0.0104*****	**-0.0238*****
	(0.0026)	**(0.0023)**	**(0.0018)**	**(0.0017)**	**(0.0032)**	**(0.0036)**	**(0.0073)**
Constant	0.790***	0.327***	0.282**	-0.464***	-0.532***	-0.832***	-1.188***
	(0.09)	(0.11)	(0.12)	(0.10)	(0.18)	(0.17)	(0.15)
Fixed Effects	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	904	904	904	904	904	904	904
R-Squared	0.0085	0.0065	0.0129	0.01	0.0156	0.0217	0.0684

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers. The dependent variables are knowledge of traditional medicine in percentages, parental transmission of medicinal knowledge and language of medicinal knowledge in Columns 1 to 3; knowledge of traditional folktales in percentages, parental transmission of folktale knowledge and language of folktale knowledge in Columns 4 to 6; and knowledge of accounting, usage of a diary and visits to the library all in percentages in Paraguay in 2011. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is for a Probit model in Columns with state fixed effects and errors clustered at the district level. Clustered standard errors in parentheses *** p<.01, ** p<.05, *p<.1

Table 13. Missionary Effect on Indigenous Assimilation: Marriage, Population and Language in Brazil and Paraguay

	1	2	3	4	5	6	7
	Mixed Marriage	Caboclo Marriage	Percentage Catholic	Percentage Indigenous	Guarani Language	Spanish Language	GUA & SPA Language
	BRA 1890	BRA 1890	BRA 1890	BRA 2010	PAR 2012	PAR 2012	PAR 2012
Mission Distance	**-0.0911*** **	**-0.0401*** **	**-0.0353***	**-0.302** **	**0.0218*** **	**-0.0172*** **	**-0.00778** **
Robust SE	**(0.0175)**	**(0.0096)**	**(0.0185)**	**(0.1360)**	**(0.0066)**	**(0.0063)**	**(0.0038)**
Bootstrap SE	**(0.0155)**	**(0.0116)**	**(0.0209)**				
Constant	158.0**	35.22	178.9***	153.0***	-5.059	11.66	-8.521
	(63.07)	(31.83)	(63.35)	(46.73)	(9.97)	(8.59)	(5.60)
GEO Controls	**YES**	**YES**	**YES**	**NO**	**YES**	**YES**	**YES**
Fixed Effects	**NO**	**NO**	**NO**	**NO**	**YES**	**YES**	**YES**
Observations	63	63	63	467	1928	1928	1928
R-squared	0.582	0.661	0.229	0.006	0.1273	0.1447	0.0291

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers. The dependent variables are the percentage of mixed and caboclo marriages in Brazil in 1890 in Columns 1 and 2 and percentage Catholic in Column 3; percentage of indigenous population in 2010 in Column 4; and percentage of Guarani, Guarani and Spanish, and Spanish speakers in Paraguay in 2012 in Columns 5 to 7. Geographic controls include area, altitude, temperature and rainfall in Columns 1 to 3 and additionally distance to the nearest coast, distance to the nearest river, latitude and longitude in Columns 4 to 7. Please refer to the paper for units and additional details of these variables. Estimation is by OLS in Columns 1 to 4 and for a Probit model with state fixed effects in Columns 5 to 7 with errors clustered at the district level. Robust, bootstrap and clustered standard errors in parentheses *** $p<.01$, ** $p<.05$, * $p<.1$

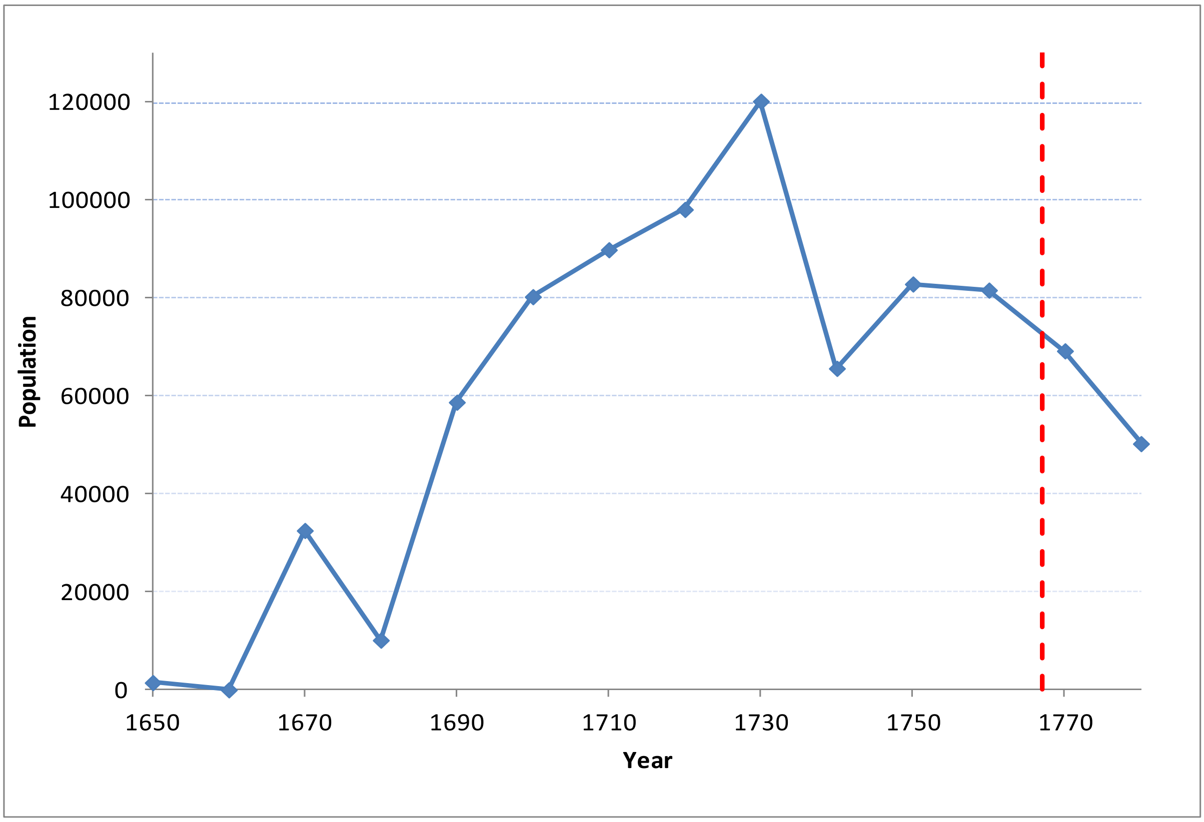
Table 12. Robustness Checks: Missionary Effect on Education by Resident Status, Population Density, Health and Tourism

	1	2	3	4	5	6	7
	Population Density	Population Density	Population Density	Med. Years Edu. Resident	Med. Years Edu. Non-Resident	Health Index	Touristic Activities
	Full	<200 kms	Pre-Colonial	Full	Full	Full	Full
	ARG BRA PAR	ARG BRA PAR	ARG BRA PAR	Brazil	Brazil	Brazil	Brazil
Mission Distance	**0.426****	**0.128**	**1.028**	**-0.00836*****	**-0.00357**	**-0.0385****	**0.000109**
	(0.1660)	**(0.1900)**	**(1.12)**	**(0.0016)**	**(0.0026)**	**(0.0173)**	**(0.0011)**
Constant	901.9	-303.9	-3.222	48.22***	24.76	121.3	3.722
	(1046.00)	(961.70)	(2.82)	(10.56)	(17.74)	(121.60)	(3.13)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Fixed Effects	**YES**	**YES**	**YES**	**NO**	**NO**	**NO**	**NO**
Observations	548	281	69	237	190	467	427
R-squared	0.18	0.096	0.302	0.176	0.137	0.144	0.0261

Note: The table shows the coefficient of distance to the nearest Jesuit mission in kilometers. The dependent variable is median years of schooling in Brazil for residents and non-residents in Columns 1 and 2; population density in Columns 3 and 4; pre-colonial population density in Column 5; mortality under 5, infant mortality and the IFDM Health Index in Columns 5 to 8; and prevalence of tourism in percentages in Column 9. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS with state fixed effects for Columns 3 and 4 and of a Probit model in Column 8. Robust standard errors in parentheses (except in Column 8) *** $p<.01$, ** $p<.05$, *$p<.1$

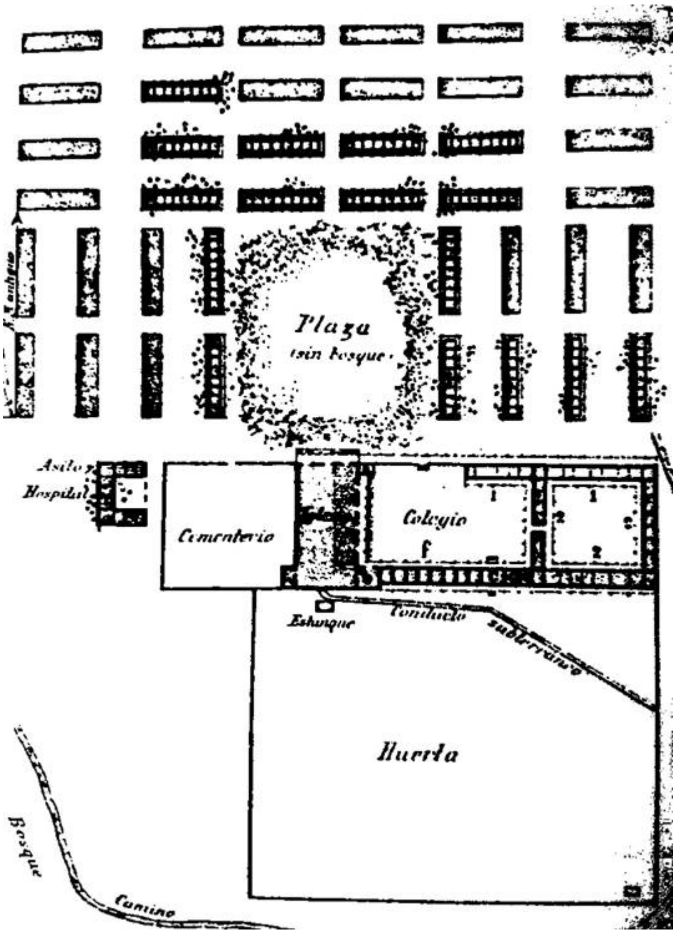
Appendix Figures

Figure A.1. Historical Population of the Guarani Jesuit Missions (1650-1780)



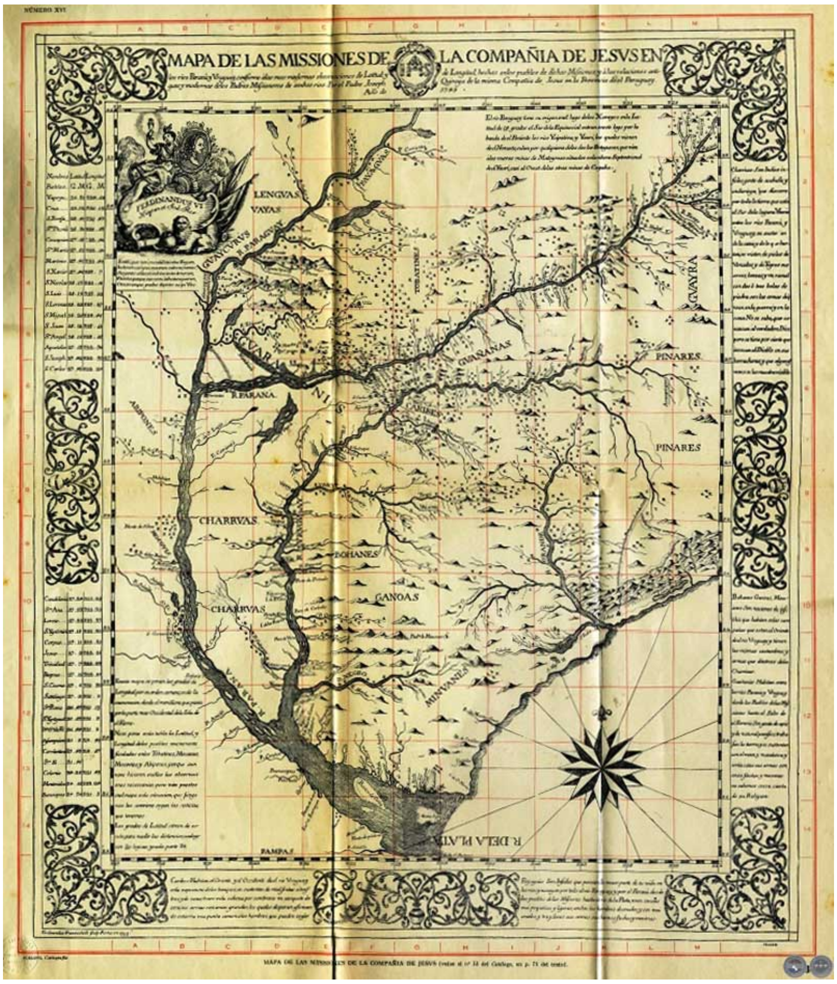
Note: Total contemporary Guarani Jesuits Missions population counts from surviving records. The red line represents 1767, which corresponds to the expulsion of the Jesuits from Latin America.

Figure A.2. Historical Blueprint of a Guarani Jesuit Mission



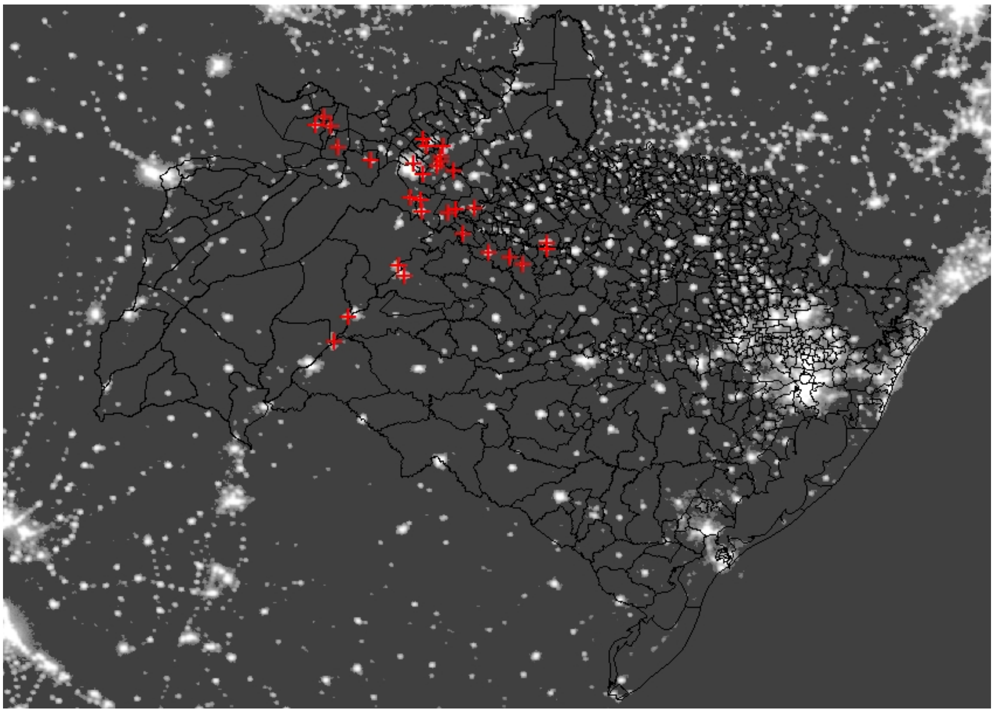
Note: Urban blueprint of the Jesuit Mission of San Ignacio de Miní taken in 1899 by Juan Queirel, taken from Hernández (1913).

Figure A.3. Historical Map of the Jesuit Missions of Paraguay



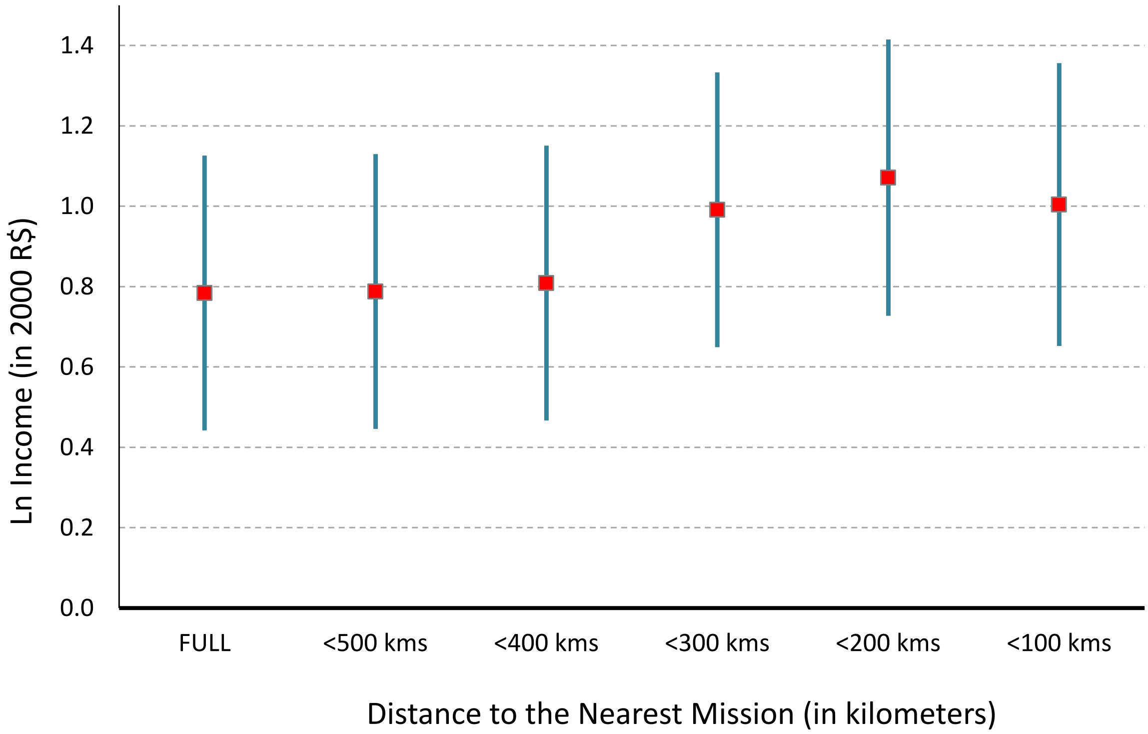
Source: Drawn by Gustavo Laterza (1647).

Figure A.4. Nighttime Satellite Maps of the Guarani Jesuit Missionary Area



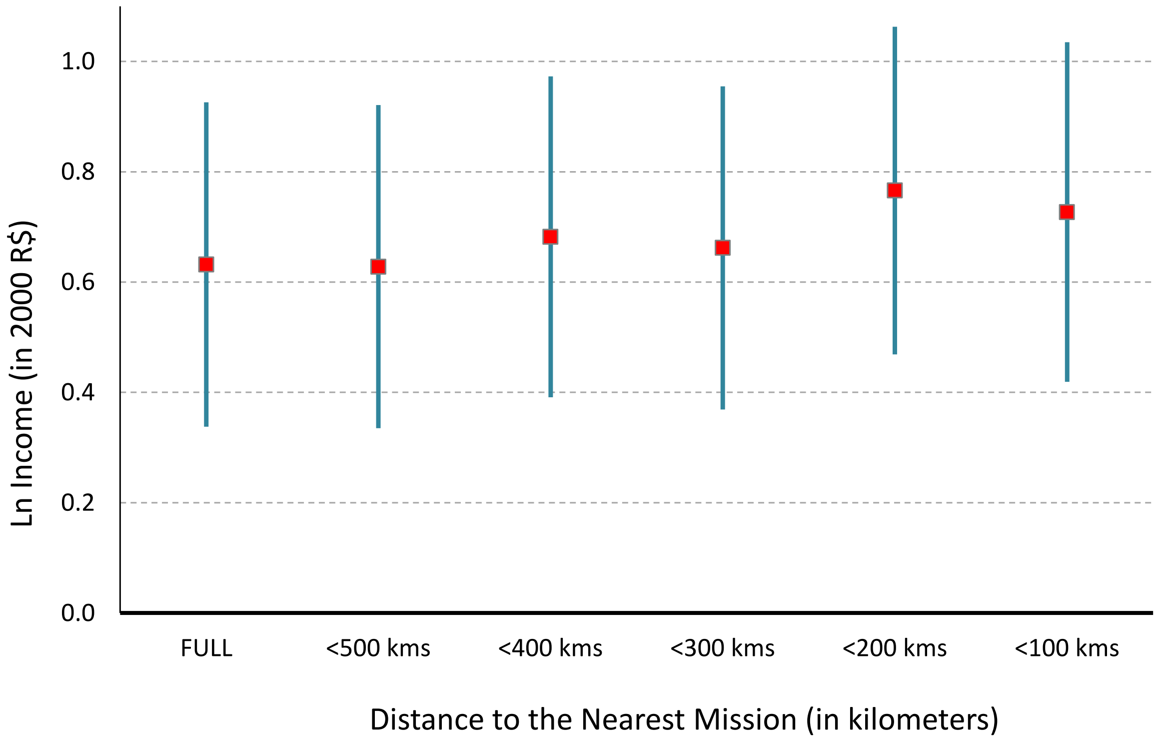
Note: The maps depict the nighttime satellite images (F18-2010) of the Guarani Jesuit missionary area along with municipal level boundaries for the states of Corrientes and Misiones (Argentina), Itapua and Misiones (Paraguay) and Rio Grande do Sul (Brazil), without and with the location of the Guarani Jesuit Missions (red crosses).

Figure A.5. Missionary Effect on Income (Dummy Formulation): Brazil



Note: This graph plots the unconditional coefficients for a regression of the logarithm of (2000) income in Brazilian Reals on a dummy for missionary presence at different distance thresholds. Point estimates are represented by red squares and 95% robust error bands by blue lines.

Figure A.6. Missionary Effect on Income (Dummy Formulation) with Geographic and Weather Controls: Brazil



Note: This graph plots the coefficients for a regression of the logarithm of (2000) income in Brazilian Reals on a dummy for missionary presence with geographic and weather controls (altitude, area, temperature and rain) at different distance thresholds. Point estimates are represented by red squares and 95% robust error bands by blue lines.

Figure A.7. Latin America Map with Tordesillas Line

Note: Map of Latin America with state level boundaries for Argentina, Brazil and Paraguay, and national level boundaries for the rest of Latin American countries along with the Tordesillas line, dividing the Spanish and Portuguese empires.

Appendix Tables

Table A.1. Guarani Jesuit Missions: 1609-1767

#	Mission Name	Year of Foundation	Country	Mean Number of Inhabitants	Mean Number of Families
1	San Ignacio Guazú	1609	Paraguay	2,610	635
2	Loreto	1610	Argentina	3,797	915
3	San Ignacio de Miní	1611	Argentina	2,464	611
4	Santiago	1615	Paraguay	-	-
5	Encarnación o Itapua	1615	Paraguay	4,239	918
6	Concepción	1620	Argentina	3,867	906
7	Corpus	1622	Argentina	3,209	690
8	Santa María la Mayor	1626	Argentina	2,480	623
9	San Nicolás	1626	Brazil	4,692	1,070
10	Yapeyú	1626	Argentina	4,202	1,003
11	Candelaria	1627	Argentina	2,361	568
12	San Javier	1629	Argentina	3,000	743
13	San Carlos	1631	Argentina	2,854	674
14	San Miguel	1632	Brazil	3,870	921
15	Apóstoles	1632	Argentina	2,999	689
16	Santo Tomé	1632	Argentina	-	-
17	San José	1633	Argentina	2,391	518
18	San Cosme y Damián	1634	Paraguay	1,611	393
19	Santa Ana	1638	Argentina	3,409	776
20	Mártires	1638	Argentina	2,554	646
21	Santa María de Fe	1647	Paraguay	-	-
22	La Cruz	1657	Argentina	-	-
23	Jesús	1685	Paraguay	1,719	353
24	San Luis Gonzaga	1687	Brazil	3,765	911
25	San Juan Bautista	1687	Brazil	3,310	773
26	San Borja	1690	Brazil	2,960	665
27	San Lorenzo	1691	Brazil	3,067	766
28	Santa Rosa	1698	Paraguay	3,195	743
29	Trinidad	1706	Paraguay	2,459	518
30	Santo Ángel	1707	Brazil	3,614	890

Table A.2. Missionary Effect on Modern Income, Alternative Formulations: Brazil and Paraguay

	1	2	3	4	5	6	7
	Ln Income	Ln Income	Ln Income	Ln Income	Ln Income	Ln Income Q-Reg.	Ln Income Q-Reg.
	BRA & PAR Full	BRA & PAR <200kms	BRA & PAR Full	BRA & PAR Full	BRA & PAR <200kms	BRA & PAR Full	BRA & PAR <200kms
Ln Mission Distance	**-0.237*** **	**-0.283*** **					
	(0.08)	**(0.08)**					
Mission Dummy (<100 kms)			**0.363** **	**1.278** **	**0.482*** **		
			(0.16)	**(0.60)**	**(0.16)**		
Mission Distance (Q-reg)						**-0.00364** **	**-0.00508** **
						(0.001)	**(0.002)**
Distance (100-200 kms)				0.88			
				(0.57)			
Distance (200-300 kms)				0.844			
				(0.54)			
Distance (300-400 kms)				0.904*			
				(0.53)			
Distance (400-500 kms)				0.224			
				(0.53)			
Constant	26.49***	20.8	-3.462	-1.113	-2.068	28.09***	16.83*
	(8.47)	(15.11)	(2.32)	(2.31)	(3.48)	(8.32)	(9.57)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	506	245	506	506	245	506	245
R-squared	0.313	0.354	0.393	0.404	0.448	0.2559	0.3184

Note: The table shows the coefficient of the logarithm of distance to the nearest Jesuit mission in kilometers in Columns 1 and 2, a dummy for whether a municipality is within 100 kilometers of a Jesuit mission in Columns 3 to 5 and distance to the nearest Jesuit mission in kilometers in Columns 6 and 7. The dependent variables are the logarithm of income in 2000 for Brazil and Paraguay. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS, except for the quantile regressions in Columns 6 and 7. Robust standard errors in parentheses and bootstrapped standard errors in Columns 6 and 7 *** p<.01, ** p<.05, *p<.1

Table A.3. Intensity of Treatment Effect of Jesuit Missions on Income: Brazil and Paraguay

	1	2	3	4	5
	Ln Income BRA & PAR	Ln Income BRA & PAR	Ln Income BRA & PAR	Ln Income BRA & PAR	Ln Income BRA & PAR
Ln (Mission Distance X Foundation)	**-0.337*** **				
	(0.0887)				
Ln (Population / MissionDistance)		**0.373*** **			
		(0.1010)			
Ln (Population X Years Active)			**0.380*** **		
Mission Distance			**(0.1060)**		
Ln (Mission Distance X River Distance)				**-0.00532*** **	
				(0.0015)	
Mission Moved					**-0.0984***
					(0.0585)
Constant	1.831	8.099	-17.38	25.40***	0.186
	(11.92)	(9.97)	(12.39)	(7.39)	(2.34)
GEO Controls	**YES**	**YES**	**YES**	**YES**	**YES**
Observations	506	498	498	506	506
R-squared	0.51	0.51	0.55	0.388	0.873

Note: The table shows the coefficient of the logarithm of distance to the nearest Jesuit interacted with year of foundation, mean population and distance to the nearest river in Columns 1 to 4. Mission moved is a 0/1 for whether or not the nearest Jesuit mission moved. The dependent variable is the logarithm of income in 2000 for Brazil and Paraguay. Geographic controls include distance to the nearest coast, distance to the nearest river, altitude, temperature, area, rainfall, latitude and longitude. Please refer to the paper for units and additional details of these variables. Estimation is by OLS. Robust standard errors in parentheses *** $p<.01$, ** $p<.05$, *$p<.1$

Chapter 2

THE PERSISTENCE OF (SUBNATIONAL) FORTUNE

Joint with William F. Maloney, Development Economics Research Group and Chief Economist for Trade and Competitiveness, The World Bank, and Universidad de los Andes, Bogotá, Colombia.

Maloney, William F. and Felipe Valencia Caicedo. 'The Persistence of (Subnational) Fortune.' *Economic Journal.* 2015. http://dx.doi.org/10.1111/ecoj.12276

Tenochtitlán was home to one of the largest concentrations of indigenous peoples in the New World when it was conquered by the Spaniards five centuries ago, and constituted an urban agglomeration rivalling those of Europe. In the words of Hernán Cortés (1522):

> This great city of Tenochtitlán is as big as Seville or Córdoba...It has many plazas where commerce abounds, one of which is twice as large as the city of Salamanca...and where there are usually more than 60,000 souls buying and selling every type of merchandise from every land... There are as many as forty towers, all of which are so high that in the case of the largest there are fifty steps leading up to the main part of it and the most important of these towers is higher than that of the cathedral of Seville. The quality of their construction, both in masonry and woodwork, is unsurpassed anywhere.
> (Cortés, La Gran Tenochtitlán, Segunda Carta de Relación (1522). Authors' translation.)

México City, erected on the ruins of Tenochtitlán, remains one of the largest and most prosperous cities in Latin America. This paper uses new subnational data from 18 countries in the Western Hemisphere to examine the degree to which such persistence is generally the case: Do rich (high pre-colonial population density) areas before the arrival of Columbus tend to be populous and rich today?

Most similar to the present work, Davis and Weinstein (2002) find persistence in Japanese population concentrations over very long historical spells, and despite massive wartime devastation.[1] Other recent works suggest persistence in economic activity over thousands (Comin *et al.*, 2010) or tens of thousands of years (Ashraf and Galor, 2013). Such persistence is consistent first, with the importance of locational fundamentals such as safe harbours, climates suitable to agriculture, rivers, or concentrations of natural resources that, even if not used for exactly the same purposes, nonetheless retain value over time (Ellison and Glaeser, 1999; Rappaport and Sachs, 2003; Fujita and Mori, 1996; Gallup *et al.*, 1999; Easterly and Levine, 2003). It may also suggest the importance of agglomeration effects, perhaps arising from increasing returns to scale (see Krugman, 1991, 1993) or Marshallian externalities arising from human capital, infrastructure and

[1] In a tragically similar case to that of Hiroshima and Nagasaki, Miguel and Roland (2011) find that heavily bombed areas of Vietnam also recovered almost fully relative to non-bombed areas.

technological externalities (Krugman, 1992; Comin *et al.*, 2010; Glaeser *et al.*, 1992; Bleakley and Lin, 2012; Severnini, 2012; Rauch, 1993) which may lead to path dependence and persistence across time even after the initial attraction of a site has faded in importance.[2] The case of the trauma of the colonization of the New World is especially interesting since, while Hiroshima in Davis and Weinstein (2002)'s work proved resistant to losing a quarter of its population, the American Indian population was literally decimated, falling by up to 90%. Further, the conquest implied the wholesale imposition of distinct culture (preferences), political organization, and technologies. The power of agglomeration effects to preserve the spatial distribution of prosperity in the face of such shocks is far from obvious.

In particular, working against persistence in the context of colonized areas, Acemoglu *et al.* (2002) argue for what they term a "reversal of fortune": areas colonized that had large populations of exploitable indigenous populations developed extractive institutions that were, particularly during the second Industrial Revolution, growth impeding. Following Malthus in associating high pre-colonial population density with more productive and prosperous areas in pre-industrial periods (see also Becker *et al.*, 1999; Galor and Weil, 1999; Lucas, 2004), they find a negative correlation between pre-colonial population density and present day incomes. This dramatic finding against persistence has become something of a stylized fact in the literature and has been influential in moving institutions to centre stage in the growth debate. In the present context, it suggests that institutional forces can more than fully offset agglomeration and locational forces.

This paper revisits the persistence question at the subnational (state, department, region) level for the Western Hemisphere. We focus on the Americas because of the availability of anthropological and archaeological estimates of indigenous population densities before Columbus at a geographically disaggregated level, the near universal colonization by one or more European powers and hence its approximation to a natural experiment, and the

[2]For a discussion of the importance of these effects for the ongoing evolution of economic geography among developing countries see World Bank (2008).

diversity of subsequent growth experiences. We match the pre-colonial population estimates to new data on present population density and per capita income generated from household surveys and poverty maps. We then incorporate a comprehensive set of geographic controls, including new measures of agricultural suitability and river density, which we show to have explanatory power as locational fundamentals determining pre-colonial settlement patterns. Data at this finer level of geographical aggregation allow us to take a more granular look at the role of locational, agglomeration and institutional forces behind the distribution of economic activity. In particular, using subnational data with country fixed effects mitigates identification problems caused by unobserved country or region specific factors arising from particular cultural or historical inheritances, and national policies, albeit, now asking the question at a level of aggregation where the relative influence of forces for and against persistence may differ.

Our empirical results suggest that, within countries, the forces for persistence dominate. Population density today is strongly and robustly correlated with pre-colonial population density as is, to lesser extent, current per capita income. Both statistical and historical evidence suggests that both locational fundamentals and agglomeration externalities plausibly explain why such persistence should occur despite the violent interaction of cultures of entirely distinct cultural, economic, institutional and technological characteristics. These findings raise some concerns that there are very significant adjustment or sunk costs that may work against "Big Pushes" seeking to radically change the location of economic activity (Rauch, 1993; Krugman, 1991). Also, the puzzle arises of why the income findings should diverge so sharply from those found at the aggregate level, and we examine various explanations for the observed difference.

1 Data

The use of subnational data to explore differential performance along various dimensions is now well established. As noted above, Davis and Weinstein (2002) use regional level data for Japan to document the remarkable persistence of population densities, highlighting the importance of both locational fundamentals and increasing returns to scale. Mitchener and McLean (2003) exploit modes of production and geographical isolation leading to differential *de facto* institutions as explaining differential growth rates across US states. Banerjee and Iyer (2005) exploit the variation in colonial property rights institutions across India to explain relative performance in agricultural investments, productivity and human development outcomes. Michalopoulos and Papaioannou (2013) find regional economic performance in Africa to be determined more by pre-colonial ethnic grouping than by subsequent national institutions. Within Colombia, present regional development outcomes are shown to be affected by colonial institutions such as slavery, Encomienda, and early state capacity (García-Jimeno, 2005); and slavery (Bonet and Roca, 2006; Acemoglu *et al.*, 2012). Naritomi *et al.* (2012) analyse how variations in colonial *de facto* institutions in Brazil led to different public good provision outcomes in modern times. Acemoglu and Dell (2010) examine differences in productivity across Latin American subregions and postulate that the large differences in institutions and enforcement of property rights, entry barriers and freeness and fairness of elections for varying levels of government are important. Dell (2010) uses district level data from Perú and Bolivia to demonstrate the long term impact of the Mita on development through the channels of land tenure and long term public goods provision.[3] In a kindred paper using subnational data across the hemisphere, Bruhn and Gallego (2011) argue that differences in the types of regional colonial activities, whether engendering extractive or inclusive institutions, lead to lower or higher incomes, respectively. Most recently, Gennaioli *et al.* (2013) use subnational data from 110 countries to argue for the overriding importance of human capital in accounting for regional differences in development.

[3]Regional differences in institutional arrangements have also been documented in the case of slavery in the US and Brazil (Degler, 1970), and share cropping and women's rights in Colombia (Safford and Palacios, 1998; Bushnell, 1993).

1.1 Population

We compile subnational data on pre-colonial population densities, contemporary population densities and household incomes for the 18 countries in the hemisphere listed in Table 1, which summarizes the data by country.

Pre-colonial Population Density: This measures the estimated number of indigenous people per square kilometre just before colonization. These data draw on a long tradition of academic research dating from the turn of the last century, much of it fuel for the debate over whether the colonial powers encountered a "pristine wilderness" or, alternatively, a world densely inhabited by indigenous peoples subsequently devastated by disease and conquest (Denevan, 1992b). At the low end, estimates by Rosenblat (1976) are now considered grossly under-reported (Thornton, 1987) while the estimates of 100 million people in the Western Hemisphere by Dobyns (1966) are considered untenably large. Denevan offered consensus estimates in *The Native Population in the Americas in 1492* (Denevan, 1992a) (published in 1976 and revised in 1992) that are now the most comprehensive and refined to date, and employed most recently by Bruhn and Gallego (2011). The 1992 edition presents updated figures, especially for regions such as the Amazon jungle that have received recent attention and reconsideration. We employ Denevan's estimates and expand the sample further using analogous data on Canada from Ubelaker (1988), and Nicaragua from Newson (1982).[4]

Though the project of estimating populations half a millennium past is necessarily speculative, the estimates synthesize the most recent available geographical, anthropological, and archaeological findings. In particular, they draw on documentary evidence such as reports by Europeans, actual counts from church and tax records, as well as contemporary and recollected native estimates and counts. Depending on the country, projections across similar geographic areas, regional depopulation ratios, age-sex pyramids, and counts from

[4]The details on the construction of the pre-colonial density measures and their mapping to modern subnational units can be found in Bruhn and Gallego (2011)

sub-samples of the population (such as warriors, adult males, tribute payers) are used, as well as backward projections from the time of contact with Europeans. These are corroborated by evidence including archaeological findings, skeletal counts, social structure, food production, carrying capacity, and environmental modification. Importantly, neither modern GDP, climate models nor current population measures are used in the construction of these estimates.

As an example, for Central Mexico, Denevan's compendium incorporates findings from the Teotihuacán Valley project of William Sanders. Data for this project comes from documentary sources from the sixteenth century including Spanish secular and ecclesiastic tax lists of the Mexican Symbiotic Region. Estimates for 1519 population are based on existing statements about specific communities, the size of Indian armies and the number of religious conversions. The work also critically reviews the historiography for earlier estimates for the sixteenth century. Sanders complements this information from records and tributary censuses from the First Audiencia of 1528, along with conversion and depopulation ratios. The non-tributary population is also assessed through a series of visits to nearby towns, and clerical and military estimates from the first conquerors. The estimates have been collated with the Aztec empire tribute list, the 1568 official count and calculations of early agricultural productivity. These detailed contemporaneous accounts are complemented with archaeological findings in Mexico, Hispaniola, Nicaragua, and other regions of Central, South and North America. The high degree of disaggregation of the indigenous estimates allows for the mapping to modern political territorial Mexican boundaries.

Figure 1 maps the pre-colonial population densities for the hemisphere. While some related studies have focused on cities as the unit of observation, such data are not available at our frequency for the pre-colonial period and we work with regional densities. However, as Davis and Weinstein (2002) note, for numerous reasons in particular related to defining a city over time, estimated regional population densities are arguably preferable. To check for data consistency with other sources we aggregate our regional numbers to the national level. In particular, we compare our estimates to the McEvedy *et al.* (1978) population density estimates for 1500 and Bairoch *et al.* (1988) urbanization index for that same year, used among others in Acemoglu *et al.* (2002) and find a correlation between our numbers and theirs of .65 and .62, respectively. Part of the difference emerges from the number of repeated observations for Central America in their national level sources for which we have more precise and varying estimates. Further, as has been noted by, among others Acemoglu *et al.* (2002), the McEvedy and Jones estimates are controversial and are mostly based on Rosenblat (1976) which are likely to understate the pre-Columbian population (Guedes *et al.*, 2013). Hence, although the various pre-colonial population count numbers are positively correlated at the national level, Denevan's estimates, in addition to offering subnational detail, are the most reliable.

Present Subnational Population Density: This measures present population per square kilometre in each subnational unit and is drawn from a highly disaggregated spatial data set on population, income and poverty constructed on the basis of national census data by the World Bank (2008) for the World Development Report on *Reshaping Economic Geography*. Population is aggregated from the census by the present subnational unit and the density is then calculated.[5]

1.2 Income

Subnational Income per Capita: Income in 2005 PPP US dollars is drawn from the same spatial data set.[6] Household income data are preferable to national accounts data as a

[5]Censuses: US, El Salvador 2000: Brazil, Panama; 2001: Bolivia, Ecuador; 2002: Chile, Guatemala, Paraguay; 2005: México, Nicaragua, Perú, 2006: Uruguay. All other countries: figures correspond to survey data estimates at the regional level or small-area estimates based on survey and census data.

[6]Household level data sets are combined with limited or non-representative coverage with census data to generate income maps for much of the hemisphere (see Elbers *et al.*, 2003). This approach addresses the problem that in some cases such as México household income surveys are not representative at the "state" level. We thank Gabriel Demombynes for providing the data. See original study for methodological details. We expect that while somewhat more complete, our data is similar to the census based data used by Acemoglu and Dell (2010). For Argentina, Colombia and Venezuela, the spatial data base reports the unsatisfied basic needs index rather than income. We project subnational GDP (production) series on this index to scale it to household income. GDP source: Argentina (CEPAL, Consejo Federal de Inversiones, Colombia (DANE)),

measure of regional prosperity. In the case of natural resource rich regions, income may or may not accrue to the locality where it is generated and hence may provide a distorted measure of level of development. As an example, the revenues from oil pumped in Tabasco and Campeche, México, are shared throughout the country, although they are sometimes (but not always) attributed entirely to the source state in the national accounts (see Aroca *et al.*, 2005). This is a broader issue that emerges wherever resource enclaves are important. For instance, from a national accounts point of view, the richest subnational units in Argentina, Colombia, Chile and Perú, respectively, are Tierra del Fuego (oil), Casanare (oil), Antofagasta (copper), and Moquegua (copper), all of which, with the exception of the last, are average or below average in our household survey measured income. Further, the geographical inhospitability of these locales ensured and continues to ensure relatively little human habitation: Antofagasta is in the driest desert in the world and Tierra del Fuego is the closest point in the hemisphere to Antarctica. This combination can give rise to a negative, although relatively uninteresting, correlation of pre-colonial population density with present income. That said, such correlations still emerge even in our income data due to the selection of the population in these areas: The very small population related to extraction of natural resources has relatively high levels of human capital and remuneration and hence, we may still find that areas which the indigenous avoided are now relatively well-off in per capita terms.

Income Distribution The gini of personal incomes in each region as calculated by Bruhn and Gallego (2011)

1.3 Locational Fundamentals

To establish the importance of locational fundamentals, we match the population and income subnational data to a broad set of geographical controls. Accounts of 18th century

Venezuela (Instituto Nacional de Estadística). We expand the sample to include Canada and the United States using the (2005) censuses. The resulting estimates of mean per capita income have been rescaled so that the population-weighted average matches 2007 GDP per capita at 2005 US dollars (PPP adjusted).

explorers, and anthropological studies confirm the importance to Indian settlements of both arable land and waterways for food and transport, characteristics also attractive to subsequent European settlers and potentially current inhabitants.[7] We incorporate two new measures to capture agricultural suitability and river density.

Suitability for Agriculture: Since agriculture was critical to early settlement, we employ a new measure of agricultural suitability as developed by Ramankutty *et al.* (2002) and first employed by Michalopoulos (2012) and subsequently by Ashraf and Galor (2013, 2011a). This measure uses a combination of three different data sets that integrate satellite based measures of cultivable land, climatic parameters that may restrict the use of this soil (mean-monthly climate conditions including temperature, precipitation and potential sunshine hours) and the IGBP-DIS global soil data sets that containing soil properties such as soil carbon density, nitrogen content, pH, and water holding capacity. Combining these through a model of land suitability, Ramankutty *et al.* (2002) generate an index of the probability that a particular grid cell will be cultivated. We employ a spatial average of this measure over subnational units.

Waterways and Coasts: For measures of the ubiquity of settlement-suitable waterways, we employ the recently developed HydroSHEDS data that provide globally consistent hydrographic information at high resolution as collected during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM). HydroSHEDS generates a mapping of river systems from which we develop a measure of the density of rivers suitable for transport.[8]

[7]Denevan (1992b) discusses the extensive evidence on the importance of agriculture throughout the hemisphere in pre-colonial times. De Vorsey Jr (1986) cites the 18^{th} century explorer William Bartram as noting that "An Indian town is generally so situated, as to be convenient for procuring game, secure from sudden invasion, a large district of excellent arable land adjoining, or in its vicinity, if possible on an isthmus betwixt two waters, or where the doubling of a river forms a peninsula; such a situation generally comprises a sufficient body of excellent land for planting corn, potatoes, squash, pumpkins, citrus, melons, etc." p. 13.

[8]HydroSHEDS stands for Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales. The HydroSHEDS project was developed by the World Wildlife Fund and U.S. Geological Survey among other organizations. Densities were calculated using zonal statistics in ARC-GIS map. Though HydroSHEDS depicts the flow of cells into a given river system, beyond a certain size we do not take into account the flow of the river per se for two reasons. First, settlements are not likely to be proportional to the size of a river, again, beyond a certain threshold. Second, due to the geographical projection, the cells

Tables 1 and 2 summarize the data.

2 Empirical Results

2.1 Locational Fundamentals and Pre-Colonial Densities

Figure 1 and Table 1 present a map and summary statistics of pre-colonial population densities. What is immediately clear is the great heterogeneity of pre-colonial population densities both within and between countries, as well as the substantial overlap of distributions across countries. The Latin American countries span densities averaging from around 0.4 person per square kilometre for Argentina to 1.7 for Venezuela, 2.5 for Brazil to 17 for Perú and 32 for México. Further, Table 1 confirms a large range of variances of initial density within country. México and Perú are not only dense on average, but have much larger variances than, for instance, the US.

However, overall, the US and Canada fit comfortably in the Latin American distribution. With a mean population density of .39, the US is above Uruguay and is roughly the same as Argentina. Canada, at 1.22 is above Argentina, Bolivia, and Uruguay and is just below Paraguay and not so far from Venezuela. Looking at both mean and variance, the US and Argentina are effectively identical: $(.39, 1.34)$ vs. $(.44, 1.45)$. A clear divide between hemispheres on the basis of population density is thus not clear.

As a first check on the relevance of our locational fundamentals proxies, Tables 3 report the results of running

$$D_{Precol,ij} = \alpha + \gamma LF_{ij} + \mu_i + \epsilon_{ij} \quad (1)$$

where $D_{Precol,ij}$, is pre-colonial density. LF is a the vector of subnational locational

do not map precisely one to one to actual flows.

fundamentals and μ_i is a country specific fixed effect. Table 3 presents estimates both with and without fixed effects (FE). We report the latter despite the fact that the territorial boundaries and corresponding national governments, institutions, and other characteristics clearly were not established at the time. First, in subsequent regressions we will care very much about abstracting from country wide effects and hence the analogous specification is desirable for reference. Second, the generation of the pre-colonial populations was done with the present national boundaries defining the unit of analysis and by different authors and hence there may be subtle differences at that level. That said, the case for fixed effects is somewhat less compelling here.

For robustness purposes, in Appendix A we also report the corresponding results using the MS (or M-S) estimator (Maronna and Yohai, 2000). Our data combine countries with very different levels and variance of initial population densities as well as often very dramatic spreads within countries. México, for instance, has many states with modest densities, but then Morelos and México City are five to ten times as large. The MS estimator is designed to handle potential good and bad leverage points (explanatory values with extreme values) as well as conventional vertical outliers in a structured way that has been shown superior to other alternatives like quantile or robust regression.

Locational fundamentals appear to explain over 23% of the within variation. Both between and within countries, agricultural suitability enters significantly and positively. In the between regression, Altitude, Temperature and Ruggedness appear significantly and positively. Within countries, consistent with Rappaport and Sachs (2003), distance to the coast and Malaria appear most significant although the MS estimates again find Ruggedness and Rainfall (negatively) correlated. The relatively high densities found in often arid relatively unsuitable areas along the coasts (see Figure 1) may reflect the marine, rather than agricultural basis of the local economy. The three significant variables account for 19 points of the 23% explained. In sum our locational fundamentals proxies suggest that indigenous populations were concerned with agriculture or fishing, being warm, avoiding malaria, staying high, perhaps to avoid other diseases or predators, and not being too wet.

2.2 Persistence: Overview and Specification

We next explore the correlation of pre-colonial population densities with present population densities and with present per capita income. Again, the summary statistics for all three variables are found in Table 1.

2.3 Current Population

2.3.1 Evidence for persistence in population

Figure 2 presents the entire sample pooled and shows a very strong and significant unconditional correlation between pre-colonial and present population densities some 500 years apart. Each point represents a state or subnational unit and there are a total of 365 observations. As a means of examining individual country experience and comparing our results to those of Davis and Weinstein (2002), Table 4 reports the raw and rank order correlation of present population density with pre-colonial population density. The results confirm that the positive relationship found for both the US and in fact the entire hemisphere, is significant and powerful. The majority, 16 of 18 countries respectively, show a positive correlation, 13 significant. Canada is the only country to show a significant negative coefficient, largely driven by the Arctic Northwest Territories, Yukon and Nunavut which have relatively lower population densities today. 14 of the 18 countries show strongly significant correlations and/or rank correlations. 12 show correlations that exceed .5, and Chile, El Salvador, Guatemala, Mexico, Nicaragua, Peru, and Venezuela all exceed .75 in correlation and a similar number in rank correlation. The conflict in the two measures for Argentina is due to the fact that Buenos Aires city went from low density to among the highest densities in our sample which lowers the raw correlation, but leaves a relatively high and positive ranking in place. Overall, for the majority of countries showing persistence, the magnitudes are broadly similar to the .76 and .83 respectively found by Davis and Weinstein (2002) for the shorter 400 year period spanning CE 1600 to 1998 in Japan.

The US is among the lowest of those showing a positive and significant correlation at .37 and, again, Canada is the only negative and significant entrant. In general, the Latin American countries show much higher degrees of population persistence than the US or Canada with Panama, Paraguay and Uruguay showing insignificant and small correlations. This partially appears to reflect differences in immigration where the US and Canada were very open, and Latin America, with a few exceptions and like Japan, relatively closed. The fourth column presents a measure of the importance of migration at the *country* level calculated from Chanda *et al.* (2014). The greatest recipients of immigrants were Argentina, Canada, Uruguay, and the US, four of six countries with low or negative raw correlations and in fact the correlation of immigration and persistence is -.65. Both Uruguay and Argentina had levels of immigration comparable to those of the US and Canada and hence similar frontier expansion effects that might weaken the initial ordering as in the US and Canadian plains or the Argentine pampas. Massive immigration that multiplies overall population by double digits can lead to the exploration of new areas and establishment of new population concentrations that might happen more slowly under normal population growth.[9]

For pooling the data in both the current population and income variables, we estimate:

$$D_{2005,ij}; Y_{2005,ij} = \alpha + \beta D_{precol,ij} + \gamma LF_{ij} + \mu_i + \epsilon_{ij} \tag{2}$$

where $D_{2005,ij}$, population density of subunit i of country j, and $Y_{2005,ij}$, present per capita

[9]From the point of view of establishing the particular channels postulated by the reversal of fortune literature, it may be argued that capital cities have a *sui generis* dynamic and should be excluded. From a general point of view of understanding agglomeration effects and persistence, this is less clear- whatever the impetus that established these cities, the existing megalopolises in Latin America are not supported in the main by government activities at present. Precisely the emergence of such "Urban Giants" has been studied by Ades and Glaeser (1995), while Krugman and Elizondo (1996) have focused on México City. In the end, even dropping these overall strengthens the persistence results. We thank Daron Acegmoglu for bringing this point to our attention.

income, are sequentially the dependent variables. Table 5 presents the results for current population. Here, fixed effects are potentially of greater importance than in the last section because of the desire to control for country level historical effects or policies that would affect the between dimension, and we focus primarily on those estimates. That said, all specifications are positive and significant. Population density shows strong persistence across time. Including the geographical fundamentals does not dramatically reduce either the significance or magnitude of the population density effect. Including the quadratic terms in the fundamentals (not shown) similarly leaves population significant and positive. As before, good agricultural conditions, not being too far from a coast, and an absence of malaria appear important determinants of modern population density. Colonial densities 500 years ago explain 15% of the variance. Including the locational fundamentals raises it to 46%.[10] In sum, despite a reasonably large set of locational controls, the pre-colonial densities themselves appear to be robustly significant. Fundamentals continue to be important as conquistadors and immigrants arrive to populate the continents. However, with the caveat that we are likely to be missing or mis-measuring some locational fundamentals, we cannot rule out an important amount of persistence existing for reasons related to the existence of the populations themselves.

2.3.2 Population Persistence Mechanisms

Beyond the geographical factors discussed above, plausible mechanisms through which populations themselves could drive persistence can be found in the value of the populations themselves, knowledge and information, and complementary technologies brought by the colonists.

Workers, Citizens and Souls. In Latin America, native populations were indeed a source of tribute and labour and hence it is not surprising that Spanish cities would be built

[10]Further, inversely weighting the observations by intensity of migration (not shown), as expected, dramatically strengthens the effect of initial density. Consistent with the finding above, interacting immigration with initial population density confirms a strong negative impact on persistence and weighting by the (1-immigration) increases both the point estimate and significance (not shown). We thank David Weil for this suggestion.

near existing population centres, whatever factors drove their initial settlement. In other regions under Spanish colonization, the native populations were valued for otherworldly and strategic reasons. The missions set up along the Alta California (now US) coast-San Diego, Los Angeles, Santa Barbara, San Jose and San Francisco-were established beside major native population centres (as in the Southwest) to recruit souls to Christianity, but also to create colonial subjects to occupy territories perceived under threat of English and Russian encroachment (Taylor, 2001). In these cases, it was the population agglomeration itself, rather than the locational fundamentals per se, that were the attraction as exploitation was not the primary motivation.

Clearly, however important the people, to the degree that the initial settlements were driven by geography, the present spatial distribution of activity fundamentally reflects that geography. However, history suggests that location decisions are not always so straightforward as, for example, escaping malaria. Tenochtitlán was allegedly determined by the God Huitzilopotchli through a dream to be established where an eagle was found eating a snake while perched atop a cactus. This turned out to be a small, swampy, island whose chief attraction appears to be that it was uncoveted by the neighbouring tribes and was defensible. Parkes (1969) notes that the Mexica (Aztecs) were the last tribe of seven to enter the valley and wandered as outcasts, selling their services as mercenaries to the dominant tribes, and eating reptiles and pond scum to survive. They had the worst pickings of a not entirely favourable locale. The valley of México, and in particular Tenochtitlán, had unreliable weather, with a short growing season and frequent drought. Famine was not uncommon. The lake was subject to storms and a major flood in 1499 caused the loss of much of Tenochtitlán (Thomas, 1993). Simpson (1962) notes that "With the silting up of the lakes and consequent flooding, the city was frequently inundated with its own filth and became a pest hole. Epidemics were a scourge for centuries and were not brought under control until the opening of the Tequixquiac drainage tunnel in 1900" (page 164). Geography itself does not appear sufficient to drive the permanence of the largest and richest city in

Latin America.[11] There appears to be some path dependence arising from the agglomeration itself.

Knowledge and Commerce. In the US, pre-colonial native populations were relatively small, topping out at around 2 people per square kilometre, and they were generally, with the exception of South Carolina (Breen, 1984), not exploited for tribute or labour by French, Anglo and Dutch colonizers. This suggests that while the argument that the Spanish and Portuguese located near indigenous populations for purposes of tribute or forced labour through the Encomienda or Mita is compelling, it is not the only mechanism through which pre-colonial agglomerations were perpetuated. To begin with, throughout the New World explorers depended on native cartography and knowledge to map the relevant geographical and demographic sites (De Vorsey, 1978). New settlement was likely not to be random, but influenced by the previous "known world". In addition, colonizers needed the knowledge and skills accumulated by the native populations. Cortés employed the stone masons and architects of the pyramids, canals and aqueducts of vanquished Tenochtitlán to remodel Moctezuma's palace into his own, and to raise the most important city in the New World from the ruins of the Aztec capital. The large population of craftsmen and artisans was of world caliber (Parkes, 1969). The conquistadors more fundamentally needed those with a knowledge of plant life, agronomy, and hunting to feed their new towns. Hence, just by virtue of already supporting a civilization in all its dimensions, Tenochtitlán was attractive beyond the brute labour force it offered and in spite of its actually lacklustre locational fundamentals.

In non-Spanish North America, the competing colonial powers also established many cities including Albany (Dutch), Augusta (British), New York (Dutch), Philadelphia (British), Pittsburgh (French and British), St.Louis (French) on or next to native population settlements. Partly, the colonists, like the native populations, valued the areas of rich alluvial lands along the major river systems that served as the primary mode of transportation and

[11] see also Michaels *et al.* (2012) for examples of the persistence of non-fundamentals based urban location in France vs. England.

communication, or the strategic locations. Bleakley and Lin (2012) argue that portage sites around rapids or falls gave rise to agglomerations in commerce and manufacturing that persist today, suggesting path dependence and increasing returns to scale. However, the native populations were critical attractions in themselves as well, again, largely for informational, commercial, and strategic reasons. As Taylor (2001) notes, "On their contested frontiers, each empire desperately needed Indians as trading partners, guides, religious converts, and military allies. Indian relations were central to the development of every colonial region"(p. 49). From Canada to Louisiana, trade and defence led the French to establish their trading posts as nodes of trade and negotiation for securing alliances and food. In the North, French and Dutch Fur traders exploited existing networks of native tribes as suppliers of pelts. Quebec, for example, was located in an area where the local natives were skilled hunters and the nearby and numerous Huron nation served as provisioners and trade middlemen. Similarly, on Vancouver Island and throughout the Pacific Northwest, the British traded extensively with natives in sea otter pelts. Pre-colonial Indian population concentrations offered benefits to colonizers along many dimensions, and those of trade in goods and information are classic positive externalities associated with agglomerations.

Complementary Technologies. As a final effect working in the opposite direction, for some indigenous agglomerations, contact with European culture and technology may have perpetuated their dominance after an initial period of trauma, particularly given the proximity to the Industrial Revolution. Comin *et al.* (2010) for instance, document an association between technology in 1500 AD and present income, roughly our period. Ashraf and Galor (2011a) argue that at the moment of transition between technological regimes, more cultural diffusion facilitates innovation and the adoption of new technologies. As one suggestive example, Steckel and Prince (2001) argue that one reason that the US plains Native Americans were the tallest people in the world in the mid-19th century was the buffalo and game made more accessible with the introduction of horses, metal tools, and guns by Europeans (see also Coatsworth (2008)). Our documented patterns of persistence may therefore be partly driven by the degree to which the conquest transferred the old world technological endowment. The population centres of the earlier Maya, Anasazi, and Toltec civilizations have vanished. Perhaps partly because of their contact with the Spanish, the Aztec population centre persists.[12]

Taken together, locational fundamentals, agglomeration externalities, and technological transfer may plausibly contribute to an explanation of why pre-colonial densities, even after the decimation of the local population, mapped to early colonial densities which, in turn, have persisted to this day. The question does remain, in light of the (Rauch, 1993; Krugman, 1991) discussion, about whether even if the Spaniards valued the Aztec survivors for themselves, the costs were really so prohibitive as to prevent them from being moved to a more desirable geographical location? The answer is probably yes. Tenochtitlan at its peak had somewhere between 200,000 and 350,000 inhabitants which after decimation still implies moving somewhere around 20,000 individuals, their homes, workshops, plots of land, infrastructure etc.. Further, to take them somewhere new would imply the loss of all the accumulated knowledge of how to best survive in the area: how to farm it, how to defend it. We could argue that that the relatively few conquistadors made the task especially onerous. However, as we will see below, the few cases where we do find substantial re-allocations of population are in response to major shifts in fundamentals and are often accompanied by substantial immigration.

2.4 Current Income

2.4.1 Evidence for persistence of income

The previous section confirms for the Americas Davis and Weinstein's (2002) finding that population density is persistent over very long periods of time. A large literature argues from Malthus that high population densities in pre-industrial periods signal higher productivity and prosperity (see, for example Becker *et al.*, 1999; Galor and Weil, 1999; Acemoglu *et al.*,

[12]See Maloney and Valencia Caicedo (2014) for a discussion of technological transfer in the Americas.

2002; Lucas, 2004). The relationship between present population and present income may be expected to be less tight than historically was the case for at least two reasons: as Ashraf and Galor (2011b) and Galor (2011) note, the traditional Malthusian relationship between population and wealth weakens with technological progress, and the natural resource endowment effects discussed earlier. Further, in the process of demographic transition, population density may be more correlated with high population growth and poverty. Hence, though there is a positive and significant relationship between the current population and income, it is not obvious that there should be. Again, Acemoglu *et al.* (2002) precisely argue at the country level, that high prosperity areas in pre-colonial times, measured by population density, became low prosperity areas today as measured by GDP per capita. The causality, again is that higher indigenous population densities led to extractive institutions that subsequently depress growth. Figure 3 shows that our data when aggregated support this reversal (Appendix B compares our population data to the McEvedy and Jones data.)

However, Figures 4 and 5 suggest that, at the subnational level, the relationship is more complex with some countries showing very strong evidence of persistence. The high degree of heterogeneity among the country cases suggests that understanding the drivers of the observed patterns is more convincingly done through careful examination of each as as is done below. That said, the overall summary of the available data (Table 6)-the FE regressions with and without geographical controls- pre-colonial density suggests a positive and significant effect for our sample overall. Perhaps consistent with a modern industrial economy with better infrastructure, neither agricultural suitability nor distance to the coast appear important although high altitude, rainfall and malaria all work against present day income.[13]

[13]The results are sensitive to the transformation of pre-population employed. An insignificant result is found in a log transformation because it dramatically reduces the influence of very high population density areas and hence potentially important high leverage points such as Mexico City or Cusco and increases the influence of the Galapagos or Tierra del Fuego which had and have few people. From a point of view of testing whether large densities of indigenous populations affected institutions and hence growth, the levels specification gives it the best chance and and the MS estimates(see Appendix A) suggest that, in fact, the more extreme values are "good" leverage points and not outliers. In no specification do we find a remotely statistically significant reversal. Further, for the sample used in the slavery regressions below, both functional forms generate significant and positive coefficients. See original working paper for a complete set of specifications.

2.4.2 Reconciling the subnational with national findings

The summary regressions raise the question of why, at the subnational level, we find evidence for persistence, while at the national level Acemoglu *et al.* (2002) find reversals. We discuss three although clearly there could be others.

First, it may be that national institutions drive the overall development trajectory and when fixed effects strip these out, only the local agglomeration effects, locational fundamentals and perhaps less important subnational institutional effects remain. However, it is not axiomatic that subnational institutions were not as important as national and that we should not see the same exclusionary institutions and consequences replicated at the local level. Colombia, for instance, is famously fragmented into highly independent subregions often segmented by harsh and mountainous terrain.[14] As Safford and Palacios (1998) note, "Provincial government remained effectively independent of the Audiencia [the local Spanish seat of control], and Santa Fe de Bogotá lacked formal authority of what is now western Colombia"(p. 55). National conditions and institutions were arguably relatively less important than those local compared to other countries, and, as noted earlier, a variety of local institutional structures coexisted (see again García-Jimeno (2005); Bonet and Roca (2006)) and affected local development outcomes.[15] But even countries considered more centrally consolidated show a high degree of fragmentation with a somewhat tentative reach of central institutions. To quote a 19th century observer from southern Chile:

[14]The titles of the two principal English-language histories emphasize precisely the lack of national integration: *Colombia, Fragmented Country, Divided Society* by Bushnell and *The Making of Modern Colombia: A Nation in Spite of Itself* by Safford and Palacios.

[15]Several regions employed both native and African slaves and evolved extractive institutions to manage them, others far less. Similarly, the Mita, Resguardo, and Encomienda are found to varying degrees in different departments. Independence saw several (repressed) attempts at regional succession, and the construction of a strong national state was effectively resisted. As an example, Bushnell (1993) recounts that the 1863 Constitution created nine United States of Colombia, but with far more restricted central power than was the case in the North American analogue. For instance, states issued their own stamps; the national government had responsibility only for "inter-oceanic" transport routes (that is, pertaining to the Panama railroad) thereby weakening any integrative national infrastructure project; and the upper house of the national Congress was called the Senate of Plenipotentiaries "as if its members were the emissaries of sovereign nations" (p. 122).

> Not so many years ago the inhabitants of the central region spoke of those in the South as distant and unknown, without the beneficial influence of civilization or the protection of the Government. Those in the upper altitudes considered those of the valleys as residents of another hemisphere, to which one could not travel except at great risk and financial sacrifice. Anyone who claimed that he had gone to Santiago or come from the South was treated as a dreamer or a liar; if he could prove with documents and irrefutable witnesses that he had made the journey, he was celebrated as if he had gone to China.
> (Pedro Ruiz Aldea, *La Tarantula* (Concepción) August 9, 1862, cited in Monteón (1982), page 3)

The seeming absence of a blanketing national "civilization" or [institutions of] government protection allows local institutions to emerge, and potentially dominate the national. Hence, if, in fact, differing concentrations of indigenous peoples appreciably affect institutional structures, it is not clear that the local effects should not be as or more powerful than the national.[16]

Second, it may be that moving to the subnational level increases the importance of locational fundamentals or agglomeration effects as suggested by Davis and Weinstein (2002) relative to institutional effects. Indeed, studies that have tried to measure agglomeration economies carefully (Ciccone and Hall, 1996; Duranton, 2005; Ellison and Glaeser, 1997; Greenstone *et al.*, 2010) have all done so using highly disaggregated subnational data. Summerhill (2010) finds that in São Paulo Brazil, a "potentially coercive" colonial institution, the *aldeamento* that regulated indigenous populations is *positively* correlated with income per capita at the end of the twentieth century. He argues that there were both extractive and settler (effectively agglomeration effects), and the net effect was positive. We offer similar findings. Appendix C uses the share of slaves in the population as a proxy for extractive institutions, and suggests that regions with a higher incidence of slavery have both lower incomes and less, although still strongly positive and significant, persistence: we may have found stronger persistence in the absence of extractive institutions. Hence, it is possible that at the subnational level, the net effect yields persistence, while at the national level where

[16] Michalopoulos and Papaioannou (2013), for instance, find this to be the case in Africa where pre-colonial tribal patterns are more correlated with present income than subsequent national institutions.

local agglomeration and geographical effects are diluted, national institutions dominate.[17]

Finally, it is possible that the aggregate negative relationship between pre-colonial density and present income is due to factors other than a correlation with extractive institutions. For example, Easterly and Levine (2012) show a negative correlation between indigenous density and the proportion of Europeans in colonial society which they, like Glaeser *et al.* (2004), argue affects income today through channels including human capital, institutions, technology, or culture. Relatedly, Chanda *et al.* (2014) argue that the reversal arises from migrants from technologically advanced areas moving to low density places and thereby propelling them from backward to advanced. The resolution of the national/subnational discrepancy clearly depends on the proposed mechanism underlying the aggregate relationship. In this particular case, we would need to understand why the driver of the negative density-European/advanced area relationship is not replicated at the subnational level although, again, it may simply be that local agglomeration and geographical forces dominate.

Distinguishing among these hypotheses is difficult. Perhaps weighing in against the link of pre-colonial densities with extractive/exploitative institutions is that, as in Bruhn and Gallego (2011), we find no correlation between pre-colonial indigenous densities and present income inequality (See Appendix D). That is, if extractive/exploitative institutions were instituted more in high density areas with long lived impacts on the level of income, we might expect them to influence the distribution of that income as well. This appears not to be the case.[18]

In the next section, we take a more careful historical look at individual low, medium and high density country cases to get a clearer view of how the different forces interacted to yield the patterns we see at the subnational level, and the two low density countries which offer our only negative evidence for reversals.

[17]Our thanks to Noam Yuchtman for suggesting this interpretation.

[18]We are grateful to a referee who prompted us to look at the distribution data.

2.4.3 Low Density and Persistent: The US

Persistence holds strongly in the US. California, Massachusetts, and Rhode Island again, show the highest pre-colonial density and above average incomes. Among the mid-level pre-colonial density states, New Jersey, Connecticut, Delaware, are also among the richest, and Washington and Oregon are solidly above average. This mass of points on the two coasts drives the upward sloping relationship while a diffuse mass of largely southern and mountain states anchors the low pre-colonial density-low current income nexus.

As noted earlier, higher incomes plausibly find their roots both in the initial native agglomerations and locational fundamentals that attracted both native populations and Europeans. Both effects continued to be important across the centuries. For example, New York, Boston and Chicago have all played to their locational particularities, especially in transport, but they have also built on their strengths in accumulated human capital and information (see, for example Glaeser (2005)). There is also an argument for poor institutions driving the poorer regions in line with Acemoglu *et al.* (2001). The adverse disease environment and climate of much of the South discouraged settlement and, in the end, colonization required the importing of African slaves.

The state most likely to capture the colonization-driven inversion dynamic might have been Mississippi since it incorporated the third largest native civilization in North America, was abused by the Spaniards, and is now the poorest state. However, the reversal of the state's fortune from a rich cotton centre in the 19th century is likely more due to the institutional, demographic and education legacy of African slavery than the long vanished native population (see again Appendix C). As Taylor (2001) notes, the Spanish conquistador Hernando de Soto arriving in the fertile Mississippi river valley in 1540-1542 was impressed by the size of native populations, the expansive maize fields, the power of the chiefs to command large numbers of well trained warriors, even the pyramids, one of which was the third largest in North America after those of central México (The pyramid at Cahokia near present day St. Louis). De Soto died on the banks of the Mississippi, frustrated at finding no gold, and the Spaniards withdrew to México City, but not before widespread pillaging and infection decimated the native population. When the French returned a century later, only the Natchez people near present day Natchez, Mississippi remained in strength and organization. French encroachments on Natchez territories in 1729 led to massacres by the French and their Choctaw allies and dispersion and sale into slavery in the French West Indies of the surviving population. With the passage of another century, Natchez and Mississippi would emerge very prosperous at the height of the cotton boom.

Our results are consistent with Mitchener and McLean (2003) using population data from 1700 that combines immigrant and black population and confirms persistence from 1700 to 1880 and then a very slight reversal moving to the present. The latter 20th century result, but not the earlier, loses all significance when they control for settler origin dummies suggesting that, as in Chanda *et al.* (2014) the composition of immigration is contaminating the institutional experiment. Further, the correlation of actual measured productivity across the period 1880-the present shows strong persistence. For a low range of pre-colonial densities, the US suggests the persistence of economic activity.

2.4.4 Low Density Reversals: Argentina and Chile

Argentina and Chile, provide the only two examples of statistically significant "reversals" (Figure 5). Hence, understanding the cause of their negative relationship is of particular interest. For Argentina, the evidence supports an idiosyncratic geographical fundamentals story rather than an institutional one. The richest areas in Figure 5-the Province of Buenos Aires, La Pampa, Córdoba, Santa Fe and Entre Rios surround Buenos Aires City-tend, in fact, to be in areas of low pre-colonial population density. The other richer departments, Santa Cruz and Chubut, are relatively undiversified mineral producers in relatively unattractive climates and hence show the "resource inversion" discussed earlier.

At the other extreme, Corrientes and Misiones are relatively underdeveloped humid semi-tropical areas that were traditionally isolated and show the highest pre-colonial density and, hence, potentially extractive institutions. But it must be kept in mind that these densities map in both absolute and relative magnitude to those of Massachusetts and California within an overall distribution that, again, is remarkably similar to that of the US. Hence, a theory of institution-driven inversion would need to explain why the endogenously emerging institutions would be so different from the US. In addition, Buenos Aires may well not have been such a paragon of inclusionary institutions that would account for its unusual growth. It was a major port of slave disembarkation in the New World and, in the last years of Spanish domination, it was 30% black (Andrews, 1980).[19]

It seems more likely that the present distribution of income arises largely from Buenos Aires' status as the principal Atlantic port of the Spanish empire. This was not always the case. Despite the evolution of the surrounding pampas economy, prior to the mid 18th century Buenos Aires was a backwater, surviving on smuggling contraband silver and slaves. This was largely due to the repression of natural locational advantage. By Spanish law, the production of silver and other products of the interior towns were directed over the Andes to Lima on the Pacific, where they were loaded on convoys passing through the Isthmus of Panama and then to Spain. The more logical route-through the Atlantic port of Buenos Aires, and then directly to Spain-was forbidden. However, largely for geostrategic reasons arising from the emergence of the North American colonies as a potential Atlantic power, the policy was reversed in 1776 when Spain established Buenos Aires as the capital of the new Viceroyalty of Rio de la Plata. Trade was now mandated through Buenos Aires and forbidden through Lima, leading to an abrupt reorientation of the country's economy away from the traditional interior towns, and towards the emerging coastal economy (Scobie, 1964). Hence, by royal fiat, locational fundamentals went from being repressed to dominant.

[19]As a final point, Ades and Glaeser (1995) argue that industry did not play a prominent role in the rise of Buenos Aires so that a case for it being more suited to the second wave of the Industrial Revolution seems unlikely. Even by 1914, only 15 percent of the labour force was in manufacturing and the government displayed "hostility toward manufacturing and innovation" p 221.

From here, the agglomeration related externalities arising from becoming the dominant Atlantic port can explain the pattern we see. Finally, the finding of Chanda *et al.* (2014) that immigration upends even the original reversal of fortune relationship applies with special relevance to Argentina in which, in 1900, 30% of the population was recent immigrant and most concentrated in Buenos Aires, compounding the shift in the economic centre of gravity there.

Chile also shows a significant negative relationship between pre-colonial densities and present income but one which, again, does not appear driven by the institutional story for three reasons. First, several observations at the highest end of the country's relatively low density (4.7 per square kilometre)-Bio Bio, Maule, O'Higgins, Los Lagos, and Araucania-are among the poorest. However, these form a contiguous region, with the area below the Bio Bio River that includes them dominated by the Mapuche Indians and conquered only very late in the 19th century and hence never experienced Spanish rule. More likely, the technological complementarities discussed earlier were at play- the institutional case is not as compelling, perhaps, as one stressing the costs of being out of the global technological loop. In fact, the eventual conquest had to wait for the Chileans to import recent advances in weaponry to which the Mapuches did not have access. The subsequent oppression exacerbated these lags. The capital, Santiago, offers a counter example of a regression discontinuity flavour: it has the same density and is contiguous to this region, but it was conquered several hundred years earlier and is much more prosperous. Second, the country is one of extremes with extractive industries in some of the driest and coldest areas of the planet which were not attractive to native populations. This implies a relatively uninteresting correlation of relatively low pre-colonial densities, and moderately high incomes (for a very few people) today. Finally, as in Argentina, the fact that the overall density is roughly equivalent to that of Canada raises the question of why such effects could be so so much stronger in Chile.

2.4.5 Medium Density and Persistent: Colombia and Bolivia

Colombia, a middle density country, is an important case for understanding the relative import of the different forces for and against persistence and, in particular, that of extractive institutions (see Acemoglu *et al.*, 2012; García-Jimeno, 2005). First, though it is not among the countries with the highest pre-colonial density, it is a classic example of Spanish conquest with the usual attendant institutions. Hence, while we might argue that something about Anglo or French colonists led to different colonizer-native dynamics, this would not be the case in Colombia. Second, it had relatively little immigration so the Chanda *et al.* (2014) concern is mitigated. Third, as noted above, it is a perhaps the case which offers the greatest independence of subnational observations from national conditions and institutions. As noted earlier, the country is highly geographically fragmented and its regions have shown a fierce autonomy, long resisting centrally imposed rule. Yet, despite the relative strength of local institutions, Colombia still shows one of the cleanest examples of persistence in the sample (Figure 5) a fact confirmed also by Meisel (2014) using repeated censuses and records of tributary Indians. Not only the capital, but other areas of high pre-colonial density-Valle de Cauca, Santander, and Antioquia-have among the highest present day incomes. Hence, again, local agglomeration and locational forces appear to be dominant.

One particular reversal within the country is illustrative of the relative strength of locational fundamentals in particular. Although understated in the figures, Cauca department and its principal city Popayán fell from one of the two most important regions in Colombia–a major provider of early Colombian presidents and possessor of one of the country's two mints–to one of the poorer regions. The Spaniards favoured it for the availability of indigenous labour to extract its mineral wealth, and its subsequent use of imported African slaves defined its culture in fundamental ways. However, the city that it lost market share to, Cali, in Colombia's now second richest department, Valle de Cauca, had an indigenous population density 30% larger and only 10% fewer slaves per capita than

Cauca. In fact, it had the largest number of slaves of any department in Colombia.[20] The period critical to the reversal appears to be 1878 to 1915 with the construction of the Pacific Railroad connecting Cali with Buenaventura, Colombia's largest Pacific port, and through the Panama Canal (finished in 1914) to the rest of the world, while Popayán remained relatively isolated (Safford and Palacios 2002). It is likely that the location of the railroad, while importantly dictated by Cali's proximity to the Cauca River, is partly due to political economy considerations. However, a story related to initial populations or slavery does not appear clearly. It seems more likely that a permanent shock to locational fundamentals altered the relative attractiveness of the two regions.[21]

Of interest is that Cali's new locational advantage did not also diminish Antioquia and the Bogotá/Cundinamarca agglomeration as industrial centres. In the colonial period, both had a locational advantage in terms of climate and soil suitable for agriculture, proximity to mineral reserves, and disease inhibiting altitude. Yet, none of these are important to explaining the overwhelming dominance of both areas in the manufacturing and service sectors, while the need to cross, especially in Bogotá's case, several mountain ranges to access world markets is a major drag on competitiveness. This is suggestive that, as as in the US case, agglomeration effects, in particular, the availability of talent and knowledge- are critical to the continued dominance of these areas.[22] In sum, then, in a country where

[20]According to the 1843 Census of Colombia, 7.1% of the population was slaves in Cauca and 6.4% in Valle; in 1851 4.7% and 4.3% respectively. Initial indigenous density was 7.1 and 9.2 respectively.

[21]A similar story is the rise and fall of Mompóx, Colombia. This affluent port in the Magdalena River saw its demise when the river shifted course, allowing the development of Magangué. Since then, this UNESCO World Heritage Site has virtually remained stuck in time.

[22]The Bogotá/Cundinamarca agglomeration dominates the country in most modern services and manufactures. The capital city, Bogotá, has revealed comparative advantage (participation of sector in value added relative to country average greater than 1) in non-food manufacturing (12% of value added), commerce (14%), financial services (10%), real estate services (10%), services to firms (7%), air transport services (1%), few of which are tied to locational fundamentals. In these areas and industry in general, it is the largest single producer in the country. In particular, it accounts for 50% of all financial services. Emphatically, it has neither comparative advantage or much production in the agriculture (0%) or minerals (0%) sectors which first attracted the colonists. As capital city, it also shows a comparative advantage in public administration, but this is not dominant or unusually large (9% of value added relative to 7% on average for the country as a whole). The enveloping department of Cundinamarca, maintains a comparative advantage in agricultural production, but also in both agricultural and non agricultural manufacturing and is the third and fourth largest national producer respectively. The growth of Antioquia historically was driven by mining and then by coffee. It maintains a comparative advantage in both, but each accounts for roughly 1% of departmental

local institutions were relatively important, agglomeration and locational fundamentals appear to dominate.

Bolivia also provides a case of a moderate level of indigenous density with significant persistence although it has fewer observations and important leverage points that drive the results. Like Colombia, it is also fragmented with Santa Cruz, and la Paz as distinct poles of economic activity, much the same as Medellin, Bogota and Cali. The critical influence of the relatively high density Colchabamba and La Paz remain, although Santa Cruz, somewhat like Monterrey in Mexico, is an emerging industrial pole that weakens the relationships of persistence.

2.4.6 High Density and Persistent: El Salvador, Nicaragua, Perú and México

El Salvador, Nicaragua, Perú and México have among the highest densities in our sample. While we might expect the strongest agglomeration as well as negative institutional effects in these countries, overall they show support for persistence. In Figure 5, Both El Salvador and Nicaragua show clear and statistically significant positive slopes. México and Perú are the emblematic examples of the colonization of the New World. Though less clearly significant than the other two, both offer support for the importance of the forces of persistence, albeit contaminated by changes in locational fundamentals.

For Perú, Figure 5 suggests that Lima, La Libertad, Ica and Piura all correspond to very high pre-colonial density areas that remain among the better off regions today. However, Lambayeque province weakens the statistical relationship by showing the highest density observation but below average current income. Lambayeque's decline appears largely driven by compounding natural disasters-negative locational fundamental shocks. In pre-colonial times, the region was a major centre of the Chimor and then Inca cultures. The Spanish

value added. It has a comparative advantage in manufacturing (18%) and commerce (11.5%) and is the second largest producer of manufactures, commerce, and financial services after the Bogotá/Cundinamarca agglomeration.

colonizers subsequently built a livestock industry on appropriated native land and irrigation systems, as in Tenochtitlán, taking advantage of the infrastructure and knowledge of the previous civilization. From 1650 to 1719, a dynamic sugar based hacienda economy emerged and generated numerous fortunes. However, after 1720 the economy collapsed into a century long period of stagnation. While this was partly due to competition from other Peruvian (including local native) and Caribbean producers, as Ramirez (1986) argues in her detailed study of the region, a plague of cane-eating rats in 1701 followed by two devastating floods in 1720 and 1728 constituted idiosyncratic but very long lived shocks which, compounded by a shortage of finance (see Cushner, 1980), caused widespread foreclosures and the bankruptcy of the traditional producing class. Only in the late colonial period did the regional economy recover somewhat to a now average level income as the new owners shifted from sugar to livestock and tobacco.[23]

México appears to combine two distinct sets of growth dynamics that interact to obscure any clear relationship. The first is the persistence effect. The Mexican Federal District (city) is the highest density region in our sample and it is one of the richest regions in all of Latin America. Morelos, the second densest region in our sample, has above average income. Both suggest persistence in the most native intensive regions of the hemisphere. Tlaxcala, the third most dense area in México ranks among the lower levels of prosperity. However, it seems unlikely that we can attribute it to especially extractive institutions since, in exchange for being the principal allies of the Spaniards and sheltering them in a particularly dire moment in the conquest of Tenochtitlán, the Tlaxcalans were granted "perpetual exemption from tribute of any sort," a share of the spoils of conquest, and control of two bordering provinces, an agreement that was substantially respected for the duration of Spanish rule (see Marks, 1994, p. 188).[24] Among the very highest pre-colonial densities in our sample,

[23]Lambayeque did differ in its continued heavy reliance on Indian labour as competitor sugar growing areas shifted more toward African slaves, although it is not clear whether this should have generated more or less toxic extractive institutions.

[24]In fact it may have been the opportunities for adventurism in partnership with the Spaniards in other areas of the New World that diverted energies from the home region. Tlaxcalans aided the Spaniards in dominating conquered tribes moving North. The oldest church in the US, found in Santa Fe, New México

agglomeration effects again appear dominant.

However, there is a second dynamic. The present high income of the low pre-colonial density states of Baja California Sur, Nuevo León, Baja California Norte, Chihuahua, Sonora, and Coahuila provide a strong countervailing "reversal" that offsets the persistence effects. The proximity of these states to the increasingly dynamic US border makes it difficult to disentangle the influence of various types from the North (proximity to markets, knowledge spillovers), where it was in large part an appendage of the US economy. At the time of the establishment of the border at the Rio Grande, it was linked by population flows and contraband; during the civil war, it was a significant Southern export outlet; and by the turn of the century, it had received substantial US investments in railroads and mining that gave the impetus to the development of capitalism in the North (Mora-Torres, 2001). For instance, US firms operated mines in the North for export to US foundries (e.g. Consolidated Kansas City Smelting in Chihuahua). The three large foundries that formed the basis for the future dynamism of the principal industrial city in northern México, Monterrey, Nuevo Leon (with spillovers to much of the north of México) were primarily oriented toward the US market, and the largest was established by the Guggenheim interests with US capital (Morado, 2003).[25] As Marichal (1997) notes, the emerging industry in these areas gave impetus to a set of *de facto* and eventually *de jure* institutions and pro-industry regulations which may well have only been able to emerge in an environment where the regulatory structure had not been driven by extractive considerations. That said, the fact that a positive correlation emerges when we abstract from the border states causes us to think that the proximity to the US was the primary driver of the prosperity of the low density North.

was constructed by Tlaxcalan artisans.

[25]As Mora-Torres (2001) notes, these foundries emerged largely as a result of the McKinley tariffs of 1890, which taxed foreign imports at roughly 50 percent. This threatened both Mexican exports of ore to the US, as well as the smelters on the US side that processed them. The response was to move the smelters over the border to the railway centre of Monterrey. The result of the accumulated US capital investment was "that the northern economy became an extension of the U.S. economy and that the North turned into the new centre of Mexican capitalism" p. 9.

3 Conclusion

This paper documents that, within countries, economic activity in the Western Hemisphere has tended to persist over the last half millennium and in spite of the major trauma that was colonization. Despite the literal decimation of the previous populations, the imposition of new cultural and political forms and technologies, areas that were rich and populated before the arrival of Colombus remain highly populated and tend to be rich today.

In the same way that Davis and Weinstein (2002) demonstrated the resiliency of Hiroshima's population to mass devastation and a 25% fall in population, we show comparable correlations of population densities across time in the Americas despite, again, mass devastation and the up to 90% reduction in their population. Our findings inform the discussion surrounding the difficulty of changing the distribution of economic activity (Rauch (1993); Krugman (1991)). Despite the graphical and statistical evidence for most countries that persistence in population is extremely strong, there are notable outliers. Buenos Aires, Argentina rose from a backwater to the densest population by far. Several Northern Mexican states, such as Baja California, or Nuevo Leon emerged from obscurity to become industrial centres. Each case, however, was accompanied by a major "big push"': the release of a perverse restriction on locational advantage in Argentina, and the emergence of a major economic power next door to Mexico. In both Argentina and the US, the dispersion around the central tendency is quite high suggesting that massive migration can shake up the population substantially if not actually overturning it.

Though a less uniform finding, and in spite of theoretical reasons to think it might not be the case, there is also overall a tendency for income to persist over time as well and there is no evidence for a reversal of fortune as Acemoglu *et al.* (2002) find at the country level. This is clearly the case for low pre-colonial density countries like the US, but also for classic Latin conquest cases like Colombia, and, for the extreme high density cases like El Salvador, México, Nicaragua and Perú. Across all our case studies, the large changes in relative positions, such as in Popayán (Colombia), Lambayeque (Perú), Buenos Aires, (Argentina), or the North of México appear largely driven by shifts in locational fundamentals.

Our case studies suggest reasons for both fundamentals and pre-colonial densities to be important drivers of this persistence. Not only would colonizers also value the rivers, coasts, fertile land, natural resources, and climate that initially attracted the native populations, but they would need the native populations themselves as sources of human capital (architects, agronomists, and craftsmen), trading partners, sources of information, strategic bulwarks against enemy encroachment, and souls to save. Hence, scale economies and Marshallian externalities related to population were probably as relevant to determining where colonists located their settlements as locational fundamentals. In turn, the contact with new technologies may have, after the initial trauma, strengthened these agglomerations. Many of the regions of the very highest pre-colonial density remain among the most prosperous regions today: the persistent prosperity of California and New England, in the US, or Antioquia, or Bogotá in Colombia, despite massive structural transformations away from natural resource based production toward more sophisticated manufacturing and services does suggest that the forces arising from concentrations of knowledge, trade or labour are critical. At the subnational level, geographical and agglomeration factors appear to cause fortune to persist.

Appendix A M-S estimates

The M-S estimator is a combination of M and S estimates. In the case where some variables are categorical (0-1) and some are continuous and random which may contain leverage points, as is the case here, M estimates are not robust and S estimates are computationally intensive. The MS estimator combines both and though less well-known than, for instance, quantile or robust regression for managing potential outliers, it has several advantages. First, it is more robust to bad leverage points. Second, it is likely to provide more efficient estimates of the standard errors than the bootstrapped quantile estimates since it adjusts for outliers. Finally, it attains the maximum breakdown point, being robust to up to half of the observations being contaminated. In practice, a sizeable share of our observations in all pooled specifications are identified as outliers and hence a high breakdown point is desirable. The standard "robust" estimator in STATA is a class of M estimator, however it is not robust, in particular, to masked outliers. That is, when calculating whether a observation has a standardized distance above a critical value, it uses the variance calculated using outliers. An upward biased estimate of the standard deviation may therefore allow a true outlier to remain in the sample. The MS estimator obviates this problem. Table A1 shows our results to persist using this estimator.

Appendix B McEvedy and Jones vs our population data

Figure A1 shows that our aggregated measure of pre-colonial density and the national measure of McEvedy *et al.* (1978) used by Acemoglu *et al.* (2002) are highly correlated and that the reason that the correlation is not higher is the repetition of values for Central America in the latter. There is clearly a difference in scale between the two measures and ours are probably preferable. As AJR note, the McEvedy and Jones data has been highly controversial and most recently Guedes *et al.* (2013) argue that they likely understate the true pre-Columbian population by large magnitudes. Peru, for example, they argue may be understated by a factor of 2-7; Mexico 2-5 times. M and J postulate a total value for Central America of 800000 where other estimates of Guatemala alone run as high as 2 million. Our data reflects these more recent anthropological data and are more reliable.

Appendix C The institutional channel: slavery in Brazil, Colombia, and the US

Though the paper documents the relative importance of locational fundamentals, agglomeration externalities and perhaps technological transfer in determining present income, we also find evidence for the negative impact of extractive institutions, even if they did not dominate the others.[26] As a proxy for extractive institutions we are able to collect data on the incidence of slavery at the subnational level for Brazil and Colombia and the US where censuses are available. As a direct measure of extractive institutions, we exploit the data on slavery, measured as the percentage of enslaved and "free coloured people," in the three countries for which they are national historic censuses. For Brazil, we used the 1872 Census, for Colombia the 1851 Census and for the United States, we used the 1860 Census as well as the data compiled in Nunn (2008). [27] To capture the broader influence of slavery, both in the year of the census and in previous years, we include both slaves and the general black population which would include now-freed slaves.

While data comparability and classification issues are non-trivial, the average share of the population enslaved in the mid 19th century was 28% in the American South, 13% in Brazil and 2.9% in Colombia. We use the more expansive measure that includes free Blacks which

[26]The negative impact of slavery cannot be taken as a foregone conclusion since disentangling the endowment and institutional effect is difficult. Acemoglu *et al.* (2012) find that in Colombian municipalities where slave labour was demanded poverty is higher and school enrolment, vaccination coverage and public good provision is lower, than where it was not. On the other hand, in São Paulo, Brazil Summerhill (2010) finds no relationship between slavery and present incomes while Rocha *et al.* (2012) find slavery is positively correlated with human capital.

[27]We thank Jaime Bonet and Adolfo Meisel Roca for providing their colonial data for Colombia and for pointing us towards Tovar-Pinzón *et al.* (1994)'s compendium of colonial statistics.

raises Brazil to first position, although the results do not change qualitatively when we use the more narrow measure.

$$Log(Y_{2005,ij}) = \alpha + \beta D_{precol,ij} + \delta SLAVERY_{ij} + \delta_{int} SLAVERY_{ij} * D_{precol_{i}j} + \gamma LF_{ij} + \mu_i + \epsilon_{ij} \quad (3)$$

where δ_{int} captures the interaction of pre-colonial density and slavery and μ_i are now three fixed effects for Brazil, Colombia and the US South with the US North as the omitted category. Columns 1-5 in Table C1 progressively introduce the elements of equation 3. Column 1 includes pre-colonial density along with dummies for Brazil, Colombia and the American South.[28] In the full sample pre-colonial density is significant and positive, lending support from a smaller sample to the case for persistence. Column 2 repeats the same regression with the smaller sample dictated by the more restrictive slavery variable with a loss in significance of the persistence term. Columns 3 add the slavery term and it enters negatively and significantly. Column 4 adds slavery interacted with initial population density. It enters negatively and of similar sign. Further, the coefficient on pre-colonial density roughly doubles with the inclusion of the interaction of slavery and density in the levels specification and increases by 30 percent in the log specification suggesting that extractive institutions did have a negative agglomeration effect as postulated by Acemoglu *et al.* (2002).

Adding locational fundamentals (column 5) changes the coefficient little and the MS estimator confirms the free standing and interactive terms significant. Though the sample is small, nonetheless, the results offer support for extractive institutions at least reducing, if not overturning the persistence induced by agglomeration externalities and fundamentals.

In sum, despite legitimate concerns about the exogeneity of slavery, using a direct proxy

[28] The South is comprised of Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, Virginia, West Virginia.

for exclusionary institutions is suggestive of the existence of an Acemoglu *et al.* (2002) effect: slavery works against persistence. However, at the subnational level, the net effect of factors associated with of indigenous population densities– extractive institutions, agglomeration externalities, or locational fundamentals–tends to leave a positive correlation with prosperity today.

Appendix D The link between pre-colonial density and present income inequality

The regional data on income distribution of household incomes offers a proxy for extractive institutions that may shed light on whether in fact, indigenous densities mapped into extractive institutions and hence a skewed distribution of income. Table D1 presents the regression of current Gini on initial density and various other covariates the literature proposes to be important.

$$Gini = \alpha + \beta D_{precol,ij} + \delta D_{2005,ij} + \lambda lnY_{2005,ij} + \gamma LF_{ij} + \mu_i + \epsilon_{ij} \tag{4}$$

Column 3 suggests that there is no significant relationship between the log of pre-colonial density and inequality. Column 4 includes the respective proxies for current population density and income which Glaeser *et al.* (2009) show are correlated with current urban inequality. The coefficients for our regional data in the log specification (column 4) are surprisingly close to theirs for cities: the coefficient on log of current population is .006 compared to .008 and log income -.03 compared to their -.06. Pre colonial density, however, remains insignificant in the log specification. Introducing locational fundamentals in both columns 5 confirms the lack of import. This remains the case using precolonial and present density in levels. In any specification, the overall explanatory power of the free standing pre-colonial density is so truly negligible as to raise some doubts about whether modern day inequality is arising through a channel related to pre-colonial population densities, especially outside of those we have documented of present day population density and income. This, again, may be different at the national level, but at the subnational level it appears not to be the case.

References

Acemoglu, D. and Dell, M. (2010). 'Productivity differences between and within countries', *American Economic Journal: Macroeconomics*, vol. 2(1), pp. 169–88.

Acemoglu, D., García-Jimeno, C. and Robinson, J.A. (2012). 'Finding Eldorado: Slavery and long-run development in Colombia', National Bureau of Economic Research.

Acemoglu, D., Johnson, S. and Robinson, J.A. (2001). 'The colonial origins of comparative development: An empirical investigation', *American Economic Review*, vol. 91(5), pp. 1369–1401.

Acemoglu, D., Johnson, S. and Robinson, J.A. (2002). 'Reversal of fortune: Geography and institutions in the making of the modern world income distribution', *The Quarterly Journal of Economics*, vol. 117(4), pp. 1231–1294.

Ades, A.F. and Glaeser, E.L. (1995). 'Trade and circuses: Explaining urban giants', *The Quarterly Journal of Economics*, vol. 110(1), pp. 195–227.

Andrews, G.R. (1980). *The Afro-Argentines of Buenos Aires 1800-1900*, University of Winsconsin Press. Madison.

Aroca, P., Bosch, M. and Maloney, W.F. (2005). 'Spatial dimensions of trade liberalization and economic convergence: Mexico 1985–2002', *World Bank Economic Review*, vol. 19(3), pp. 345–378.

Ashraf, Q. and Galor, O. (2011a). 'Cultural assimilation, cultural diffusion and the origin of the wealth of nations', National Bureau of Economic Research.

Ashraf, Q. and Galor, O. (2011b). 'Dynamics and stagnation in the malthusian epoch: Theory and evidence', *American Economic Review*.

Ashraf, Q. and Galor, O. (2013). 'The "out of Africa" hypothesis, human genetic diversity, and comparative economic development', *The American Economic Review*, vol. 103(1), pp. 1–46.

Bairoch, P., Batou, J. and Chevre, P. (1988). 'The population of european cities. data bank and summary of results: 800-1850', .

Banerjee, A. and Iyer, L. (2005). 'History, institutions, and economic performance: The legacy of colonial land tenure systems in India', *American Economic Review*, vol. 95(4), pp. 1190–1213.

Becker, G.S., Glaeser, E.L. and Murphy, K.M. (1999). 'Population and economic growth', *American Economic Review*, vol. 89(2), pp. 145–149.

Bleakley, H. and Lin, J. (2012). 'Portage and path dependence', *The Quarterly Journal of Economics*, vol. 127(2), p. 587.

Bonet, J. and Roca, A.M. (2006). 'El legado colonial como determinante del ingreso per cápita departamental en Colombia', Banco de la República - Economía Regional.

Breen, T.H. (1984). 'Creative adaptations: Peoples and cultures', *Colonial British America*.

Bruhn, M. and Gallego, F.A. (2011). 'Good, bad, and ugly colonial activities : Studying development across the Americas', *Review of Economics and Statistics*.

Bushnell, D. (1993). *The Making of Modern Colombia: A Nation in Spite of Itself*, University of California Press.

Chanda, A., Cook, C.J. and Putterman, L. (2014). 'Persistence of fortune: Accounting for population movements, there was no post-columbian reversal', *American Economic Journal: Macroeconomics*.

Ciccone, A. and Hall, R.E. (1996). 'Productivity and the density of economic activity', *American Economic Review*, vol. 86(1), pp. 54–70.

Coatsworth, J.H. (2008). 'Inequality, institutions and economic growth in Latin America', *Journal of Latin American Studies*, vol. 40, pp. 545–569.

Comin, D., Easterly, W. and Gong, E. (2010). 'Was the wealth of nations determined in 1000 bc?', *American Economic Journal: Macroeconomics*, vol. 2(3), pp. 65–97, doi: 10.1257/mac.2.3.65.

Cushner, N.P. (1980). *Lords of the Land: Sugar, Wine, and Jesuit Estates of Coastal Peru, 1600-1767*, SUNY Press.

Davis, D.R. and Weinstein, D. (2002). 'Bones, bombs, and break points: The geography of economic activity', *American Economic Review*, vol. 92(5), pp. 1269–1289.

De Vorsey, L. (1978). 'Amerindian contributions to the mapping of North America: A preliminary view', *Imago Mundi*, vol. 30, pp. 71–78.

De Vorsey Jr, L. (1986). 'The colonial Georgia backcountry', *Colonial Augusta:"Key of the Indian Countrey"(Macon, Ga., 1986)*, pp. 3–26.

Degler, C.N. (1970). *Out of Our Past: The Forces that Shaped Modern America*, Harper & Row, New York.

Dell, M. (2010). 'The persistent effects of Peru's mining mita', *Econometrica*, vol. 78(6), pp. 1863–1903.

Denevan, W. (1992a). *The Native Population of the Americas in 1492*, University of Wisconsin Press.

Denevan, W. (1992b). 'The pristine myth: the landscape of the Americas in 1492', *Annals of the Association of American Geographers*, vol. 82(3), pp. 369–385.

Dobyns, H.F. (1966). 'An appraisal of techniques with a new hmispheric estimate', *Current Anthropology*, pp. 395–416.

Duranton, G. (2005). 'Testing for localization using micro-geographic data', *Review of Economic Studies*, vol. 72(4), pp. 1077–1106.

Easterly, W. and Levine, R. (2003). 'Tropics, germs, and crops: How endowments influence economic development', *Journal of Monetary Economics*, vol. 50(1), pp. 3–39.

Easterly, W. and Levine, R. (2012). 'The european origins of economic development', National Bureau of Economic Research.

Elbers, C., Lanjouw, J.O. and Lanjouw, P.F. (2003). 'Micro–level estimation of poverty and inequality', *Econometrica*, vol. 71(1), pp. 355–364.

Ellison, G. and Glaeser, E.L. (1997). 'Geographic concentration in u.s. manufacturing industries: A dartboard approach', *Journal of Political Economy*, vol. 105(5), pp. 889–927.

Ellison, G. and Glaeser, E.L. (1999). 'The geographic concentration of industry: Does natural advantage explain agglomeration?', *American Economic Review*, vol. 89(2), pp. 311–316.

Fujita, M. and Mori, T. (1996). 'The role of ports in the making of major cities: Self-agglomeration and hub-effect', *Journal of Development Economics*, vol. 49(1), pp. 93–120.

Gallup, J.L., Sachs, J.D. and Mellinger, A.D. (1999). 'Geography and economic development', *International Regional Science Review*, vol. 22(2), pp. 179–232.

Galor, O. (2011). *Unified Growth Theory*, Princeton Univ Press.

Galor, O. and Weil, D.N. (1999). 'From malthusian stagnation to modern growth', *American Economic Review*, vol. 89(2), pp. 150–154.

García-Jimeno, C. (2005). 'Colonial institutions and long-run economic performance in Colombia: Is There Evidence of Persistence?', *Documento CEDE*.

Gennaioli, N., La Porta, R., Lopez-de Silanes, F. and Shleifer, A. (2013). 'Human capital and regional development', *The Quarterly Journal of Economics*, vol. 105, p. 164.

Glaeser, E.L. (2005). 'Urban colossus: Why is New York Americas largest city?', *Economic Policy Review*, p. 7.

Glaeser, E.L., Kallal, H.D., Scheinkman, J.A. and Shleifer, A. (1992). 'Growth in cities', *Journal of Political Economy*, vol. 100(6), pp. 1126–52.

Glaeser, E.L., La Porta, R., Lopez-de Silanes, F. and Shleifer, A. (2004). 'Do institutions cause growth?', *Journal of Economic Growth*, vol. 9(3), pp. 271–303.

Glaeser, E.L., Resseger, M. and Tobio, K. (2009). 'Inequality in cities', *Journal of Regional Science*, vol. 49(4), pp. 617–646.

Greenstone, M., Hornbeck, R. and Moretti, E. (2010). 'Identifying agglomeration spillovers: Evidence from winners and losers of large plant openings', *Journal of Political Economy*, vol. 118(3), pp. 536–598.

Guedes, J.d., Bestor, T.C., Carrasco, D., Flad, R., Fosse, E., Herzfeld, M., Lamberg-Karlovsky, C.C., Lewis, C.M., Liebmann, M., Meadow, R. *et al.* (2013). 'Is poverty in our genes?', *Current Anthropology*, vol. 54(1), pp. 71–79.

Krugman, P. (1991). 'History versus expectations', *The Quarterly Journal of Economics*, vol. 106(2), pp. 651–667, doi:10.2307/2937950.

Krugman, P. (1992). *Geography and Trade*, vol. 1 of *MIT Press Books*, The MIT Press.

Krugman, P. and Elizondo, R.L. (1996). 'Trade policy and the third world metropolis', *Journal of Development Economics*, vol. 49(1), pp. 137–150.

Krugman, P.R. (1993). 'On the relationship between trade theory and location theory', *Review of International Economics*, vol. 1(2), pp. 110–22.

Lucas, R.E. (2004). 'The industrial revolution: Past and future', *Annual Report*, (May), pp. 5–20.

Maloney, W.F. and Valencia Caicedo, F. (2014). 'Engineers, entrepreneurs and development in the Americas', World Bank, Washington, DC.

Marichal, C. (1997). 'Avances recientes en la historia de las grandes empresas y su importancia para la historia económica de México', in (C. Marichal and M. Cerutti, eds.), *Historia de las grandes empresas en México, 1850-1930*, Universidad Autónoma de Nuevo León - Fondo de Cultura Económica.

Marks, R.L. (1994). *Cortés: The Great Adventurer and the Fate of Aztec Mexico*, Alfred A. Knopf.

Maronna, R. and Yohai, V. (2000). 'Robust regression with both continuous and categorical predictors', *Journal of Statistical Planning and Inference*, vol. 89(1-2), pp. 197–214.

McEvedy, C., Jones, R. *et al.* (1978). *Atlas of World Population History.*, Penguin Books Ltd, Harmondsworth, Middlesex, England.

Meisel, A. (2014). 'No reversal of fortune in the long run: Geography and spatial persistence of prosperity in Colombia, 1500-2005', Banco de la Republica de Colombia.

Michaels, G., Rauch, F. and Redding, S. (2012). 'Urbanization and structural transformation', *Quarterly Journal of Economics*, vol. 127(2), pp. 535–586.

Michalopoulos, S. (2012). 'The origins of ethnolinguistic diversity', *American Economic Review*, vol. 102(4), pp. 1508–39.

Michalopoulos, S. and Papaioannou, E. (2013). 'Pre-colonial ethnic institutions and contemporary African development', *Econometrica*, vol. 81(1), pp. 113–152, ISSN 1468-0262, doi:10.3982/ECTA9613.

Miguel, E. and Roland, G. (2011). 'The long run impact of bombing Vietnam', *Journal of Development Economics*, vol. 96(1), pp. 1–15.

Mitchener, K.J. and McLean, I.W. (2003). 'The productivity of US states since 1880', *Journal of Economic Growth*, vol. 8(1), pp. 73–114.

Monteón, M. (1982). *Chile in the Nitrate Era: The Evolution of Economic Dependence, 1880-1930*, University of Wisconsin Press Madison, Wisc.

Mora-Torres, J. (2001). *The Making of the Mexican Border*, University of Texas Press.

Morado, C. (2003). 'Empresas mineras y metalurgicas en Monterrey, México. 1890-1908. parte ii. tres plantas metalúrgicas', Ingenierias.

Naritomi, J., Soares, R.R. and Assuncao, J.J. (2012). 'Institutional development and colonial heritage within Brazil', *Journal of Economic History*, vol. 72(1), pp. 393–422.

Newson, L. (1982). 'The depopulation of Nicaragua in the sixteenth century', *Journal of Latin American Studies*, vol. 14(2), pp. 235–286.

Nunn, N. (2008). 'Slavery, inequality, and economic development in the Americas: An examination of the engerman-sokoloff hypothesis', in (E. Helpman, ed.), *Institutions and Economic Performance*, pp. 148–180, Harvard University Press.

Parkes, H.B. (1969). *A History of Mexico*, Houghton Mifflin.

Ramankutty, N., Foley, J., Norman, J. and McSweeney, K. (2002). 'The global distribution of cultivable lands: Current patterns and sensitivity to possible climate change', *Global Ecology and Biogeography*, vol. 11(5), pp. 377–392.

Ramirez, S.E. (1986). *Patriarchs: Land Tenure and the Economics of Power in Colonial Perú*, University of New Mexico Press, Albuquerque, 1st edn., ISBN 082630818.

Rappaport, J. and Sachs, J.D. (2003). 'The United States as a coastal nation', *Journal of Economic Growth*, vol. 8(1), pp. 5–46.

Rauch, J.E. (1993). 'Does history matter only when it matters little? the case of city-industry location', *The Quarterly Journal of Economics*, vol. 108(3), pp. pp. 843–867, ISSN 00335533.

Rocha, R., Ferraz, C. and Soares, R. (2012). 'Settlement colonies across plantation fields: Evidence on the relationship between human capital and long term development', PUC-Rio.

Rosenblat, A. (1976). 'The population of hispaniola at the time of columbus', *The native population of the Americas in 1492*, pp. 43–66.

Safford, F. and Palacios, M. (1998). *Colombia: Fragmented Land, Divided Society*, 1st ed. edn.

Scobie, J.R. (1964). *Argentina : A City and a Nation*, Oxford University Press, New York.

Severnini, E.R. (2012). 'The power of hydroelectric dams: Agglomeration spillovers', .

Simpson, L. (1962). *Many Mexicos*, Univ of California Press.

Steckel, R.H. and Prince, J.M. (2001). 'Tallest in the world: Native americans of the great plains in the nineteenth century', *The American Economic Review*, vol. 91(1), pp. pp. 287–294, ISSN 00028282.

Summerhill, W. (2010). 'Colonial institutions, slavery, inequality, and development: Evidence from São Paulo, Brazil', *Slavery, Inequality, and Development: Evidence from São Paulo, Brazil (April 14, 2010)*.

Taylor, A. (2001). *American Colonies: The Settling of North America the Penguin History of the United States, Volume 1*, Penguin History of the United States, New York, N.Y: Penguin Books.

Thomas, H. (1993). *Conquest: Montezuma, Cortés, and the Fall of Old México*, Touchstone.

Thornton, R. (1987). *American Indian Holocaust and Survival: A Population History Since 1492*, vol. 186, University of Oklahoma Press.

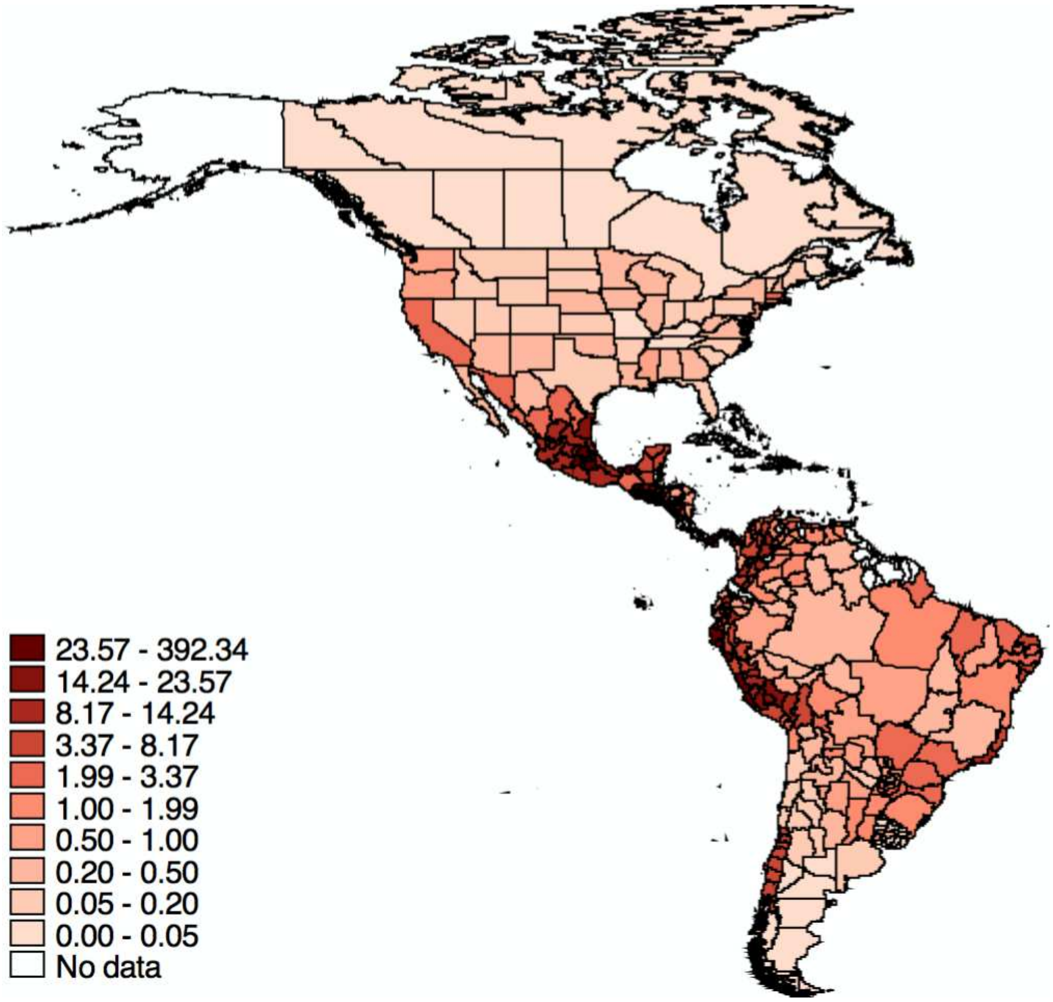
Tovar-Pinzón, H., Tovar-Mora, J.A. and Tovar-Mora, C.E. (1994). *Convocatoria al Poder del Número: Censos y Estadísticas de la Nueva Granada, 1750-1830*, Archivo General de la Nación (Colombia).

Ubelaker, D. (1988). 'North American Indian population size, AD 1500 to 1985', *American Journal of Physical Anthropology*, vol. 77(3), pp. 289–294.

World Bank (2008). *World Development Report 2009: Reshaping Economic Geography*, ISBN 978-0-8213-7608-9.

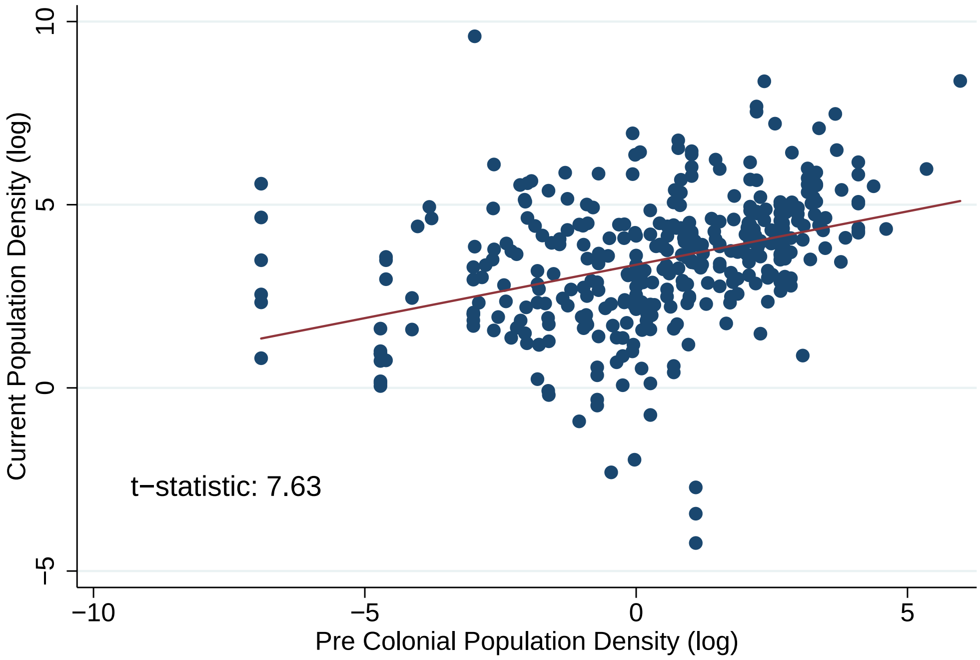
Tables and Figures

Figure 1: *Pre-colonial Population Density*



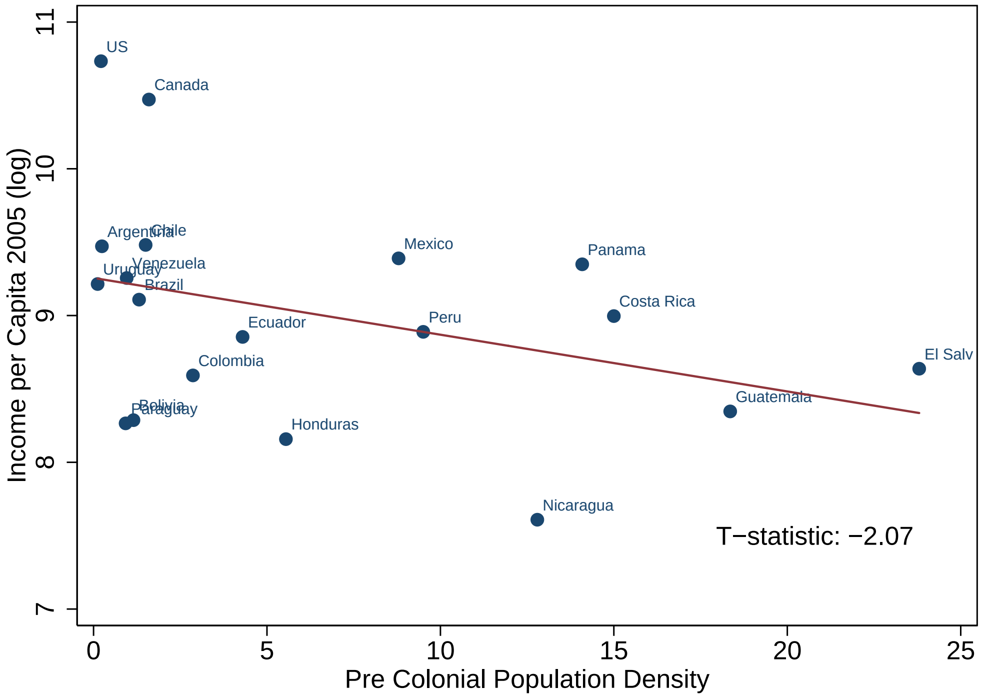
Note: Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, Income is per capita (PPP 2005 US dollars) in 2000. Data from national censuses, Denevan (1992), and Bruhn and Gallego (2010). More detailed data sources and descriptions in the text.

Figure 2: *Persistence in Subnational Population*



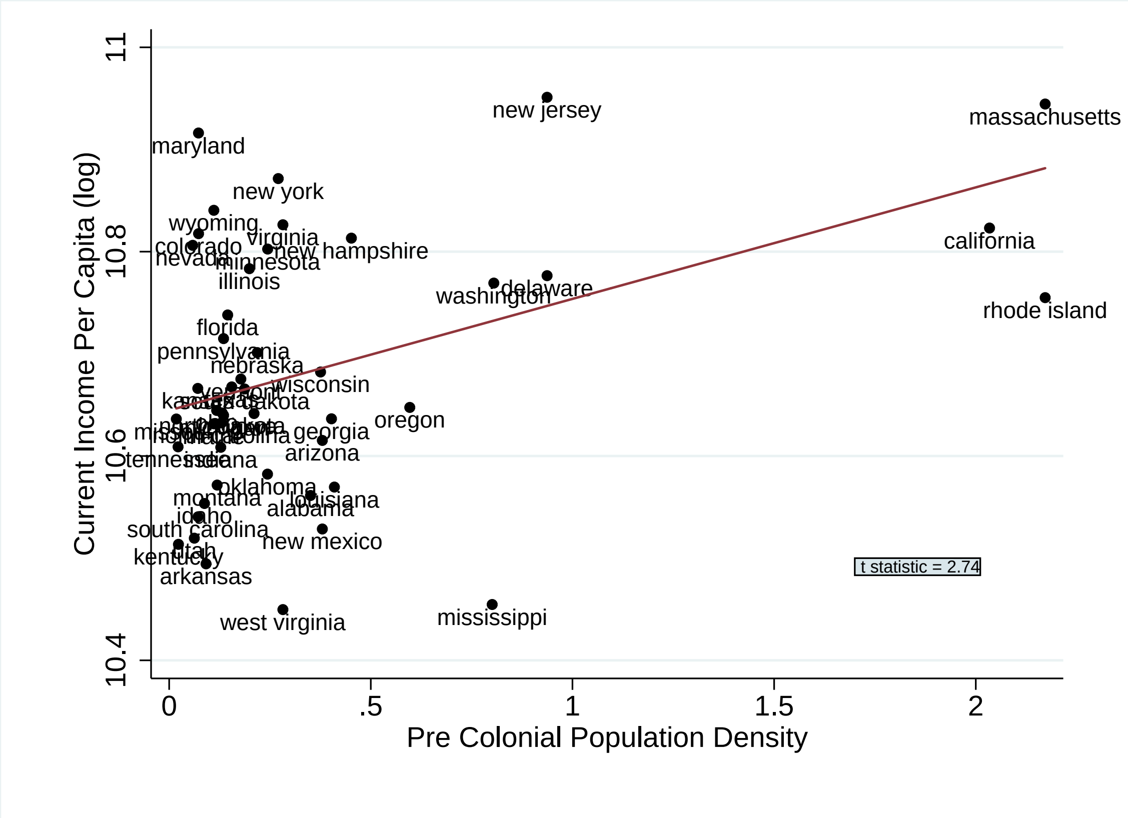
Note: Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, Current Population Density is the total population in 2000 divided by the area of the state or province in square kilometres. Data from national censuses, Denevan (1992), and Bruhn and Gallego (2010). More detailed data sources and descriptions in the text.

Figure 3: *Income pc 2005 against Pre-colonial Population Density (Aggregate)*



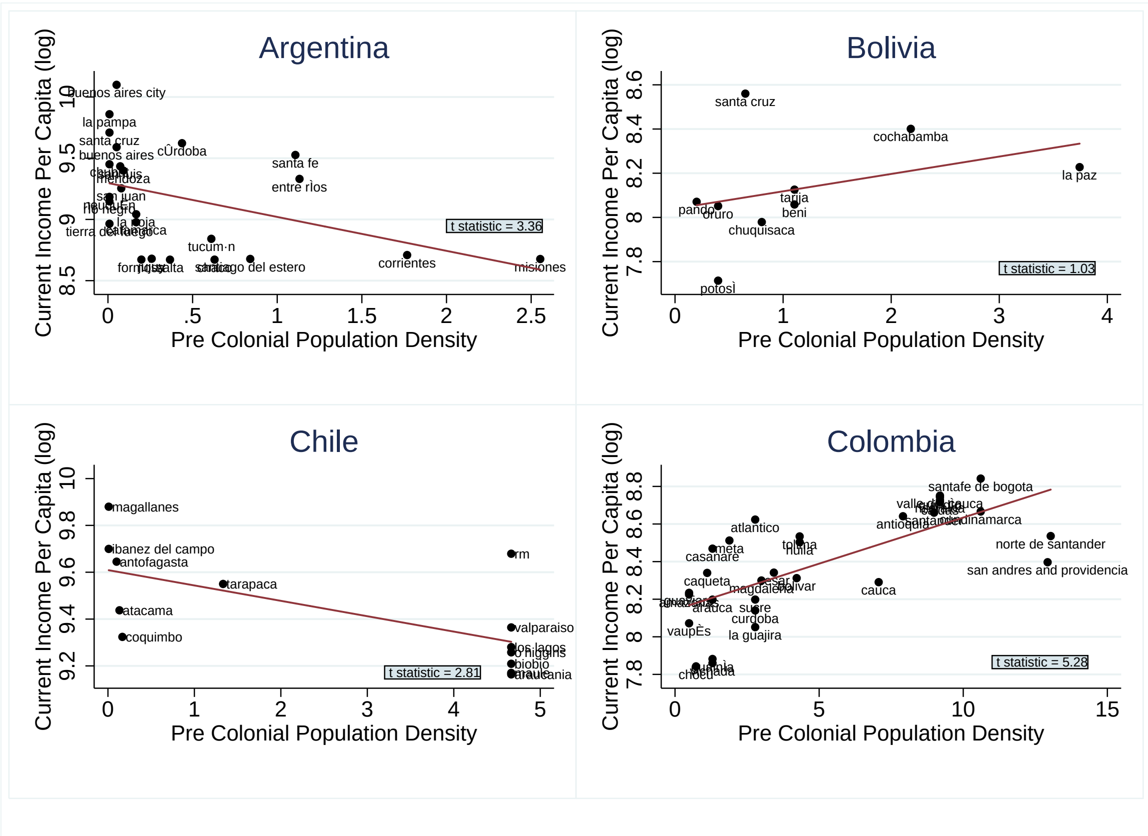
Note: Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, Income is per capita (PPP 2005 US dollars) in 2000. Data from national censuses, Denevan (1992), and Bruhn and Gallego (2010). More detailed data sources and descriptions in the text.

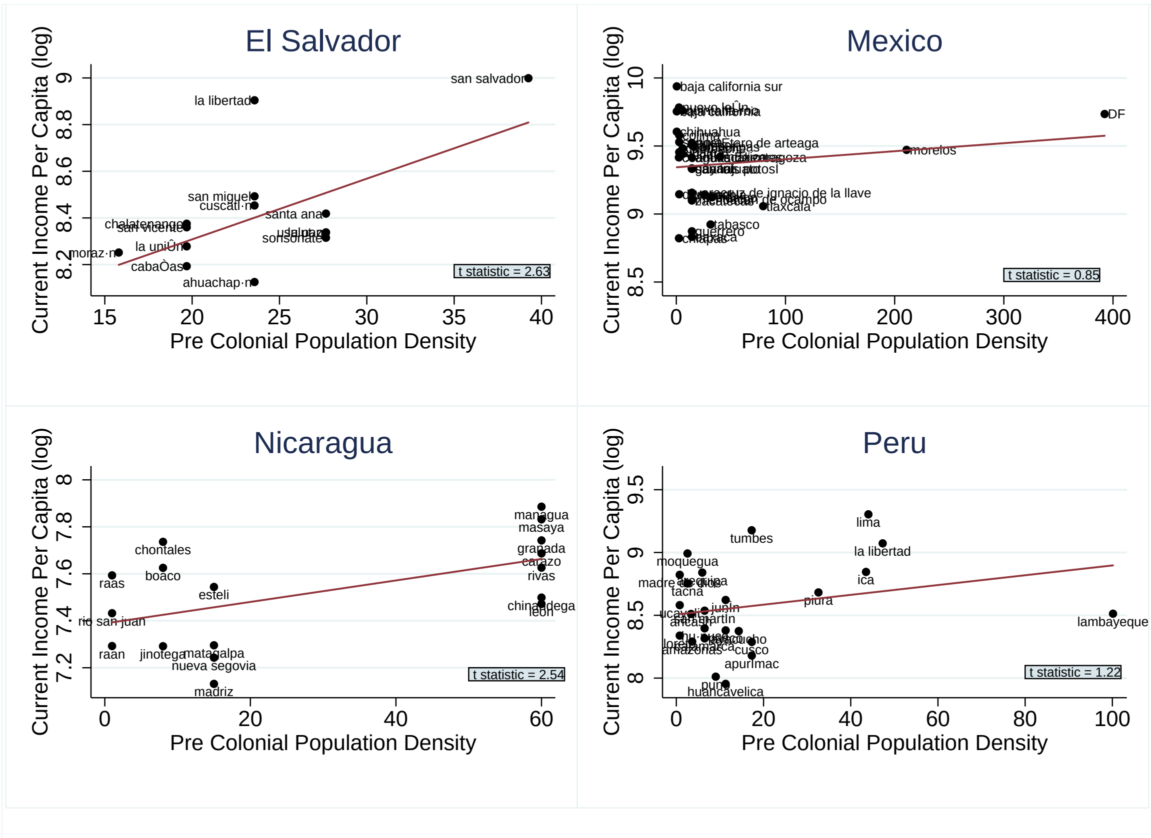
Figure 4: *Income pc 2005 against Pre-colonial Population Density (Subnational US)*



Note: Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, Income is per capita (PPP 2005 US dollars) in 2000. Data from national censuses, Denevan (1992), and Bruhn and Gallego (2010). More detailed data sources and descriptions in the text.

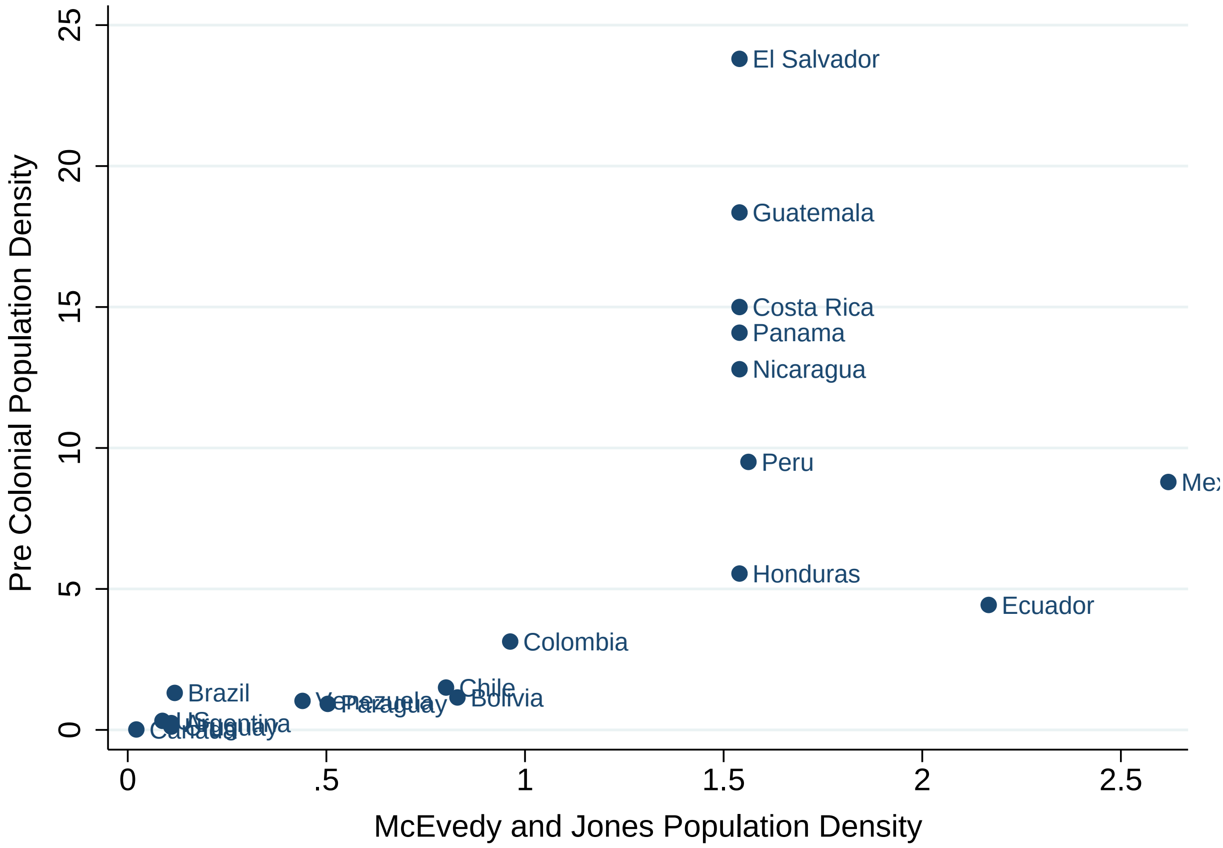
Figure 5: *Income pc 2005 against Pre-colonial Population Density (Subnational)*





Note: Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, Income is per capita (PPP 2005 US dollars) in 2000. Data from national censuses, Denevan (1992), and Bruhn and Gallego (2010). More detailed data sources and descriptions in the text.

Figure B1: *Aggregate Subnational Population Density Data vs. McEvedy*



Note: Graph plots the weighted average of the subnational pre-colonial population data against McEvedy *et al.* (1978).

Table 1: *Summary Statistics- Pop. Density and Income*

	Obs	**Pre-colonial Population Density**				**Current Population Density**				**Income**			
		Mean	Coef. Var	Min	Max	Mean	Coef. Var	Min	Max	Mean	Coef. Var	Min	Max
Argentina	24	0.44	1.45	0.01	2.55	626.06	4.80	1.20	14727.03	10576.16	0.46	5834.35	24328.34
Bolivia	9	1.18	0.96	0.20	3.74	9.53	0.84	0.82	26.17	3494.36	0.25	2239.15	5219.44
Brazil	27	2.55	0.97	0.20	8.58	53.39	1.40	1.41	346.75	7590.93	0.46	3343.24	18287.33
Canada	13	1.22	1.06	0.02	3.00	6.34	1.19	0.01	24.40	34540.71	0.17	27479.80	48436.04
Chile	13	2.65	0.87	0.01	4.66	53.05	1.99	1.05	393.50	12852.48	0.24	9545.53	19533.39
Colombia	30	4.96	0.82	0.49	13.04	424.40	2.36	0.48	4310.09	4554.56	0.27	2546.91	6917.57
Ecuador	22	5.76	0.78	0.01	12.06	56.10	0.92	2.01	182.80	5764.57	0.30	3738.26	10463.96
El Salvador	14	24.19	0.24	15.80	39.25	326.73	1.30	95.58	1768.80	4669.67	0.29	3378.47	8094.27
Guatemala	8	22.95	0.35	5.64	29.08	248.97	1.57	10.23	1195.48	3699.73	0.56	2132.71	8526.96
Honduras	18	8.09	0.55	1.00	17.64	134.67	1.22	15.81	614.83	3171.35	0.30	1512.21	5170.91
Mexico	32	31.90	2.38	0.40	392.34	227.55	3.36	5.61	4352.62	12119.95	0.29	6780.40	20709.32
Nicaragua	17	29.82	0.89	1.00	60.00	103.28	1.20	8.58	473.80	1896.24	0.22	1250.37	2658.39
Panama	9	13.40	0.67	0.06	24.78	38.66	0.88	2.42	116.80	9046.41	0.31	4880.31	13950.97
Paraguay	18	1.27	0.56	0.20	3.29	58.62	2.28	0.10	579.36	4162.39	0.18	2923.94	5516.21
Peru	24	17.36	1.30	0.78	100.15	31.80	0.18	1.08	222.23	5623.75	0.35	2846.11	10980.10
US	48	0.39	1.34	0.02	2.17	169.50	0.99	5.16	1041.54	44193.13	0.14	34533.35	62765.91
Uruguay	19	0.11	2.05	0.00	0.85	33.44	1.80	2.25	263.51	8195.26	0.21	6024.20	13965.81
Venezuela	19	1.78	0.42	0.35	2.78	96.70	0.48	0.40	415.52	9788.84	0.13	7843.90	13191.90

Note: Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, Current Population Density is the total population in 2000 divided by the area of the state or province in square kilometres and Income is in per capita (PPP 2005 US dollars) in 2000. Data from national censuses, Denevan (1992), and Bruhn and Gallego (2010). More detailed data sources and descriptions in the text.

Table 2: *Summary Statistics: Geographical Controls*

	Mean	**P50**	**SD**	**Min**	**Max**
Agriculture	0.56	0.58	0.28	0.00	1.00
Altitude	0.66	0.19	0.92	0.00	4.33
Dist. to Coast	0.87	0.91	0.12	0.45	1.00
Malaria	1.09	0.20	1.53	0.00	5.85
Rainfall	1.28	1.10	0.95	0.00	8.13
Rivers	3.28	3.29	1.23	0.00	6.92
Ruggedness	12.68	9.93	10.33	0.00	47.43
Temperature	19.97	20.40	5.83	2.38	29.00

Note: Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^{o}C; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010). Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the regions average distance to the nearest coastline in thousands of kilometres from Gennaioli et al. (2014). More detailed data sources and descriptions in the text.

Table 3: *Pre-Colonial Population Density and Locational Fundamentals (pooled)*

	OLS	Between	OLS FE
Agriculture	0.9	0.9**	1.9***
	(1.36)	(0.38)	(0.46)
Rivers	-0.10	-0.10	0.3
	(0.16)	(0.14)	(0.21)
Dist. to Coast	2.0	2.0	4.8***
	(1.90)	(1.35)	(1.51)
Temperature	0.2**	0.2***	0.03
	(0.06)	(0.02)	(0.05)
Altitude	0.9***	0.9***	0.3
	(0.26)	(0.13)	(0.27)
Rainfall	0.1	0.1	-0.002
	(0.17)	(0.12)	(0.10)
Ruggedness	0.06*	0.06***	0.005
	(0.03)	(0.01)	(0.01)
Malaria	0.1	0.1	-0.2*
	(0.09)	(0.09)	(0.11)
Constant	-11.1***	-11.1***	-11.3***
	(1.32)	(1.45)	(1.99)
N	330	330	330
R^2	0.423	0.423	0.232

Note: Regression of sub national Log Pre-colonial Population Density on locational fundamentals. Estimation by OLS with country fixed effects. Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, from Denevan (1992), and Bruhn and Gallego (2010). Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^oC; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010). Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the region's average distance to the nearest coastline in thousands of kilometres from Gennaioli et al. (2014). More detailed data sources and descriptions in the text. Robust SE clustered at the country level are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: *Persistence in Population Density (country by country)*

	N	Raw Correlation	Rank Correlation	Immigration
Argentina	24	0.29	0.63***	0.95
Brazil	27	0.58***	0.62***	0.91
Bolivia	9	0.70**	0.67**	0.28
Chile	13	0.87***	0.79***	0.63
Canada	13	-0.69***	-0.66**	0.97
Colombia	30	0.72***	0.69***	0.63
Ecuador	22	0.59***	0.49**	0.39
ElSalvador	14	0.84***	0.66***	0.50
Guatemala	8	0.81**	0.83**	0.27
Honduras	18	0.71***	0.51**	0.48
Mexico	32	0.78***	0.68***	0.37
Nicaragua	25	0.89***	0.82***	0.60
Panama	17	0.072	-0.033	0.64
Paraguay	9	0.39	0.33	0.54
Peru	18	0.84***	0.74***	0.36
US	24	0.39***	0.37**	0.97
Uruguay	23	-0.33	-0.32	0.96
Venezuela	48	0.84***	0.82***	0.69

Note: Correlation coefficient and Spearman rank correlation coefficient. Current Population Density is the log of the total population in 2000 divided by the area of the state or province in square kilometres, from national censuses, and Bruhn and Gallego (2010). Pre-colonial Population Density is the log of the number of indigenous people per square kilometre before the arrival of Columbus, from Denevan (1992), and Bruhn and Gallego (2010). Immigration from Chanda et al (2013). More detailed data sources and descriptions in the text. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: *Persistence in Population Density (pooled)*

	OLS	Between	Within FE	Within FE
Pre-Colonial Density	0.3***	0.3**	0.4***	0.3**
	(0.10)	(0.12)	(0.14)	(0.11)
Agriculture				1.8***
				(0.50)
Rivers				-0.2
				(0.18)
Dist. to Coast				4.8***
				(1.37)
Temperature				0.01
				(0.02)
Altitude				0.1
				(0.15)
Rainfall				0.08
				(0.08)
Ruggedness				0.0001
				(0.01)
Malaria				-0.3***
				(0.09)
Constant	0.10	0.1	0.6	-4.5*
	(0.36)	(0.55)	(0.59)	(2.18)
N	365	365	365	330
R^2	0.136	0.282	0.147	0.464

Note: Regression of Log Current Population Density against Log Pre-colonial Population Density. Estimation by OLS with country fixed effects. Current Population Density is the total population in 2000 divided by the area of the state or province in square kilometres, from national censuses, and Bruhn and Gallego (2010). Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, from Denevan (1992), and Bruhn and Gallego (2010). Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^oC; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010). Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the region's average distance to the nearest coastline in thousands of kilometres from Gennaioli et al. (2014). More detailed data sources and descriptions in the text. Robust SE clustered at the country level in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: *Persistence in Income (pooled)*

	OLS	Between	Within FE	Within FE
Pre-Colonial Density	-0.4	-2.8	0.1**	0.08***
	(0.37)	(1.70)	(0.04)	(0.02)
Agriculture				-0.1
				(0.08)
Rivers				-0.02
				(0.03)
Dist. to Coast				-0.1
				(0.43)
Temperature				-0.007
				(0.01)
Altitude				-0.1***
				(0.03)
Rainfall				-0.07**
				(0.02)
Ruggedness				-0.001
				(0.00)
Malaria				-0.05***
				(0.02)
Constant	9.1***	9.1***	9.0***	9.6***
	(0.06)	(0.24)	(0.00)	(0.41)
N	365	365	365	330
R^2	0.010	0.093	0.004	0.135

Note: Regression of the Log of Income per capita in 2000 (PPP 2005 US dollars) against Pre-colonial Population Density. Estimation by OLS with country fixed effects. Income per capita (in logs) is taken from national censuses. Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, from Denevan (1992), and Bruhn and Gallego (2010). Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^{o}C; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010).Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the region's average distance to the nearest coastline in thousands of kilometres from Gennaioli et al.(2014). More detailed data sources and descriptions in the text. Robust SE clustered at the country level are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A1: *MS Estimations*

	(1) Pop1500	(2) Pop2005	(3) Income	(4) Income Slavery
Pre-Colonial Density			0.1***	5.2***
			(0.03)	(0.63)
Log Pre-Colonial Density		0.4***		
		(0.06)		
Agriculture	-0.6	1.7***	-0.2**	-0.03
	(0.40)	(0.32)	(0.07)	(0.08)
Rivers	-0.1	-0.2	-0.03*	-0.08***
	(0.37)	(0.21)	(0.02)	(0.02)
Dist. to Coast	2.8	4.3***	-0.4**	-0.03
	(2.58)	(1.09)	(0.14)	(0.23)
Temperature	-0.05	0.01	-0.003	0.005*
	(0.06)	(0.02)	(0.00)	(0.00)
Altitude	-0.07	0.01	-0.1**	0.09*
	(0.21)	(0.08)	(0.07)	(0.04)
Rainfall	-0.2***	0.05	-0.08***	0.08**
	(0.08)	(0.82)	(0.01)	(0.04)
Ruggedness	0.02**	-0.005	0.008**	-0.003
	(0.01)	(0.01)	(0.00)	(0.00)
Malaria	-0.1	-0.2**	0.005	-0.05***
	(0.09)	(0.10)	(0.01)	(0.01)
Brazil				-1.9***
				(0.09)
Colombia				-2.5***
				(0.06)
South				0.02
				(0.08)
Slavery				-0.005**
				(0.00)
Slavery*Pop				-0.1***
				(0.03)
Constant	-7.9***	-3.6**	9.4***	11.0***
	(2.50)	(1.76)	(0.16)	(0.22)
N	330	330	330	78

Note: Dependent variable is the Log Income per capita in 2000 (PPP 2005 US dollars). Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus. Estimation by robust MS regression with country fixed effects. Income per capita (in logs) is taken from national censuses. Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, from Denevan (1992), and Bruhn and Gallego (2010). Dummies for Brazil, Colombia, and the US South (according to the US Census). Slavery is measured as a fraction of the population and is taken from Bergad (2008) and Nunn (2008). Interaction of slavery with Pre-colonial population density. Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^{o}C; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010). Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the region's average distance to the nearest coastline in thousands of kilometres from Gennaioli et al. (2014). More detailed data sources and descriptions in the text. Robust SE are in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C1: *Current Income and Slavery (Brazil, Colombia and United States)*

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
Pre-Colonial Density	2.9**	1.9	2.6**	5.5***	4.9***
	(1.16)	(1.33)	(1.27)	(1.45)	(1.65)
Brazil	-1.9***	-2.0***	-1.6***	-1.6***	-1.4***
	(0.09)	(0.11)	(0.21)	(0.20)	(0.21)
Colombia	-2.5***	-2.4***	-2.4***	-2.6***	-2.4***
	(0.07)	(0.09)	(0.08)	(0.08)	(0.19)
South	-0.09**	-0.1***	0.2	0.09	0.07
	(0.04)	(0.04)	(0.13)	(0.13)	(0.11)
Slavery			-0.009**	-0.006	-0.005
			(0.00)	(0.00)	(0.00)
Slavery*Pop				-0.1**	-0.1***
				(0.05)	(0.05)
Agriculture					-0.2
					(0.17)
Rivers					-0.02
					(0.05)
Dist. to Coast					0.05
					(0.41)
Temperature					-0.0008
					(0.01)
Altitude					0.06
					(0.08)
Rainfall					-0.03
					(0.03)
Ruggedness					-0.005
					(0.01)
Malaria					-0.06
					(0.04)
Constant	10.7***	10.7***	10.7***	10.7***	10.9***
	(0.02)	(0.03)	(0.03)	(0.02)	(0.47)
N	105	78	78	78	78
R^2	0.937	0.940	0.947	0.953	0.954

Note: Dependent variable is the Log Income per capita in 2000 (PPP 2005 US dollars). Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus. Estimation by OLS with country fixed effects. Income per capita (in logs) is taken from national censuses. Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus, from Denevan (1992), and Bruhn and Gallego (2010). Dummies for Brazil, Colombia, and the US South (according to the US Census). Slavery is measured as a fraction of the population and is taken from Bergad (2008) and Nunn (2008). Interaction of slavery with Pre-colonial population density. Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^{o}C; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010). Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the region's average distance to the nearest coastline in thousands of kilometres from Gennaioli et al.(2014). More detailed data sources and descriptions in the text. Robust SE clustered at the country level in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table D1: *Income Distribution (pooled)*

	OLS	Between	Within FE	Within FE	Within FE
Log Pre-Colonial Density	0.006	0.003	0.002	-0.002	-0.003
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
Log Present Density				0.006***	0.003
				(0.00)	(0.00)
Income				-0.03**	-0.02**
				(0.01)	(0.01)
Agriculture					0.02
					(0.01)
Rivers					-0.006
					(0.01)
Dist. to Coast					-0.02
					(0.06)
Temperature					0.002*
					(0.00)
Altitude					0.01**
					(0.00)
Rainfall					0.003
					(0.01)
Ruggedness					0.0002
					(0.00)
Malaria					-0.004
					(0.00)
Constant	0.5***	0.5***	0.5***	0.7***	0.7***
	(0.03)	(0.05)	(0.01)	(0.12)	(0.10)
N	260	260	260	260	256
R^2	0.023	-0.091	0.002	0.044	0.061

Note: Dependent variable is the gini coefficient in 2000 (PPP 2005 US dollars) as estimated by Bruhn and Gallego (2010). Pre-colonial Population Density is the number of indigenous people per square kilometre before the arrival of Columbus. Income per capita (in logs) is taken from national censuses. Present Population Density is the number of people per square kilometre in 2000. Agriculture is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). Temperature is a yearly average in ^{o}C; altitude measures the elevation of the capital city of the state in kilometres; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2010). Malaria is the Malaria Ecology Index as calculated by Kiszewski et al. (2004). Ruggedness is the Terrain Ruggedness Index from Nunn and Puga (2012). Inverse distance from the nearest coast is ratio of 1 over 1 plus the region's average distance to the nearest coastline in thousands of kilometres from Gennaioli et al. (2014). More detailed data sources and descriptions in the text. Robust SE clustered at the country level in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Chapter 3

ENGINEERS, INNOVATIVE CAPACITY AND DEVELOPMENT IN THE AMERICAS

Joint with William F. Maloney, Development Economics Research Group and Chief Economist for Trade and Competitiveness, The World Bank, and Universidad de los Andes, Bogotá, Colombia.

"You have all the elements, but you cannot make steel"

—Andrew Carnegie[1]

1 Introduction

Carnegie's taunt to the owners of the Birmingham Steel Company in Alabama highlights the complexity of technological transfer to lagging regions. As Wright (1986) documents, shortfalls in management, learning by doing, and the R&D capacity necessary to adapt technologies to local conditions all impeded the establishment of a dynamic steel (and textile and lumber) industry in the American South, and hence slowed catch-up to the North. The issue of differential technological transfer remains central to the more general convergence debate.[2] Most recently Comin et al. (2008); Comin & Ferrer (2013) argue that the diverging measured intensity of use of new technologies (as a share of economic activity) plausibly explains observed TFP differentials and can drive simulations that closely track the magnitudes of the Great Divergence of the last two centuries (e.g. Pritchett, 1997). That human capital is a critical ingredient in technology adoption also enjoys a substantial supporting literature.[3]

The nature of the relevant human capital has been less clear. Literacy and accumulated years of schooling/enrollment have received the most attention, although other dimensions figure importantly in the literature as well: Lucas (1993); Young (1993) and Foster & Rosenzweig (1995), among others, stress the importance of accumulated "learning by doing"; Baumol (1990) and Murphy et al. (1991), entrepreneurial skills and orientation; Mokyr (2005), the minority of "trained engineers, capable mechanics and dexterous craftsmen on

[1]Cited in Wright (1986) p.171

[2]See also, Parente & Prescott (1994); Eaton & Kortum (1999, 2001); Caselli (2001); Comin & Hobijn (2004); Keller (2004); Klenow & Rodriguez-Clare (2005); Comin et al. (2008, 2010a); Comin & Hobijn (2010); Comin et al. (2012)

[3]See, for example, Nelson & Phelps (1966); Foster & Rosenzweig (1996); Cohen & Levinthal (1989); Benhabib & Spiegel (1994); Basu & Weil (1998); Temple & Voth (1998); Howitt (2000); Acemoglu & Zilibotti (2001); Caselli (2001); Comin & Hobijn (2004); Benhabib & Spiegel (2005); Aghion et al. (2005); Howitt & Mayer-Foulkes (2005); Ciccone & Papaioannou (2009); Goldin & Katz (2009)

whose shoulders the inventors could stand" (pg.16); Rosenberg (2000) and Nelson (2005), the accumulated ability and scientific institutions to manage new ideas for innovation and invention; Cohen & Levinthal (1989); Griffith et al. (2004), the capacity for research and development needed for technological transfer.

Several authors including Mokyr (1998), and Howitt & Mayer-Foulkes (2005) stress that higher-order human capital and the institutions that generate and housed it may have had an even more determinant role at the dawn of the Second Industrial Revolution (circa 1870-1914), which saw an increased emphasis on more structured scientific inquiry such as laboratory-based R&D.[4] This scientifically oriented human capital, and a technologically savvy entrepreneurial class,[5] were necessary to tap into the expanding and increasingly sophisticated global stock of knowledge and convert it into local growth. The technological leap forward also meant an erosion in the efficacy of existing levels of human capital and innovative capacity relative to that needed to continue to adopt (see Howitt (2000); Aghion et al. (2005)). Building on this insight, Howitt & Mayer-Foulkes (2005) argue for multiple equilibria in innovation where countries whose human capital/innovative capacity evolved with the frontier at the time of the technological leap forward could innovate or adopt, but those whose frontier adjusted human capital did not keep up slipped to an equilibrium where even the adoption of technologies was difficult, and stagnation followed.[6] Iyigun & Owen (1998, 1999) relatedly argue that if the the initial stock of both professional (scientific) and entrepreneurial human capital is too low, the return to accumulating human capital will be low and economies can find themselves in a development trap.

---

[4]Rosenberg (2000) and Nelson (2005) stress the incremental and cumulative nature of technological progress and related institutions more generally as a central dynamic of industrialization.

[5]As numerous authors have stressed from Schumpeter (1934) to the present, technological progress without entrepreneurs to take it to market does not lead to growth (See Aghion & Howitt, 1992; Baumol, 1990, 2010; Glaeser, 2007; Glaeser et al., 2009, 2010; Braunerhjelm et al., 2010; Iyigun & Owen, 1998, 1999). Over the longer term this reflects the accumulation of a specific kind of human capital, at the very least, suited to the evaluation and management of risk, but extending to skills for managing people, credit, and technologies which need to be learned.

[6]See also Gancia et al. (2008) for related discussion of convergence clubs resulting from education-technology complementarities.

Empirically, documenting the impact of even very basic measures of human capital on growth or relative incomes has proved surprisingly complex.[7] Further, there have been relatively few efforts to systematically capture what kind of human capital matters, or even to document the stocks of different types of capital. Judson (1998), Wolff & Gittleman (1993), Self & Grabowski (2004) Castelló-Climent & Mukhopadhyay (2013) attempt to document whether tertiary education matters more or less than primary education. Murphy et al. (1991) document that countries with a higher proportion of engineers grow faster relative to those with a higher proportion of law concentrators. The problem is exacerbated when a longer historical perspective is taken, and even more so at the sub-national level. Related to the present work, Acemoglu & Dell (2010) in their analysis of sub-regional differences in incomes in the Americas, stress technological know-how, efficiency of production, and human capital as determinants of both within and across country productivity differences, but lack specific measures of human capital. Campante & Glaeser (2009) argue that the "lion's share" of the differences in long run income level between the cities of Buenos Aires and Chicago is human capital, but they lament that literacy remains the primary, albeit coarse, measure (see, for example, Mariscal & Sokoloff (2000)). Voigtländer & Squicciarini (2014) show that mid-18th century French cities with more subscriptions to the *Encyclopédie*, capturing higher order human capital, grew faster after the dawn of the industrial revolution. Waldinger (2012) shows that the dismissal of scientists in Nazi Germany led to a permanent decrease in growth. However, neither the historical prevalence of Mokyr's engineers and mechanics, nor Rosenberg's and Nelson's systems of innovation are documented in a globally comparable form.[8]

---

[7]For overviews see Krueger & Lindahl (2001); Sianesi & VanReenen (2003); Stevens & Weale (2004) and Acemoglu & Zilibotti (2001); Pritchett (2001); Easterly (2002); Benhabib & Spiegel (1994). A recent literature has sought to explain the often small measured impact by incorporating measures of the quality of human capital (see, for example Hanushek & Woessmann, 2007; Behrman & Birdsall, 1983; Hanushek & Woessmann, 2012)

[8]Collected articles in Fox & Guagnini (1993) have examined the evolution of engineering capacity in several advanced countries although the comparability of the measures across countries is not always clear, and there is no attempt to establish a link to economic performance.

This paper, first, makes a very basic contribution: it establishes the stylized facts surrounding the relative density of engineers at the end of the 19th century at the national level for the Western Hemisphere and representative countries of Europe. It does the same at the sub-national level for a five country panel: the US, Argentina, Chile, Mexico and Venezuela. This is done in a systematic way drawing on graduation records, membership in professional societies, and census data. We see these estimates, in the first instance, as a measure of what they are: the stock of higher level scientifically oriented human capital directly linked to productive activity available at the beginning of the Second Industrial Revolution. Second, because our national measures are based on graduates of domestic engineering schools, they also proxy for the universities and institutions that support them, and for which data are more elusive (see Nelson, 2005). Further, we are sympathetic to the use in Murphy et al. (1991) of engineering density as a proxy for "good entrepreneurship," perhaps more specifically the advancement of the long-run cumulative process of developing entrepreneurial technological depth. In sum, we see it as a broad proxy for innovative capacity.

To achieve a higher degree of granularity geographically, in measures of human capital, and in type of innovation efforts, we develop a rich data set for the United States at the *county* level. This vastly expands the degrees of freedom and permits controlling for an extensive set of geographical, growth related, and human capital controls. In particular, we develop measures of literacy and density of lawyers and medical doctors that allow us to ensure we are capturing the impact of higher order scientific vs general human capital. Further, we also incorporate a measure of patenting density which, in tandem with the engineering proxy used in all exercises, allows us to more fully capture capacity for both adoptive and inventive activities.

We then show that our measures of innovative capacity in 1900 have an impact on present income in all samples. For the US at the county level, we show engineering and patenting to have a robust relationship with income today even after controlling for plausibly correlated factors such as railroad construction, agglomeration levels, lagged industrialization, other higher order human capital, and a number of locational fundamentals. At a higher level of aggregation, we document that countries at very similar distances from the technological frontier as measured by income per capita in 1900– for instance Sweden and Argentina– had enormous differences in innovative capacity and that, consistent with Howitt & Mayer-Foulkes (2005) this could drive the resulting convergence clubs they find themselves in today. We then use historical evidence to validate our ranking of innovative capacity and through several case studies we document the divergent development outcomes arising within even identical goods in countries with distinct innovative capacities, and that entire industries were lost when frontier-adjusted human capital was not maintained.

Finally, we ask what determined engineering capacity in 1900. The county level US data confirms a positive impact of pre-colonial indigenous indian densities that suggest the importance of agglomeration externalities working through innovative capacity, as well as a negative impact of slavery, providing an additional channel through which that institution may have negatively affected growth. Our hemispheric sample documents a broad similarity between colonizer and colony innovative capacity. This suggests, consistent with recent literature, that substantial explanatory weight should be put on the human capital, productive structures, values and institutions imported during the colonial period.[9]

2 Data

2.1 Measuring engineering/innovative Capacity

Our primary measure of innovative capacity across all countries is the number of engineers with domestically emitted university degrees per 100,000 male workers. Unlike literacy data, which countries sometimes collect as part of the census, countries do not tabulate such

[9]See McCleary & Barro (2006); Putterman & Weil (2008); Spolaore & Wacziarg (2009); Becker & Woessmann (2009); Galor & Michalopoulos (2009); Comin et al. (2010a); Spolaore & Wacziarg (2012); Easterly & Levine (2012); Alesina et al. (2014); Fulford et al. (2015).

information in a uniform fashion. Hence, we construct these series using three sources of data.

Engineering Graduates: To the degree possible, calculations are done with actual graduates of engineering colleges and universities within the country. Clearly, many engineers even in the US acquired valuable training on the ground, or may have had partial degrees from some type of technical program. However, such skills are difficult to capture with any degree of commonality across geographical units. As a consistent metric across countries, we take the number of degrees awarded.[10] Though most countries employed substantial numbers of foreign engineers, we are interested in indigenous technical capacity and the institutional structure to generate it, so we focus on domestically trained engineers. Some nationals studied abroad, however the historical evidence from Argentina, Chile, Colombia and Mexico suggests the numbers are small and difficult to document. Since the working life of an engineer is roughly 40 years, we begin accumulating the stock in 1860, discounting the stock in each period by .983 as the rate of death/attrition in each year. In some cases, we have a long series of graduation records which make this procedure straightforward. In Bolivia, Denmark, Mexico, New York, Perú, Spain, Sweden, Venezuela, or México, the flow of graduated engineers is available for the 1860-1900 period. We refer to Ahlström (1982)'s estimates for Germany and France, the frontier countries, which are generated in a virtually identical manner, yet we do not have access to his data and these are not our calculations.[11] In other cases, for instance, Argentina, Brazil, Chile, Colombia, Ecuador, and the US as a whole, the information is less complete and we bring other sources of data to bear to fill in the gaps in the series.

Membership in Engineering Societies: Data on membership in Engineering societies or official registries validate broad orders of magnitude of our generated stocks. In some

[10] Fox & Guagnini (1993) tabulate for several advanced countries the number of students enrolled. However, we find often that the difference between students enrolled and eventual graduates can differ greatly so enrollment rates are not as reliable.

[11] In fact, he calculates the stock for France, Germany as well as Sweden for which we do have the raw underlying data and hence can verify that we are doing the calculations in a virtually identical fashion.

cases, such as Brazil, registry with the government was required to be a practicing engineer. What is considered an engineer, however, is less clear and hence these measures are less definitionally tight. In other countries, such as Colombia or Argentina, membership in Engineering associations was not required so registration likely underestimates.

Census Data: Census data are also available in several countries. Census data have the advantage of being collected over time by several countries and across sub-national units. However, here, also, it is the individual respondent who is deciding whether he is an engineer or not with limited institutional confirmation, or detail on the actual level of education. This is fine for within country analysis but less reliable for cross country comparisons.[12] Sub-national data derive from the Argentine census of 1895, Mexican National Census of 1895, Chilean Census of 1907, the Venezuelan Census of 1926, and the US Census of 1900. For the US county level data, we use the census of 1880 to generate measures of literacy, and density of engineers, lawyers and medical doctors.

Patenting For the US, we also develop a measure of average patenting activity from 1890-1910 drawing on patents granted by the United States Patent and Trademark Office (USPTO) again, at the country level, provided by Akcigit et al. (2013). This is likely to capture Mokyr's more structured scientific inquiry at the frontier that began to assume a central role in the second industrial revolution. Alternatively it may be a channel through which the engineering proxy affects growth. Comparable patent data is not available for the Latin American countries and hence the variable only enters in the county-level US analysis.

Annex I discusses how these three sources of data were combined for each country in detail.

[12]As numerous local historians have noted (Serrano (1993) in Chile, Bazant de Saldaña (1993) in Mexico) and in the case for which we have the best information, the US, censuses are often substantially higher than the actual graduates of engineering programs.

2.2 Sub-national Income per Capita

Income in 2005 PPP US Dollars is drawn from a highly disaggregated spatial data set on population, income and poverty constructed on the basis of national census data by the World Bank (2009) for the World Development Report on *Reshaping Economic Geography.*[13]

2.3 Other Controls

As controls in our regressions, we also employ data on:

Literacy: Aggregate literacy rates we take from (Mariscal & Sokoloff, 2000; Núñez, 2005). Sub-national literacy rates were gleaned from census data from Argentina, Chile, Mexico, Venezuela, and the US.

Higher Level Non-Engineering Human Capital: This is measured as number of lawyers and medical doctors per 100,000 inhabitants (US Census 1900).

Railroads: At the national level, we employ the density of railroads measured as kilometers of track per 1000 square kilometers in 1900 (Pachón & Ramírez, 2006; Thorp, 1998). At the sub-national level, we employ the Interstate Commerce Commission's data on miles of track per 100 square miles converted to the same units above for consistency in 1899 (ICC, 1899). Individual country level data was not available for Latin America.

[13]These "poverty maps" combine household level data sets with limited or non representative coverage with census data to generate income maps for much of the hemisphere (see Elbers et al., 2003). Such household level data is arguably preferable as a measure of regional prosperity to national accounts data. In the case of natural resource rich regions, income may or may not accrue to the locality where it is generated and hence may provide a distorted measure of level of development. As an example, the revenues from oil pumped in Tabasco and Campeche, Mexico, are shared throughout the country, although they are often attributed entirely to the source state in the National Accounts (see Aroca et al., 2005). This is a broader issue wherever resource enclaves are important. For instance, from a national accounts point of view the richest sub national units in Argentina, Colombia, Chile and Peru respectively are Tierra del Fuego (oil), Casanare (oil), Antofagasta (copper), Moquegua (copper) all of which, with the exception of the last, are average or below average in household survey measured income. For further detail see **?**

Population Density in 1900: These are collected from census data from the individual countries. Argentina (1895), Brazil (1900), Chile (1907), Colombia (1905), Mexico (1895), Peru (1876), Venezuela (1926), and the US (1900).

Pre-colonial Population Density: This measures the estimated number of indigenous people per square kilometer just before colonization. Though the project of estimating populations half a millennium past is necessarily speculative, the estimates synthesize the most recent available geographical, anthropological, and archaeological findings. In particular, they draw on documentary evidence such as reports by Europeans, actual counts from church and tax records, as well as contemporary and recollected native estimates and counts.[14]

Slavery: As a measure of institutions that is available for the United States sample, we used the 1860 Census as well as the data compiled in Nunn (2008).

Geographical Controls: in addition to the set of sub-national geographical variables collected by Bruhn & Gallego (2011) including temperature, altitude, and annual rainfall, we add a measure of agricultural suitability and river density as developed in **?**. Clearly, populations could also be sustained by marine-based economies where farmland and rivers were of less importance. Hence proximity to the coast for saltwater trade, transport, fishing potential and amenities potentially persists in importance, much as it was subsequently for European settlement, and to capture this we employ a measure of Distance to the Coast as calculated by Gennaioli et al. (2013). We further include a measured of ruggedness of terrain from Nunn & Puga (2012).[15]

[14]Depending on the country, projections across similar geographic areas, regional depopulation ratios, age-sex pyramids, and counts from sub-samples of the population (such as warriors, adult males, tribute payers) are used, as well as backward projections from the time of contact with Europeans. These are corroborated by evidence including archaeological findings, skeletal counts, social structure, food production, intensive agricultural relics, carrying capacity, and environment. See **?** for more detail.

[15]Ashraf & Galor (2011) have further suggested as determinants of population time elapsed since the Neolithic revolution, distance from the regional technological frontier. As their data is at country level, these

Infectious Disease/Malaria We employ a measure of infectious disease as proxied by the Malaria Ecology Index as calculated by Kiszewski et al. (2004) which incorporates published estimates describing the proportion of blood meals taken from human hosts, daily survival of the vector, and duration of the transmission season and of extrinsic incubation.

Table 1 presents the summary statistics at the state level and table 2 at the US county level.

3 The Impact of Innovative Capacity

3.1 The Engineering Data

Figure 1 plots our measure of national innovative capacity against GDP per capita, both in 1900.[16] The availability of data means that our effective sample going forward is restricted to the relatively larger countries depicted here. Several facts merit note.

First, there is substantial variance in the stock of engineers that is weakly related to income in 1900. The Northern United States with a density of 160 is the highest in our sample, roughly double the average for the country as a whole, 84, while the US South shows under a third of the engineering density of the North at 60. Lagging as it is, the American South is miles ahead of the Latin American countries who average under 20. What is most striking is that countries that we tend to associate with declining relative position across the previous century, especially Argentina and to a lesser degree Chile and Mexico, show densities below countries of very similar levels of income: Argentina and Chile

effects would be absorbed by the fixed effects and we do not include them.

[16]Maddison does not tabulate a separate series for the American South, but Mitchener & McLean (2003) estimates place the US South roughly 50% below the national average and New England 50% above. Imposing these differentials on Maddison's data, places the South roughly 15% higher than Spain and the North roughly triple. Clearly, issues can be taken with even Maddison's Herculean effort, however, the available alternatives do not suggest that the picture would change much. Prados de la Escosura (2000) PPP based estimates with the OECD correlate .89 with those of Maddison, and do not significantly change the level of Spain relative to the US, although they move Portugal up perhaps 40%, now above Mexico but still 20% below Spain.

had roughly the same level of income as the American South, Sweden and Denmark yet had roughly a third of its engineering capacity of the South, and a fifth of the Scandinavian countries (100). Even if the number of engineers were underestimated by a factor of two, the lag with the US and Scandinavia would still be dramatic. We argue that that natural resource rents, while elevating income, were not being deployed as they were in the US or Scandinavia to the development of innovative capacity that would prepare them for the next phase of industrialization. In Howitt & Mayer-Foulkes (2005)'s framework, we have countries with similar levels of Schumpeterian backwardness, but with radically different levels of absorptive capacity.

Second, the dominance of the US in the Western Hemisphere is clearly not being driven by some idiosyncratic US data issue that would exaggerate its density. The US average is broadly in the same league as Denmark and Sweden, and even the North is below the calculations by Ahlström (1982) for France (200) and Germany (250),the frontier countries of the era. Nor is some sort of idiosyncratic data issue driving the consistently low scores of Latin America. All cluster very near each other and the colonial mother countries.

3.2 Consistency with historical evidence

Our engineering estimates are consistent with historical evidence. France and Germany were acknowledged leaders in the sciences and engineering. The relative positions of the two peripheral areas- Scandinavia vs the Iberian peninsula correspond closely to Landes (1998)' characterization of their attitudes towards science and the enlightenment. Both Sweden and Denmark's institutions of higher technical learning date from the 1700s. Sweden's high density is consistent with the characterization by Sandberg (1979) of the country as the "Impoverished Sophisticate." The overproduction of engineers led many to emigrate to the US and 19^{th} century Swedish engineers are credited with inventing the blowtorch, ball bearings, ship propellers, the safety match, the revolver, the machine gun, dynamite, and contributing to the development of bicycles, steam turbines, early calculators, telephony

(Ericsson) among others.

The US started relatively early and energetically in the training of engineers. The first institution of engineering education emerged from the revolutionary war at West Point, established in 1802, which trained engineers for both military and civilian purposes. Subsequently the American Literary, Scientific and Military Academy at Norwich, Vermont awarded its first Civil Engineering degrees in 1837, and Rensselaer School in New York, in 1835. By 1862 there were roughly a dozen engineering schools in the East, but also as far west as Michigan and south as Maryland. The Polytechnic College of the State of Pennsylvania, founded in 1853 granted degrees in mechanical engineering in 1854, and mining engineering in 1857.

The passage of the Morrill Land Grant Act in 1862 led to an acceleration in the establishment of engineering programs, roughly sextupling the number in the decade after passage. The Act led to the establishment of the Columbia School of Mines in 1864, Worcester Polytechnic in 1868, Thayer School of Civil Engineering at Dartmouth College in 1867, Cornell University as well as new Universities in Iowa, Nebraska, Ohio, and Indiana. It also gave impetus to the foundation and consolidation of engineering schools in the South. As early as 1838 the University of Tennessee was teaching courses in Civil Engineering, but in 1879 it began awarding doctorate degrees in Civil and Mining Engineering. Texas AM awarded its first degree in Civil Engineering in 1880, Virginia Tech in 1885 in Mining Engineering, and the University of Kentucky, although having an engineering program dating from 1869, graduated their first civil engineer in 1890. Auburn University in Alabama began its engineering program in 1872, and North Carolina State in 1887. In sum, the post-Civil War period saw the expansion of engineering education throughout the country.

It also saw a deepening, with the profession in the U.S. diversified further into sub-branches. For example, the University of Missouri established both Civil and Military

Engineering departments in 1868, and the first department of Electrical Engineering in 1886. The establishment of professional societies in Civil Engineering (1852), Mining (1871), Mechanical (1880) and Electrical (1884), testifies the the consolidation of a process of specialization and diversification. By 1890, a modern and world class engineering profession was firmly established in the US.

Canada's degree of sophistication is probably higher than that suggested by the density numbers. Although the first graduates were in the 1870s, substantial engineering courses were in place by the 1850s. Further, the articulation of the different fields of engineering occurred later than in the US but not much.[17] It is also the case that the four principal Canadian Universities emitting graduates- McGill, University of Toronto, *Ecole Polytechnique* in Montreal, and Queen's University in Kingston Ontario- lay within a circle of 350 mile radius with Cornell University at its center, and that includes many of the principal US departments of the time. Hence, Canada was likely part of the greater New England scientific community.

The data for Latin America are consistent with the observation by Safford (1976) in his classic *Ideal of the Practical* that "Latin American societies in general, and the upper classes in particular, have been considered weak in those pursuits that North Americans consider practical, such as the assimilation, creation, and manipulation of technology and business enterprise in general"(p 3). The national scientific establishments and professional training of civil engineers appeared much later and on a smaller scale. As an example, perhaps the richest country in Latin America at the time, Argentina, began graduating engineers only in 1870, and Peru, one of the premier mining centers of the hemisphere, in 1880, roughly on the same time line as Alabama. Further, in countries like Colombia and Mexico, political instability undermined programs begun relatively early leading to very low levels of graduation. In addition, the process of diversification and specialization was not as

[17] The development of, for instance, mechanical engineering as a separate course occurred about 20 years after in the US, and Electrical Engineering 10-15 years after.

advanced as was the case, for example, in Missouri. General engineering associations were set up in many countries around the same time that, in the US, associations in individual sub-fields were established.

Graham (1981) argues that Brazil, consistent with our estimates, lagged far behind the American South in every aspect of industrialization, transportation and agricultural technology (p. 634). In agriculture, there was little use of plows, scrapers, cultivators or mechanical seeders until the 20th century, partly because the low level of literacy rendered pointless the agricultural journals found commonly in the American South. A long literature has focused on Argentina's weakness in innovation effort in comparison to countries such as Australia and Canada seen as similarly endowed.(see, for example Diaz Alejandro, 1985; Duncan & Fogarty, 1986; Campante & Glaeser, 2009). The determined efforts in both these countries to achieve widespread literacy in the prairies had no analogue in Latin America, nor did the extensive expansion in the form of experiment stations, seed testing services, and technical assistance.

In sum, the historical evidence confirms that lagged as the American South was relative to the North, as Carnegie suggests above, Latin America lagged even more.

3.3 Aggregate correlations

We first begin by presenting a few summary regressions documenting that, using aggregate engineering densities for 11 countries, there is evidence that our engineering measures are correlated with income. Since we have population density and income variables at the subnational level, we run the regression as a panel and bootstrap the clustered SEs at the country level:

$$Y_{2005,ij} = \alpha + \gamma_E Eng_{1900_i} + \gamma_{pop} Pop_{1900,ij} + \gamma_R Rail_{1900_i} + +\beta_L Lit_{1900,i} + \epsilon_{ij} (1)$$

where the variables are defined as above for country i and sub-national unit j: the dependent variable is income per capita today; the explanatory variables are Literacy, Engineering density in 1900, Railroad density in 1900, Population density in 1900, and a set of geographical controls.

Columns 1, 2, 3 and 5 of Table 3 show that engineering in 1900 appears significantly in explaining today's income per capita despite controlling sequentially and then together for population density and railroad density. Were we to include Denmark and Sweden, whose density we have confidence in, not to mention France and Germany, the results would be even stronger. Columns 4 suggests that with few observations, it is impossible to separate the impact of engineering and literacy although in subsequent exercises we can.

3.4 US county level data

We construct engineering and patenting density data for the 2380 counties which show no change in borders in the last century. Table 4 presents the OLS estimates including the core geographical controls. All specifications have robust errors and are clustered at the state level and include both OLS and fixed effect estimators. We estimate:

$$Y_{2000,i} = \alpha + \gamma_E Eng_{1900,i} + \gamma_P Pat_{1900,i} + \mathbf{Geo_i}'\gamma_{\mathbf{Ge}} + \mathbf{Income_{1900,i}}'\gamma_{\mathbf{Gr}} + \mathbf{HC_{1900,i}}'\gamma_{\mathbf{H}} + \mu_{state} + \epsilon_i (2)$$

To be consistent with the other samples, we begin with an OLS specification of engineering density along with a vector of geographical controls. Errors are robust and clustered by state. In column 1, engineering emerges strongly significantly and of expected sign in the

OLS specification. Column 2 then includes the set of income related controls that together work to reduce the correlation that may occur simply because denser, richer, areas with more infrastructure and in particular railroads, may be correlated with engineers in 1900 and also with income today through non-innovation related channels. We further include a measure of slavery as an institutional variable that may be correlated with low human capital but also provides other channels to present income. Population density, our measure of lagged economic activity, and railroads enter positively and significantly and will remain so throughout the analysis. Slavery, at this point, emerges negatively but insignificantly.

Column 3 seeks to ensure that the engineering measure is not simply a proxy for human capital more generally and hence includes literacy, density of lawyers (see Murphy et al., 1991), and density of physicians. Literacy, lawyers and engineers all emerge significantly. Column 4 controls for fixed effects. Engineering loses about 15% in magnitude but remains significant. Slavery now emerges significantly and positively suggesting that its primary negative impact works through human capital. Engineering remains robustly significant at the 1% level across all specifications with the complete set of geographical and initial income controls as well as alternate measures of human capital.

Columns 5 and 6 repeat the last two specifications but replacing engineering density with patenting density as the innovation capacity measure. Patenting enters significantly at 1% again with and without fixed effects. Columns 7 and 8 combine the two measures in the full specification and both remain significant at at least the 5% level with and without fixed effects. Both measures decline 25-20% in magnitude suggesting that one channel through which engineering operates is through patenting and that some of patenting's effect is as a proxy for engineering density perhaps working through non-patenting channels. However, that each continues to enter very significantly and independently suggests that they are capturing different effects, perhaps more technological adoption in engineering and inventive activity in patenting.

Though we have attempted to control for other channels through which our engineering measure may be correlated with present income beside the capacity to manage and generate new technologies, however, we attempt to control for residual upward bias by instrumenting engineers. There may be additional bias in the opposite direction since the large share of counties (50%) reporting zero engineers is more likely to reflect measurement error, rather than that there was absolutely no capacity of any kind to adopt technologies.[18] In the spirit of Moretti (2004), we also attempt to instrument engineering density using the log distance to the nearest Morrill Land Grant colleges and universities. As discussed earlier, the Morrill program was introduced in 1868 precisely to remedy the perceived shortfalls in regional technical assistance in agricultural and mechanical innovation and hence are very related to the effect we are trying to measure. In practice, this program financed the first engineering departments in the emerging West and Midwest and especially in the South. It was to an important degree supply driven. Prior to the Civil War, the South had actively opposed the bill, fearing greater interference in matters such as universal primary education. The withdrawal of the Confederate States from the US Congress allowed the bill to be passed. However, during Reconstruction, recognizing its technological lag, the South started privately institutes such as Georgia Tech, and actively embraced the Morrill Program.

The first stage of a basic 2SLS reveals a strong positive correlation between engineering density and the Morrill proxy with very high Cragg-Donald F-tests (1% level) suggesting a strong instrument. Column 9 present the second stage results for the complete specification with fixed effects and engineers enter again at the 1% level with a value an order of magnitude higher than the OLS estimates. We do not present all previous specifications simply because, as with the OLS specifications, both engineering and patenting retain their

[18]The vast majority of zeros are found in small counties which, in 1900, may not have had the scale to generate an engineer. The maximum county size is 1,240,403 with the 99th percentile at 140,000. 88.9% of zeros are found in counties below 20,000 of of counties with 5,000 inhabitants, 75% are zeros.The zeros also pose an issue in comparability of the OLS and IV estimates since IVs offer a local estimate over the support where there is variance in both the instrument and the variable to be instrumented. In the present case, this may also push up the IV estimates.

significance and broad magnitudes throughout.

Column 10 presents the results of a Buchinsky quantile regression model with selection into being a zero on the instrument stage. This specification is also desireable because it relaxes the assumption of joint normality implicit in the standard Heckman model. The first stage again suggests a strong instrument at the 1% level. The coefficient on engineering falls to half the 2SLS and maintaining its strong significant to half that of the IV, 3.51. As before, the first stage is strongly significant. As another alternative approach to the zeros, although with important losses in degrees of freedom, we aggregated to the state level. The OLS and instrument estimates are 1.2 and 2.1 respectively (not shown) and significant.

Taken together, the US data suggests that innovative capacity, spanned by engineering and patenting density, has a strong and independent effect on future income levels.

3.5 International sub-national engineering data

To see whether innovative capacity retains its predictive power beyond the US, we collect engineering data at the sub-national (state) level for Argentina, Chile, Colombia, Mexico, Venezuela and the US from census data. To give a feel for the disparities, Figure 2 maps this data for the US and Mexico by decile of engineering density and strikingly confirms that the border divided worlds apart. In fact, the data likely understate the true difference since our calculated stocks in Figure 1 suggest substantial overstatement in the Mexican census data. Perhaps predictably, the advanced New England states and the heavily mining dependent and generally less populated Western states show the highest density while the emerging industrial centers of the Midwest are close behind. The South is concentrated in the lower ranks with South Carolina, Georgia, Arkansas and Alabama in the bottom deciles- the lowest density in the US. What is striking, however, is that the country that was the principal mining center of the Spanish empire is almost entirely concentrated in the first and second quintiles with Sonora and the two Baja Californias appearing in the third and fourth deciles. Taking out Mexico City and the border states, Mexico is almost uniformly below even the American South in density of engineers. Despite four centuries of mining, it had not acquired a corpus of trained professionals in the field compared to relative newcomer, the American West. The other countries show similar patterns.

Table 5 employs the sub-national data and comes to similar conclusions to those previous. We estimate:

$$Y_{2005,ij} = \alpha + \gamma_E Eng_{1900_{ij}} + \gamma_{pop} Pop_{1900,ij} + \gamma_L Lit_{1900,ij} + \mu_i + \epsilon_{ij} (3)$$

Engineering density is persistently significant and broadly of the magnitude of the OLS estimates from the US. The finding of continued significance even after controlling for a measure of population density (column 2) is consistent with Comin et al. (2010a). In column 3, Literacy again enters positively and significantly and reduces the coefficient on engineering by 40%, again, broadly consistent with the US results. Though we cannot control for a more complete set of human capital measures, the county level exercises above suggest that, in fact, engineering is capturing innovation related human capital and not human capital accumulation more generally. We also run the regressions with a complete set of geographical controls but these absorb substantial degrees of freedom and do not enter significantly so we omit them.

In sum, the various estimations suggest that our county level US findings resonate globally: both literacy and higher order human capital related to engineering and science and technology are important determinants of future income.

4 Support from History: Case Studies

This section offers historical evidence that confirms that innovative capacity was a critical barrier to taking advantage of the advances of the Industrial Revolution. The interaction of lost learning by doing, weak higher level human capital, and underdeveloped technical institutions emerges in explanations of the lag of the US South as well as Latin America. However, it also offers support for more complex view of how innovative capacity affects steady state growth. Numerous models exist for modeling the micro economics of adoption. Comin et al. (2010b); Comin & Hobijn (2010); Comin et al. (2010a) for instance are closely aligned with the opening stylized facts (theirs) about divergence at the intensive margin. Human capital shortfalls are embedded in a scalar that reflects barriers to adoption for the agent that adapts the technology to the idiosyncrasies of the country or for individual producers that find a profitable use for the technology. The models of Howitt (2000); Aghion et al. (2005); Howitt & Mayer-Foulkes (2005) add a feature central to this paper- that as the technological frontier shifts out, the skill level required to maintain the same level of absorptive capacity increases as well. Howitt & Mayer-Foulkes (2005) further add that 1. the efficacy of education is a function of the level of technological advance and 2. the introduction of a new method of technological change, loosely termed "modern R&D" such as culminated in the late 19th century with the modern R&D laboratory (the rise of institution such as government research agencies, scientific academies, universities with close to industry etc.) gives rise to the possibility of an important and discrete shift in the productivity of innovation technology. This gives rise to three equilibria: countries with with a threshold level of skill could undertake this "modern R&D"' and innovate; countries with less may still adopt and grow but with a persistent income gap relative to the innovators; countries with insufficient absorptive capacity cannot even adopt and stagnate (See Annex II, also Howitt (2000) for a model of complete stagnation). Further, advances in the frontier not accompanied by a rise in local human capital can cause a country to lose its absorptive capacity and slide to a worse equilibrium.

Our data do not permit testing explicitly for convergence clubs and we must be satisfied with a correlation with present income. However, the historical case studies do suggest the importance of these dynamics and these ideas help organize what happened around 1900 in the US South and Latin America vs the US North. The initial conditions in terms of skills broadly defined allowed the latter to fully adopt modern R&D technologies, while in the former, they did not. In the South they were unable in some cases to undertake the necessary R&D to adapt some new technologies to local conditions, for instance, in Steel. In Latin America, the erosion of their frontier adjusted human capital was so severe when faced with new technologies in metallurgy and chemistry that they were forced to abandon critical industries, in our case mining, altogether and could not, in many cases, mount a manufacturing effort.

4.1 The American South

An extensive literature deals with southern development and we present only a brief summary to draw the parallel with other cases. Wright (1986) casts much of his work explaining the US South's persistent lag exactly in terms of an innovative capacity framework. "The fundamental reason for [protracted lack of uptake of technologies] is that early industrialization is a matter of learning in the broadest sense of that term: in management, in technology, in marketing and certainly-though this is often underestimated- in learning on the part on the part of the labor force"(pp. 124-125). The South came relatively late to industrialization and lacked the indigenous technical capacity necessary for rapid catch up.[19] The emblematic failure was of the Birmingham Steel industry, which Carnegie referred to. The problems were manifold-high labor costs, product quality and marketing- all of which reflect the low level of collective, accumulated learning by doing. But also central was that the low iron, high phosphorous nature of Alabama red hematite required substantial adaptations of technology to the Southern context which the local innovative capacity was not able to engineer. Nor was it able to develop Southern versions of new inventions in the paper and textile industries. By way of contrast, Japan also initially imported technology

[19] Wright (1986) argues that "Having missed the formative phases of the 'American System', the South was lacking a machine-tools and capital-goods sector almost entirely and therefore was bypassed by the kind of adaptive, dynamic, path-breaking series of technological breakthroughs that made 'the American system' distinctive."(p. 124-125).

and processes, but over time it generated distinctive technologies and, by the 1920s, was making its own textile machinery. In lumbering and iron making, as well, Southern producers of the 1920s were not only not innovative, they were using methods phased out decades earlier elsewhere. Arguably, the big push by the federal government, ranging from the Land Grant colleges to selective location of advanced industries, and migration of higher order human capital, raised innovative capacity toward the frontier and permitted catch up.

4.2 Multiple equilibria in mining: Latin America vs. the US

The potentially catastrophic impact of a dearth of innovative capacity is nowhere more in evidence than in the industry in which Latin America for centuries had a true comparative advantage, yet by the turn of the 20th century had completely stagnated: mining. Close observation by numerous historians offers a particularly compelling window on how a similar inability to adapt new technologies in the face of declining ore quality nearly destroyed the Chilean mining industry as well. As figure 3 illustrates, Chile saw its world market share of copper fall from 40% to under 4 percent by 1911, and even as early as 1884 the *Sociedad de Minería* (Mining Association) wondered openly whether Chile's copper mines would survive at all (Collier & Sater, 1996). Chilean historians date this technological slippage to the beginning of the nineteenth century, when "the work of mining was not very systematic" and the "receipt of industrial innovations [from abroad] was slow and without visible influence"(Villalobos et al., 1990, p. 95-96).[20] One of Chile's most venerated historians, Francisco Encina noted that "from the point of view of capital and of technical and administrative aptitude, the copper industry is as demanding as the most complicated manufacturing industry" (Encina, 1972, p. 62). However, his studies revealed "an extraordinary economic ineptitude in the national population consequence of an education completely inadequate to meet the demands of contemporary life."(p. 17).

[20]Charles Lambert, a representative of a British mining company in La Serena who was trained in the *École Polytechnique in Paris*, noted in 1819 the primitive mining practice, scarce knowledge of minerals, and inefficient smelting, all of which represented poor technique relative to that employed in Europe. See also Maloney (2002).

Another prominent historian, Pinto Santa Cruz (1959) argued that Chileans failed to take advantage of opportunities for learning by doing and to evolve the innovative capacity required to confront the technological revolution in mining and hence became dependent on foreign firms.[21]

Figure 3 captures this importing of technical ability, first in the 1870s and 80s as Britain expanded in the nitrate and coal industry, and then after 1905 when major foreign copper companies took over the copper industry. The census data shows the density of foreign entrepreneurs increased from almost zero in 1870 to 80 in 1920, the last census which permitted disaggregating by nationality/profession, or roughly 4 times Chile's domestic density in 1900. Local capacity was increasing as well, however, the share of foreign engineers in the country total increased sharply from 1% of total engineers in the country to around 40% across this period. These movements emerged concomitant with Chilean production reaching new highs and market share of an expanding global supply staging and important recovery. As in Mexico, below, and consistent with Howitt & Mayer-Foulkes (2005)'s education externality, both the quantity and the quality of the engineering graduates produced by local universities were thought inferior to the talent imported from Europe and the US (Serrano, 1993; Bazant de Saldaña, 1993). Increasing frustrated by the creeping influence of foreigners across the major industries, it is perhaps not surprising that Chileans developed a self-perception that they were perhaps "unfit for the modern era"(Monteón, 1982, p. 62 and 35).[22] By 1918, American interests controlled 87% of Chilean copper output (O'Brien, 1989).

[21] "The technological demands of the period, in contrast to what is occurring today in some areas of mining or industry, were relatively modest and thus not too costly. What could and had to be done in the national mining companies and in agriculture was perfectly compatible with the resources accumulated in the long periods of bonanza. If the process had been initiated and maintained adequately, without doubt it would have created the means to confront more challenging tasks, such as those posed by copper mining when it was necessary to exploit less rich veins. However, faced with the technological revolution, the local mining companies did not have either sufficient accumulated resources or organizational and administrative capacity- both of which were indispensable. In these circumstances, there was no other option but the introduction of foreign capital and expertise."Pinto Santa Cruz (1959)(p 71)

[22] Prominent intellectual Tancredo Pinochet Le-Brun(1909), granting that Chileans were inferior to Europeans, still wondered, "Don't we have minds in this country that can go to Europe to learn what professors, whom we have imported and continue importing, have studied? Are we truly incapable of steering our own ship?" *La Conquista de Chile en el Siglo XX*, Santiago, La Ilustracion, page 81 cited in Monteón

Similar stories of an inability to exploit new technologies leading to decline in the mining industry can be found throughout the region. The engineering data in Figure 1 supports the historical evidence that in Mexico local entrepreneurs lost share in the industry they had dominated for centuries precisely due to lacking the capacity to master emerging technologies (Ruiz Larraguivel, 2004; Brading, 1971; Marichal, 1997). Even in Zacatecas, San Luis de Potosí, and Guanajuato, long centers of mining, engineering density was at low levels compared to the newcomers in the US West. Around 1900, abandoned, underexploited and newly discovered mines fell to foreign hands that could bring new global technologies to bear. As an example, the Guggenheim interests opened smelters in Monterrey (1892) and Aguascalientes (1894) purchased the largest Mexican Smelting and Refining company in 1906, introduced modern methods of extracting and refining silver ores and in addition, started the production of lead and zinc mining (Bernstein, 1964; O'Brien, 1989). By the early 20th century, the Americans absolutely dominated the industry.[23] In Upper Peru (now Bolivia), the decline of silver production in some of the most famous mines, like those at Potosí, arose from the "failure to apply new mining techniques, heavy mortality among Indian laborers and the exhausting of previous rich veins" (Scobie, 1964, p.59). In Ecuador, Hurtado (2007) argues that the discovery of new mineral deposits was hindered by a resistance to scientific methods.[24]

The US eventual dominance of the Chilean copper and Mexican mining industries

(1982)).

[23]See Maloney (2012) for data on nationality of owners.

[24]More generally, Di Tella (1985) argues that Argentina proved unable to move beyond a state of exploiting the pure rents of a frontier or extraction of mineral riches, and beyond the "collusive rents" offered by state-sanctioned or otherwise imposed monopolies to tap the "unlimited source of growth" found in exploiting the quasi-rents of innovation, as the US, Canada and Australia were able to do. They remained in an adoption or, perhaps, stagnation equilibrium. The same phenomenon is seen in agriculture where the absence of innovative infrastructure was recognized by contemporary Argentines as key to explaining the lagging performance of the wheat industry compared to that in Canada and Australia.Fogarty et al. (1985) attributes to weak innovative capacity the outcome of a quasi-experiment whereby the Spanish Merino sheep were introduced into New South Wales, Australia, and Argentina's River Plate region in the same year and had the same access to European capital, but by 1885 showed yields of only half the wool per sheep in Argentina.

strikingly illustrates the road that could have been taken with the same homogenous product. Not only does Wright (1999) argue that US in the 19th century "parlayed its [natural] resource-based industrial prosperity into a well-educated labor force, an increasingly sophisticated science-based technology, and world leadership in scientific research itself" (Wright, 1987, p. 665), but he uses precisely the US copper industry as an example of national learning and of innovation as a network phenomenon. Wright stresses that in the post civil war period, the US became the foremost location for education in mining engineering and metallurgy. It was the revolution in metallurgy (e.g. the Bessemer process and the introduction of electrolysis on a commercial scale for the refining of copper) overwhelmingly an American achievement, that propelled the copper industry during the last decades of the 19th century. The transference of these technologies by US firms to their mines and smelters in Chile and Mexico revolutionized the antiquated industries in both countries, dramatically increased production, and left them dominant in both.[25]

The US reaped high growth dividends from inventing new technologies in mining, and its engineering and scientific capital became the best in the world. At the same time, and with exactly the same goods, Latin America's declining human capital relative to the expanding technological frontier left it unable even to adapt new technologies, and the domestic industries stagnated. The success of the Chilean State Copper Company, established in 1976, testifies that this need not be permanent and at least an adoption equilibrium was reachable by nationals with the accumulation of the necessary human and knowledge capital.

4.3 Retrogression in industry in Brazil: Minas Gerais

In Iron manufacturing, Baer (1969); Rogers (1962); Birchal (1999) argue that despite a tradition of iron smelting dating from the mid-sixteenth century, the techniques used at the

[25]The Guggenheim's El Teniente mine was the first in the world to apply the flotation process in concentrating low-grade ores. Mechanizing digging made Chuquicamata in the north the largest open pit mine and, again, a new concentration process was introduced using sulfuric acid and electrolytic precipitation to treat the mine's ore. From 1912-1926, copper production in Chile quintupled as a result, reversing a 25 year period of stagnation (O'Brien, 1989).

end of the nineteenth century were primitive. While particularly the northern US colonies engaged in a sustained process of learning by doing and innovation in both iron and steel (Swank, 1965) from the early 18th century on, from 1830 to 1880 Brazil actually experienced a "retrogression in technique"(Rogers, 1962, p. 183). Unable to innovate, Brazilian firms instead lobbied for protection from cheaper iron imports.[26] The critical innovation for the development of the native steel industry was the foundation in 1879 of the *Escola de Minas* (Mining School) at Ouro Preto, Minas Gerais, which, as the *Escuela de Minas de Antioquia* was a major diffuser of new practices and led to the establishment of the first new blast furnace since the failures at the beginning of the century. On the other hand, the textile industry for which we have entrepreneurship data above was less fortunate. As (Birchal, 1999, p. 183) notes "the existing informal and spontaneous technological innovative system was not developed enough to take the process of technological assimilation farther in the direction of a profound modification of existing foreign technologies, or to create a more complex indigenous technological alternative" again, much as Wright argues for the American South.

This raises the larger question of, given the sheer disparity of our innovative capacity numbers, if it was so hard for the American South to start competitive industries with its innovative capacity captured by 60 engineers per 100,000 individuals, how did Latin America's industry expand so quickly at the turn of the 20th century with an average of 10? Much also may lie in the Potemkin nature of much of Latin American industrialization that, as in the American South, was dependent on imported capital goods and innovated little. Across the region, blocks in the input-output table were rapidly filled in but, as Haber (2005, 2006) notes, these industries were not modern in the sense of being at the technological frontier or being able to export to other countries. Much as Wright notes in the American South, Latin America relied heavily on foreign technology imports, and was sluggish in

[26]Of the thirty ironworks in the headwater region of the Rio Doce in 1879, only seven used Italian forging methods, while the rest used the old African cadinho (crucible) technique. Graduates of the *Escola de Engenharia do Exercito* (Military Engineering School) established in 1930 led the steel industry as it developed through the 1960s.

developing an indigenous local machine and capital goods industry, a result attributed to low innovative capacity.[27] The fact that Latin America evolved the highest levels of tariffs in the world prior to World War I –on average five times the rates in Europe– is arguably the result of the need to protect an industry erected on weak foundations of entrepreneurship, accumulated learning by doing, and higher level human scientific capital.[28] This supports Haber's theory that the standard view of protectionism stimulating industrialization is potentially backwards. An emerging, but technologically backward and uncompetitive industry demanded protection. In turn, lack of exposure to foreign competition blunted the need to upgrade quality and technical capacity.

4.4 Mechanisms of influence today

Table 6 offers some suggestive mechanisms through which these engineering densities in 1900 could continue to affect output today. We collect five indicators that broadly capture modern day innovation-related inputs and outputs and calculate the simple correlation. The first is the dynamism of the system of research and development measured as total R&D expenditures as a share of GDP. The second asks about firm capacity for innovation ranging from pure licensing to pioneering their own new products and processes.[29] These two, arguably, correspond most closely to Howitt & Mayer-Foulkes (2005)'s R&D model. The third draws from a globally consistent measure of management quality from Bloom & Van Reenen (2010) and in particular, the sum of the scores on the two questions dealing with how firms identify new production processes to adopt. On the output side, we have Comin & Hobijn (2010); Comin & Ferrer (2013); Comin et al. (2008)'s measure of technological adoption at the extensive margin, averaging their

[27] "Since... capital goods industries now required well-developed scientific and engineering capabilities, Mexico had little choice but to import its capital equipment. The blast furnaces and rolling mills came from the United States, the high-speed cigarette machinery from France, the paper-making machinery from Switzerland, the textile looms, spindles, and other equipment from England, Belgium, the United States, or Germany." Haber (1997), p. 18

[28] Coatsworth and Williamson and Clemson and Williamson, cited in Haber (2005).

[29] "In your country, how do companies obtain technology? [1 = exclusively from licensing or imitating foreign companies; 7 = by conducting formal research and pioneering their own new products and processes].

industrial and sectoral scores[30], and finally patent applications filed under the Patent Cooperation Treaty (PCT) per million population as tabulated by the World Economic Forum (World Economic Forum et al., 2012). Together, these give an impression of measure of national absorptive and inventive capacity in the present. In virtually every case, the correlation between our engineering numbers in 1900 and these indicators today is above .9.[31]

5 Local and inherited determinants of innovative capacity

Innovative capacity has been postulated to emerge as a function of local conditions, but also effectively exogenous pre-existing imported or inherited factors. For the former, Acemoglu et al. (2002) and Engerman & Sokoloff (1994) have argued that a large indigenous populations, or particular factor endowments might lead to extractive institutions. Such institutions could clearly dampen innovative capacity through the restriction of the population allowed access to education of any kind. On the other hand, **?** have argued that, at the sub-national level, large indigenous populations may have provided the kernel of an agglomeration that would increase the productivity of engineers, entrepreneurs, and other innovation related factors and hence foment their replication in line with Howitt & Mayer-Foulkes (2005)'s externality. Geographical factors, such as an agreeable climate, may repulse or attract talent. Few would argue that the geographical fundamentals of the San Francisco Bay area are not attractors of high level human capital, as was the case of Florida in the early 20th century (Cobb, 1993). Likewise, engineers are unlikely to remain in the inhospitable areas where mines are often found after the industry loses profitability.

It is also likely that institutions, human capital and attitudes brought by the colonists affected the evolution of innovative capacity. The education level of the immigrants, and how

[30]Their data on the arguably more relevant intensive margin is not yet available

[31]While it may be interesting to compare engineering densities, the available UNESCO data is on flows and suffers from very important differences in definition across countries.

steeped they were in the scientific project radiating from England–the quality of the stock planted in the local soils– is relevant. In fact, the striking similarity of both engineering levels and histories between countries and former colonial masters suggests that these larger forces may be found in the often mutually reinforcing production structures, institutions, and values brought with the settlers themselves. A recent literature has attempted to put the influence of such inherited characteristics on a firmer empirical basis.[32]

Table 7 presents, first, the results for the US county level for both engineers and patents. Pre-colonial population density and South enter at the state level; the others enter at the county level. Because of the zeros in engineers, we present both OLS (Column 1) as well as quantile estimates with selection to report a zero (Column 2). Column 3 reports OLS for patents and Column 4 the corresponding quantile regressions. Taking the results as a whole, pre-colonial population enters strongly significantly and positively in all specifications with both engineers and patents. This offers a channel through which agglomeration benefits likely offset negative institutional effects, consistent with **?**. Slavery enters negatively and very significantly in all specifications suggesting that reduced investment in higher education is a channel through which slavery had a depressing impact on future incomes. South continues to enter significantly in all except the engineers selection model suggesting and impact beyond the set of factors associated with slavery- productive structure, institutions,

[32]Alesina et al. (2014) and Fulford et al. (2015) find at the national and sub national level respectively that ancestry of inhabitants matters for performance. Spolaore & Wacziarg (2009) have found that the distance from the technological frontier captured by genetic characteristics, proxying for "customs, habits, biases, conventions etc. that are transmitted across generations-biologically and/or culturally-with high persistence" is correlated with economic performance (p. 471). Putterman & Weil (2008) demonstrate that backgrounds of the ancestors migrating to a country are correlated with economic performance. Weber's assertion of a link between religious belief or religiosity and entrepreneurial qualities is re-argued by McCleary & Barro (2006); Becker & Woessmann (2009) have argued the "very long-lived (centuries) economic consequences of the emergence of Protestantism," although through its impact of human capital accumulation (literacy) rather than through work effort and thrift. Easterly & Levine (2012) argue that European origins can account to as much as half of global development and that European colonizers where important, even when they were relatively few in number.Ashraf & Galor (2013) in turn argue that cultural diversity, measured by distance from Africa, is a strong determinant for subsequent growth. Similarly, Spolaore & Wacziarg (2012) have shown that genetic distance matters for development and innovation. Galor & Michalopoulos (2009) take a genetic point of view, arguing that the failure of the landed aristocracy to lead the risky process of industrialization could be attributed to Darwinian selection reducing the representation of entrepreneurial, risk tolerant individuals within the landed gentry, and the prevalence of risk tolerant individuals among the middle and even the lower classes.

origin and variety of settlers. For engineers, only ruggedness enters positively while for patenting it enters negatively, perhaps reflecting the importance of engineers to mining, but not necessarily the likelihood that mining would generate patents. Temperature enters positively and positively, Rainfall negatively in almost all specifications. For patents, Altitude enters positively and significantly, and coastal distance negatively.

Table 8 presents the results for the full panel including Argentina, Chile, Colombia, Mexico, Venezuela and the US. Column 1 again includes colonial population density and a full set of geographical controls. Colonial density again enters positively but loses significance with the clustering. The state level geographical controls do not tell a compelling story: agricultural suitability enters negatively suggesting that engineering is less critical to farming. Malaria positively. Column 2 drops the individual fixed effects and replaces them with a dummy for having been a Spanish colony including the states which are now part of the US, and a dummy just for former Spanish colonies now part of the US. Consistent with the unconditional correlations found in Figure 1, the colonial dummy shows a very strong negative effect that suggests that, with a coefficient of -1.1 these regions have less than half the density of the US. Despite having averaged in the more generous estimate of Spain's engineering capacity, the mother country falls within the Latin cluster, and were we to have taken Riera's estimate alone, it would be average for that cluster. Portugal, while above Brazil, is similarly low. On the other hand, the US-Spanish colonial dummy is strongly positive reflecting the high density of engineers, for instance, in California. Either the Spanish heritage is not responsible for Latin America's low engineering density or the subsequent Anglo dominance more than offset it. Overall, a very high and robust share of the difference in engineering density is due to being derived from Spain and very little significant from either initial population densities or geographical factors.

This conclusion is supported by evidence on the communication of values and institutions related to educational and entrepreneurial capital formation from the Peninsular powers to their colonies, and in striking parallels in development outcomes among them. First, Spain and Portugal, confronted with the Industrial Revolution in England, failed to develop a scientific vocation nor the complementary innovation promoting institutions essential to industrialization. The colonies, legally cut off from direct commerce and interaction with Northern Europe-even trade with Cadiz was through peninsular intermediaries- were unlikely to absorb it from the industrializing center or develop it on their own. Mass education was not prioritized on either side of the Atlantic: in both mother countries literacy lagged even the black (often freed slave) population in the American South, and is of similar magnitude to that of the Latin American colonies.[33] The Peninsular tradition of higher education was largely religiously based, focused on law, philosophy, and theology, proved resistant to attempts to introduce enlightenment-informed technical curricula,[34] and was exported to the colonies.[35] This lack of a vocation toward scientific advance led to extraordinary technological dependence in both sides of the Atlantic. Between 1878 and

[33]Tortella (1994) notes that in 1900 Spain had a literacy rate of 44%. This is slightly below that of Argentina (48 %) and blacks in the American South (49%) (Collins & Margo, 2006)), and not dramatically ahead of Peru (38%), Chile (37%), Colombia (32 %), or Mexico (22%). Portugal's low level of literacy, 22%, is essentially identical to that of its colony Brazil (20%).

[34]In Portugal, the flagship university at Coimbra briefly established a more technical curriculum in 1759 under the Marquis of Pombal in the context of radical political, education and ecclesiastical reform to modernize the state and energize the economy. However, in 1777 there was a reaction against the reforms and the emphasis on natural science was abandoned and civil law regained its ancient prestige. The Spanish enlightenment in the same period saw the establishment of groups of autonomous sociedades económicas (economic societies) that sought to diffuse technology from abroad and establish libraries throughout the country, as well as some Royal Societies emphasizing applied science. But Spain began training engineers seriously only in the 1850s, and by 1867 the country had only one functioning School of Industrial Engineers, located in Barcelona (Riera i Tuébols, 1993).

[35]"The Latin American upper classes have been noted for their devotion to the study of law, the humanities, and the arts and their lack of interest in the natural sciences and technology. In the hands of the upper classes, Latin America's educational systems, at least in times past, have been dedicated to forming and maintaining the political elite and have been only mildly effective in furthering such economically practical aims as the broad diffusion of literacy and technical capacities." (Safford p. 3.) Spanish America saw universities established from the moment of conquest, yet they were largely committed to the training of ministers to convert Indians, and lawyers to staff the empire (Benjamin, 1965). As (Will, 1957, p.17) documents for Chile, although it applies with greater generality "With the exception of the inadequate facilities provided by a few religious organizations, there did not exist before the middle of the eighteenth century an institution capable of furnishing the youth of the colony with the barest essentials of a secular education." The majority of the relatively few university educated members of the Brazilian elite at independence trained at Coimbra in the reinstated legal theological tradition (Carvalho, 1982). In Ecuador, (Hurtado, 2007, p. 115) argues that education quality even among the elite was poor and unfocused on practical elements. Again, he cites the American ambassador to Quito in the 1850s who found "convents instead of presses, barracks in place of schools." See comparable accounts in Will (1957) for Chile; Safford (1976) for Colombia; and Lopez Soria (2012) for Peru.

1907 approximately 70% of Spanish patents were for introduction of foreign technologies, 85% of which were filed by foreigners, a pattern similar to that found in Colombia at mid century where 85% of patents were introduction of foreign technologies (Pretel & Sáiz, 2012; Mora et al., 2005).

Second, Spanish values and institutions are held to have impeded the development of a modern entrepreneurial corps that could formulate long term projects, and identify the higher order human capital, such as engineers, necessary to carry them out. Latin American historians note the dominance of an ideal of the *hidalgo* who despised work and commerce, that is asserted to derive from Spain. As Baumol (2010) notes, this attitude appears in Rome where commerce and manufacturing were relegated to manumitted slaves, and was codified in the thirteenth-century *Siete Partidas*, [the unifying legal code of Spain, based, in some cases verbatim, on the Roman Code of Justinian] which cautioned Spanish nobles against defilement in commerce" and which remained central to Spanish law into the 20th century. (Safford, 1976, pg.6). Tortella Casares (2000) devotes a chapter of his *Economic History of Spain*, to how this attitude across all strata undermined entrepreneurship and contributed to the scarce economic progress in Spain from 1500 to 1850, the "miscarriage" of the Industrial Revolution there, and the lack of a "competitive, dynamic, entrepreneurial class."[36] The *Siete Partidas* and their anti-commerce bias were the legal code imposed on Latin American colonies until Independence. Given the imported legal framework, the nature of social aspirations, and legal barriers to interacting with centers of commerce that might challenge this tradition, it is perhaps not surprising that the vast majority of significant industries in the region were started by immigrants and not by the local elites.[37]

---

[36](Tortella Casares, 2000, pp. 73, 227) acknowledges that it "would be naïve to attribute the economic backwardness of Spain solely to the mediocre caliber of its business entrepreneurs. But neither can one deny that social attitudes, difficult as they are to grasp, were very pervasive... My principal hypothesis... has been that a society which from the sixteenth century onwards was, intellectually speaking, frozen solid into an orthodoxy that systematically repressed original thought and freedom of action in the search of earthly happiness, finished up three centuries later without a competitive, dynamic, entrepreneurial class. The social attitudes, the accepted norms, I repeat, have been very persistent"

[37]Maloney (2012)

Finally, the development experiences show the exact same issues of inability to manage new technologies and external dominance characterizing Latin America (Tortella Casares, 2000). For example, the evolution of the Spanish mining industry precisely foreshadows the subsequent experience in Chile and elsehwere discussed earlier. Though Spanish mines were rich, and mercury had been worked for a thousand years, the lack of technical capacity and capital, and the slow growth of domestic metallurgical know how led Spanish entrepreneurs to work close to the surface and then sell out to foreigners once easy veins had been exhausted. In 1873, a UK and German led conglomerate purchased the mines on the Rio Tinto river in Andalucia, introduced new technologies, and from 1877-1891, became the world's largest producer of copper, contributing the to fall in Chile's global share in figure 3. As (Tortella Casares, 2000, pp. 96, 213-215)) summarizes: "extraction and processing constitute a classic example of the failure of Spanish entrepreneurs to confront the problems of developing an industrial sector with complex technology, intensive use of capital, [and] a fast-expanding horizon." In the trajectories of scientific and entrepreneurial human capital and in development outcomes, the similarities are so close as to suggest, consistent with the persistent Spanish dummy in the regressions, a dominant role for inherited attitudes and institutions.

6 Conclusion

Much of the growth literature stresses differences in the capacity to generate, import, and apply new technologies as central to explaining relative growth performance. In particular, Aghion et al. (2005) document that different frontier adjusted endowments of human capital broadly construed dictate very distinct growth trajectories and Howitt & Mayer-Foulkes (2005) argue that at the time of a radical shift in technological progress, such differences lead to convergence clubs of high growth and stagnant economies. To date, however, there has been little data generated on the higher level human capital and institutions required to make this possible, especially in a historical context, and none to attempt to verify its impact on income differentials.

This paper generates a data set on innovative capacity in the Americas as measured by the density of engineers in 1900. This measure, compiled using graduates of local engineering universities, professional associations and censuses, is arguably the first to offer international comparability for this key period around the Second Industrial Revolution. We see it as a measure of higher level scientifically oriented human capital per se and supporting institutions, as well as arguably a more general measure of technological sophistication of the entrepreneurial class. We show that engineering density has an effect beyond literacy or other measures of higher order human capital, such as lawyers, as well as beyond confounding measures such as railroads, and agglomerations. Instrumenting engineering preserves its significance and effect in the US.

We then provide historical evidence that broadly confirms the ranking of countries emerging from our engineering data and which suggests that precisely an inability to manage the new technologies emerging from the Second Industrial Revolution slowed growth in the Southern US, and led to a loss of competitiveness in a sector long an area of comparative advantage in Latin America– mining. The fact that the US was able to leverage this sector into a well-educated workforce, and world leadership in scientific research while Latin America lost the industry confirms the importance of innovative capacity, and the persistent effect of early human capital investments. It also lends support to the idea of multiple equilibria arising from differences in innovative capacity.

Finally, we dentify the determinants of innovative capacity in existing agglomerations, certain locational fundamentals, and extractive institutions such as slavery in the US. In the hemispheric sample, a large effect remains associated with being a Spanish colony which suggests this importance of inherited institutions, values and scientific and entrepreneurial tradition.

References

Acemoglu, D. & Dell, M. (2010). Productivity Differences Between and Within Countries. *American Economic Journal: Macroeconomics*, 2(1), 169–88.

Acemoglu, D., Johnson, S., & Robinson, J. A. (2002). Reversal of Fortune: Geography and Institutions in The Making of The Modern World Income Distribution. *The Quarterly Journal of Economics*, 117(4), 1231–1294.

Acemoglu, D. & Zilibotti, F. (2001). Productivity Differences. *The Quarterly Journal of Economics*, 116(2), 563–606.

Adkins, D. (1975). *The great American degree machine: an economic analysis of the human resource output of higher education : a technical report sponsored by the Carnegie Commission on Higher Education*. The Commission.

Aghion, P. & Howitt, P. (1992). A Model of Growth Through Creative Destruction. *Econometrica*, 60(2), 323–51.

Aghion, P., Mayer-Foulkes, D., & Howitt, P. (2005). The Effect of Financial Development on Convergence: Theory and Evidence. *Quarterly Journal of Economics*, 120, 173–222.

Ahlström, G. (1982). *Engineers and Industrial Growth: Higher Technical Education and the Engineering Profession during the Nineteenth and Early Twentieth Centuries: France, Germany, Sweden and England*. Croom Helm.

Ahlström, G. (1993). Technical Education, Engineering and Industrial Growth: Sweden in the Nineteenth and Early Twentieth Centuries. In R. Fox & A. Guagnini (Eds.), *Technology and Human Capital in Historical Perspective* (pp. 115–142). Cambridge University Press.

Akcigit, U., Kerr, W. R., & Nicholas, T. (2013). *The Mechanics of Endogenous Innovation and Growth: Evidence from Historical US Patents*. Technical report, Working Paper.

Alesina, A., Harnoss, J., & Rapoport, H. (2014). Birthplace diversity and economic prosperity.

Almada, M. & Zalduendo, E. (1962). *El Estudio de los recursos humanos de nivel universitario y técnico en la República Argentina*.

Aroca, P., Bosch, M., & F., W. (2005). Spatial Dimensions of Trade Liberalization and Economic Convergence: Mexico 1985–2002. *World Bank Economic Review*, 19(3), 345–378.

Ashraf, Q. & Galor, O. (2011). Dynamics and Stagnation in the Malthusian Epoch: Theory and Evidence. *American Economic Review*.

Ashraf, Q. & Galor, O. (2013). The 'out of africa' hypothesis, human genetic diversity, and comparative economic development. *The American Economic Review*, 103(1), 1–46.

Baer, W. (1969). *The Development of the Brazilian Steel Industry*. Vanderbilt University Press, [Nashville, Tenn.].

Basu, S. & Weil, D. (1998). Appropriate Technology and Growth. *The Quarterly Journal of Economics*, 113(4), 1025–1054.

Baumol, W. J. (1990). Entrepreneurship: Productive, Unproductive, and Destructive. *Journal of Political Economy*, 98(5), 893–921.

Baumol, W. J. (2010). *The Microtheory of Innovative Entrepreneurship*. Princeton: Princeton University Press.

Bazant de Saldaña, M. (1993). *Historia de la Educación Durante el Porfiriato*. Serie Historia de la educación. Colegio de México, Centro de Estudios Históricos.

Becker, S. O. & Woessmann, L. (2009). Was Weber Wrong? A Human Capital Theory of Protestant Economic History. *The Quarterly Journal of Economics*, 124(2), 531–596.

Behrman, J. & Birdsall, N. (1983). The Quality of Schooling: Quantity Alone is Misleading. *The American Economic Review*, (pp. 928–946).

Benhabib, J. & Spiegel, M. (1994). The Role of Human Capital in Economic Development Evidence from Aggregate Cross-country Data. *Journal of Monetary economics*, 34(2), 143–173.

Benhabib, J. & Spiegel, M. (2005). Human Capital and Technology Diffusion. *Handbook of economic growth*, 1, 935–966.

Benjamin, H. R. (1965). *Higher Education in the American Republics*. McGraw-Hill, New York ; Sydney.

Bernstein, M. D. (1964). *The Mexican Mining Industry, 1890-1950 : A Study of the Interaction of Politics, Economics, and Technology*. State University of New York.

Birchal, S. d. O. (1999). *Entrepreneurship in Nineteenth-century Brazil: the formation of a business environment*. London.

Bloom, N. & Van Reenen, J. (2010). Why do Management Practices Differ across Firms and Countries? *The Journal of Economic Perspectives*, 24(1), 203–224.

Brading, D. A. (1971). *Miners and Merchants in Bourbon México, 1763-1810*. University Press, Cambridge.

Braunerhjelm, P., Acs, Z., Audretsch, D., & Carlsson, B. (2010). The Missing Link: Knowledge Diffusion and Entrepreneurship in Endogenous Growth. *Small Business Economics*, 34(2), 105–125.

Bruhn, M. & Gallego, F. A. (2011). Good, Bad, and Ugly Colonial Activities : Studying Development Across the Americas. *Review of Economics and Statistics*.

Campante, F. & Glaeser, E. L. (2009). *Yet Another Tale of Two Cities: Buenos Aires and Chicago*. NBER Working Papers 15104, National Bureau of Economic Research, Inc.

Carvalho, J. M. d. (1982). Political Elites and State Building: The Case of Nineteenth-Century Brazil. *Comparative Studies in Society and History*, 24(3), pp. 378–399.

Caselli, F. (2001). Cross-Country Technology Diffusion: The Case of Computers. *The American Economic Review*.

Castelló-Climent, A. & Mukhopadhyay, A. (2013). Mass Education or a Minority Well Educated Elite in the Process of Growth: The Case of India. *Journal of Development Economics*.

Centro Argentino de Ingenieros (1981). *Historia de laIngeniería Argentina: Edición Especial Publicada*. Centro Argentino de Ingenieros.

Ciccone, A. & Papaioannou, E. (2009). Human capital, the structure of production, and growth. *The Review of Economics and Statistics*, 91(1), 66–82.

Cobb, J. C. (1993). *The Selling of the South: The Southern Crusade for Indusrial Developmebnt, 1936-1990.* University of Illinois Press, Urbana.

Cohen, W. & Levinthal, D. (1989). Innovation and Learning: the Two Faces of R & D. *The economic journal*, 99(397), 569–596.

Collier, S. & Sater, W. F. (1996). *A History of Chile, 1808-1994.* Cambridge Universtiy Press. 1996.

Collins, W. J. & Margo, R. A. (2006). Historical perspectives on racial differences in schooling in the united states. *Handbook of the Economics of Education*, 1, 107–154.

Comin, D., Easterly, W., & Gong, E. (2010a). Was the Wealth of Nations Determined in 1000 BC? *American Economic Journal. Macroeconomics*, 2(3), 65–97.

Comin, D., Ferrer, M., & Mestieri, M. (2010b). *TheIntensiveMargin of Technology Adoption.* Technical report, Harvard Business School.

Comin, D. & Hobijn, B. (2004). Cross-Country Technology Adoption: Making the Theories Face the Facts. *Journal of Monetary Economics*, 51(1), 39–83.

Comin, D. & Hobijn, B. (2010). An Exploration of Technology Diffusion. *The American Economic Review*, 100(5), 2031–59.

Comin, D., Hobijn, B., & Rovito, E. (2008). Technology Uusage Lags. *Journal of Economic Growth*, 13(4), 237–256.

Comin, D. A., Dmitriev, M., & Rossi-Hansberg, E. (2012). *The Spatial Diffusion of Technology.* Technical report, National Bureau of Economic Research.

Comin, D. A. & Ferrer, M. M. (2013). *If Technology Has Arrived Everywhere, Why Has Income Diverged?* Technical report, National Bureau of Economic Research.

Contreras, M. E. (1993). The bolivian tin mining industry in the first half of the twentieth century. *ISA Research Papers*, (32).

Di Tella, G. (1985). Rents, Quasi Rents, Normal Profits and Growth: Argentina and the Areas of Recent Settlement. In *Argentina, Australia, and Canada : studies in comparative development, 1870-1965*. D.C.M. Platt and Guido di Tella.

Diaz Alejandro, C. F. (1985). Argentina, Australia and Brazil Before 1929. In *Argentina, Australia and Canada: Studies in Comparative Develpment, 1870-1965*. D.C.M Platt and Guido di Tella.

Diogo, M. (2007). Aprender a ser ingeniero: La enseñanza de la ingeniería en el portugal de los siglos xviii y xix. In A. Lafuente, A. Cardoso, & T. Saraiva (Eds.), *Maquinismo ibérico*, Visiones hispanas. Doce Calles.

Duncan, T. & Fogarty, J. (1986). Australia and Argentina: On Parallel Paths. *The Hispanic American Historical Review*, 66(2), pp. 353–355.

EAFIT (2013). *Fuentes Documentales para la Historia Empresarial, Tomo II*. Fondo Editorial Universidad EAFIT.

Easterly, W. (2002). *The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics*. MIT Press.

Easterly, W. & Levine, R. (2012). *The European Origins of Economic Development*. NBER Working Papers 18162, National Bureau of Economic Research, Inc.

Eaton, J. & Kortum, S. (1999). InternationalTechnology Diffusion: Theory and Measurement. *International Economic Review*, 40(3), 537–570.

Eaton, J. & Kortum, S. (2001). Technology, Trade, and Growth: A Unified Framework. *European Economic Review*, 45(4), 742–755.

Edelstein, M. (2009). The production of engineers in new york colleges and universities, 1800-1950. In D. Eltis, F. Lewis, & K. Sokoloff (Eds.), *Human Capital and Institutions: A Long-Run View*. Cambridge University Press.

Elbers, C., Lanjouw, J. O., & Lanjouw, P. F. (2003). Micro–Level Estimation of Poverty and Inequality. *Econometrica*, 71(1), 355–364.

Encina, F. A. (1972). *Nuestra Inferioridad Económica : Sus Causas, Sus Consecuencias*. Universitaria , Santiago de Chile, 3 edition.

Engerman, S. L. & Sokoloff, K. L. (1994). *Factor Endowments: Institutions, and Differential Paths of Growth Among New World Economies: A View from Economic Historians of the United States*. Working Paper 66, National Bureau of Economic Research.

Facultad de Ingeniería (2011). *Innovación, Excelencia Tradición: Facultad de Ingeniería 1861-2011*. Universidad Nacional, Bogotá.

Fogarty, John Di Tella, G., Platt, D. C. M., & of Americanists, I. C. (1985). Staples, Super-Staples and the Limits of Staple Theory: The Experiences of Argentina, Australia and Canada Compared. In *Argentina, Australia, and Canada : studies in comparative development, 1870-1965*. D.C.M. Platt and Guido di Tella.

Foster, A. D. & Rosenzweig, M. R. (1995). Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. *Journal of Political Economy*, 103(6), 1176–1209.

Foster, A. D. & Rosenzweig, M. R. (1996). Technical Change and Human-Capital Returns and Investments: Evidence from the Green Revolution. *The American Economic Review*, 86(4), pp. 931–953.

Fox, R. & Guagnini, A. (1993). *Education, Technology and Industrial Performance in Europe, 1850-1939*. Cambridge University Press.

Fulford, S., Petkov, I., & Schiantarelli, F. (2015). *Does it matter where you came from? Ancestry composition and economic performance of US counties, 1850-2010*. Working paper, Boston College.

Galor, O. & Michalopoulos, S. (2009). *The Evolution of Entrepreneurial Spirit and the Process of Development*. Carlo Alberto Notebooks 111, Collegio Carlo Alberto.

Gancia, G., Zilibotti, F., & Acemoglu, D. (2008). *Technology-Skill Complementarity and Competition Policy*. Technical report.

Gennaioli, N., La Porta, R., Lopez-de Silanes, F., & Shleifer, A. (2013). Human Capital and Regional Development. *The Quarterly Journal of Economics*, 105, 164.

Glaeser, E. L. (2007). *Entrepreneurship and the City*. NBER Working Papers 13551, National Bureau of Economic Research, Inc.

Glaeser, E. L., Kerr, W., & Ponzetto, G. A. (2010). Clusters of Entrepreneurship. *Journal of Urban Economics*, 67(1), 150–168.

Glaeser, E. L., Rosenthal, S. S., & Strange, W. C. (2009). *Urban Economics and Entrepreneurship*. NBER Working Papers 15536, National Bureau of Economic Research, Inc.

Goldin, C. & Katz, L. F. (2009). *The Race between Education and Technology*. Cambridge, MA: Belknap of the Harvard U.

Graham, R. (1981). *Slavery and Economic Development: Brazil and the United States South in the Nineteenth Century*. Comparative Studies in Society and History. Cambridge University Press.

Griffith, R., Redding, S., & Reenen, J. (2004). Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries. *Review of Economics and Statistics*, 86(4), 883–895.

Haber, S. (1997). *Financial Markets and Industrial Developoment: A Comparative Study of Government Regulation, Financial Innovation and Industrial Structure in Brazil and Mexico, 1840-1930*. Stanford, CA:Stanford University Press.

Haber, S. (2005). *Development Strategy or Endogenous Process? The Industrialization of Latin Americ*. Technical report.

Haber, S. (2006). The Political Economy of Industrialization. *The Cambridge Economic History of Latin America*, 2, 537–84.

Hanushek, E. & Woessmann, L. (2007). The Role of Education Quality for Economic Growth. *World Bank Policy Research Working Paper*, (4122).

Hanushek, E. & Woessmann, L. (2012). Schooling, Educational Achievement, and the Latin American Growth Puzzle. *Journal of Development Economics*, 99(2), 497–512.

Harnow, H. (1997). The Role of the Engineer in Danish Modernisation, 1850–1920. *Scandinavian Economic History Review*, 45(3), 224–243.

Howitt, P. (2000). Endogenous Growth and Cross-country Income Differences. *American Economic Review*, (pp. 829–846).

Howitt, P. & Mayer-Foulkes, D. (2005). R&D, Implementation, and Stagnation: A Schumpeterian Theory of Convergence Clubs. *Journal of Money, Credit and Banking*, 37(1), 147–77.

Hurtado, O. (2007). *Las Costumbres de los Ecuatorianos*. Quito: Editorial Ecuador FTB.

ICC (1899). *Annual Report of the Interstate Commerce Commission*. United States Interstate Commerce Commission.

Iyigun, M. F. & Owen, A. L. (1998). Risk, entrepreneurship, and human-capital accumulation. *American Economic Review*, (pp. 454–457).

Iyigun, M. F. & Owen, A. L. (1999). Entrepreneurs, professionals, and growth. *Journal of Economic Growth*, 4(2), 213–232.

Judson, R. (1998). Economic Growth and Investment in Education: How Allocation Matters. *Journal of Economic Growth*, 3(4), 337–359.

Keller, W. (2004). International Technology Diffusion. *Journal of Economic Literature*, 42(3), 752–782.

Kiszewski, A., Mellinger, A., Spielman, A., Malaney, P., Sachs, S. E., & Sachs, J. (2004). A Global Index Representing the Stability of Malaria Transmission. *The American journal of tropical medicine and hygiene*, 70(5), 486–498.

Klenow, P. J. & Rodriguez-Clare, A. (2005). Externalities and growth. *Handbook of economic growth*, 1, 817–861.

Krueger, A. B. & Lindahl, M. (2001). Education for Growth: Why and for Whom? *Journal of Economic Literature*, 39(4), 1101–1136.

Landes, D. S. (1998). *The Wealth and Poverty of Nations : Why Some are so Rich and Some so Poor*. W.W. Norton, New York, 1 edition.

López, C., Carreras, A., Tafunell, X., & Fundación, B. F. (2005). *Estadísticas históricas de España: Siglos XIX-XX*. Fundación BBVA.

Lopez Soria, I. (2012). *Historia de la Universidad Nacional de Ingeniería, los aï¿½os Fundamentales, 1876-1909. Vol. 1.* Lima: Universidad Nacional de Ingeniería, Proyecto Historia UNI.

Lucas, R. E. (1993). Making a Miracle. *Econometrica*, 61(2), 251–72.

Maloney, W. F. (2002). *Missed Opportunities - Innovation and Resource-Based Growth in Latin America*. Policy Research Working Paper Series 2935, The World Bank.

Maloney, W. F. (2012). Techno-literate Entrepreneurship and Development in Latin America. *World Bank Mimeo.*

Mann, C. (1918). *A study of engineering education: prepared for the Joint committee on engineering education of the national engineering societies*. Bulletin (Carnegie Foundation for the Advancement of Teaching). Merrymount Press.

Marichal, C. (1997). Avances Recientes en la Historia de las Grandes Empresas y su Importancia para la Historia Económica de México. In C. Marichal & M. Cerutti (Eds.), *Historia de las grandes empresas en México, 1850-1930*. Universidad Autónoma de Nuevo León - Fondo de Cultura Económica.

Mariscal, E. & Sokoloff, K. (2000). *Schooling, Suffrage and the Persistence of Inequality in the Americas, 1800-1945*. In Political Institutions and Economic Growth in Latin America: Essays in Policy, History, and Political Economy, ed. Stephen Haber. Stanford, CA: Hoover Institution Press.

McCleary, R. M. & Barro, R. J. (2006). Religion and Economy. *Journal of Economic Perspectives*, 20(2), 49–72.

McInnis, M. (2004). Engineering Expertise and the Canadian Exploitation of the Technology of the Second Industrial Revolution. In J. Ljungberg & J.-P. Smits (Eds.), *Technology and Human Capital in Historical Perspective* (pp. 49–78). Palgrave Macmillan.

Mendez, N. (2013). *Historia de la Tecnología en Venezuela*. Universidad Central de Venezuela.

Mitchener, K. J. & McLean, I. W. (2003). The Productivity of US States since 1880. *Journal of Economic Growth*, 8(1), 73–114.

Mokyr, J. (1998). *The Second Industrial Revolution, 1870-1914*. Northwestern University Manuscript. Evason, 1st edition.

Mokyr, J. (2005). The intellectual origins of modern economic growth. In A. Quadrio Curzio & M. Fortis (Eds.), *Research and Technological Innovation* (pp. 17–80). Physica-Verlag HD.

Monteón, M. (1982). *Chile in the Nitrate Era: The Evolution of Economic Dependence, 1880-1930*. University of Wisconsin Press Madison, Wisc.

Mora, A. M., Gómez, S. I. J., & Bueno, H. C. (2005). *Inventos y patentes en Colombia, 1930-2000: de los límites de las herramientas a las fronteras del conocimiento*. ITM.

Moretti, E. (2004). Estimating the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data.

Murphy, K. M., Shleifer, A., & Vishny, R. W. (1991). The allocation of talent: Implications for growth. *The Quarterly Journal of Economics*, 106(2).

Nelson, R. R. (2005). *Technology, Institutions, and Economic Growth.* Harvard University Press, Cambridge, Mass.

Nelson, R. R. & Phelps, E. S. (1966). Investment in Humans, Technological Diffusion, and Economic Growth. *The American Economic Review*, 56(1/2), pp. 69–75.

Núñez, J. (2005). Signed with an x: Methodology and data sources for analyzing the evolution of literacy in latin america and the caribbean, 1900-1950. *Latin American Research Review*, 40(2), pp. 117–135.

Nunn, N. (2008). Slavery, Inequality, and Economic Development in the Americas: An Examination of the Engerman-Sokoloff Hypothesis. In E. Helpman (Ed.), *Institutions and Economic Performance* (pp. 148–180). Harvard University Press.

Nunn, N. & Puga, D. (2012). Ruggedness: The Blessing of Bad Geography in Africa. *Review of Economics and Statistics*, 94(1), 20–36.

O'Brien, T. (1989). Rich beyond the dreams of avarice: the guggenheims in chile. *Business History Review*, 63(1), 122–159.

Ortega, L. (1990). El proceso de industrialización en chile 1850-1930. *HISTORIA*, 26, 1991–1991.

Pachón, A. & Ramírez, M. T. (2006). *La Infraestructura de Transporte en Colombia Durante el Siglo XX.* Bogotá : Fondo de Cultura Económica.

Parente, S. L. & Prescott, E. C. (1994). Barriers to Technology Adoption and Development. *Journal of political Economy*, (pp. 298–321).

Pinto Santa Cruz, A. (1959). *Chile, un Caso de Desarrollo Frustrado.* Santiago : Universitaria, 1959.

Poveda Ramos, G. (1993). *Historia Social de las Ciencias en Colombia: Ingeniería e historia de las técnicas, Vol. IV y V.* Colciencias.

Prados de la Escosura, L. (2000). International Comparisons of Real Product, 1820-1990: An Alternative Data Set. *Explorations in Economic History*, 37(1), 1–41.

Pretel, D. & Sáiz, P. (2012). Patent agents in the european periphery: Spain (1826–1902). *History of Technology*, 31, 97–114.

Pritchett, L. (1997). Divergence, Big Time. *Journal of Economic Perspectives*, 11(3), 3–17.

Pritchett, L. (2001). Where Has All the Education Gone? *The World Bank Economic Review*, 15(3), 367–391.

Putterman, L. & Weil, D. N. (2008). *Post-1500 Population Flows and the Long Run Determinants of Economic Growth and Inequality.* NBER Working Papers 14448, National Bureau of Economic Research, Inc.

Riera i Tuébols, S. (1993). *Industrialization and Technical Education in Spain, 1850-1914*. Cambridge University Press.

Rincón, G., Antonio, A., & Nieves, M. A. (2005). La elite empresarial de santander (1880-1912). *Empresas y empresarios en la historia de Colombia. Siglos xix y xx*, (pp. 141–178).

Rodríguez Becerra, M. & Restrepo Restrepo, J. (1982). Los empresarios extranjeros de barranquilla 1820-1900. *Desarrollo y sociedad*, 8, 77–114.

Rogers, E. (1962). The Iron and Steel Industry in Colonial and Imperial Brazil. *The Americas*, 1(2), 172–184.

Rosenberg, N. (2000). *Schumpeter and the Endogeneity of Technology : Some American Perspectives*. Routledge, London.

Ruiz Larraguivel, E. (2004). *Los Ingenieros en la Industria Manufacturera. Formación, Profesión y Actividad Laboral*. CESU-Plaza y Valdes.

Safford, F. (1976). *The Ideal of the Practical : Colombia's Struggle to Form a Technical Elite*. University of Texas Press, Austin.

Sandberg, L. G. (1979). The Case of theIimpoverished Sophisticate: Human Capital and Swedish Economic Growth before World War i. *Journal of Economic History*, 39(1), 225–241.

Santa-Maria Alvarez, P. (1994). *Origen, Desarrollo y Realizacion de la Escuela de Minas de Medellín*. Ediciones Dike LTDE.

Schumpeter (1934). *The Theory of Economic Development*. (trans R. Opie). Boston: Harvard University Press.

Scobie, J. R. (1964). *Argentina : A City and a Nation*. Oxford University Press, New York.

Self, S. & Grabowski, R. (2004). Does education at all levels cause growth? india, a case study. *Economics of Education Review*, 23(1), 47 – 55.

Serrano, S. (1993). *Universidad Y Nacion:*. Colección Imagen de Chile. Editorial Universitaria.

Sianesi, B. & VanReenen, J. (2003). The Returns to Education: Macroeconomics. *Journal of economic surveys*, 17(2), 157–200.

Spolaore, E. & Wacziarg, R. (2009). The Diffusion of Development. *The Quarterly Journal of Economics*, 124(2), 469–529.

Spolaore, E. & Wacziarg, R. (2012). *How Deep are the Roots of Economic Development?* Technical report.

Stevens, P. & Weale, M. (2004). 4 Education and Economic Growth. *International handbook on the economics of education*, 1830(1850), 164.

Swank, J. M. (1965). *History of the Manufacture of Iron in all Ages, and Particularly in the United States from Colonial Times to 1891*. B. Franklin New York,, [2d ed.] edition.

Telles, P. C. d. S. (1994). *História da Engenharia no Brasil, Séculos XVI a XIX.* Clavero, Rio de Janeiro.

Temple, J. & Voth, H.-J. (1998). Human Capital, Equipment Investment, and Industrialization. *European Economic Review*, 42(7), 1343–1362.

Thorp, R. (1998). *Progreso, Pobreza y Exclusión. Una Historia Económica de América Latina en el siglo XX.* Washington D.C. BID- Unián Europea.

Tortella, G. (1994). Patterns of Economic Retardation and Recovery in South-WesternEurope in the Nineteenth and Twentieth Centuries. *The Economic History Review*, 47(1), pp. 1–21.

Tortella Casares, G. (2000). *The Development of Modern Spain : An Economic History of the Nineteenth and Twentieth Centuries.* Harvard University Press, Cambridge, Mass. :.

Villalobos, S. R., , & Beltrán, L. (1990). *Historia de la Ingeniería en Chile.* Hachette. Santiago.

Voigtländer, N. & Squicciarini, M. (2014). Knowledge elites, enlightenment, and industrialisation. *NBER.*

Waldinger, F. (2012). Bombs, brains, and science.

Will, R. M. (1957). *Some Aspects of the Development of Economic Thought in Chile (ca. 1775-1878).* Technical report.

Wolff, E. & Gittleman, M. (1993). The Role of Education in Productivity Convergence: Does Higher Education Matter? *Contributions to Economic Analysis*, 214, 147–147.

World Economic Forum, Schwab, K. et al. (2012). TheGlobal Competitiveness Report 2010–2011. *Geneva, Switzerland.*

Wright, G. (1986). *Old South, New South : Revolutions in the Southern Economy since the Civil War.* Basic Books, New York.

Wright, G. (1987). The Economic Revolution in the American South. *Journal of Economic Perspectives*, 1(1), 161–78.

Wright, G. (1999). Can a nation learn? american technology as a network phenomenon. In *Learning by doing in markets, firms, and countries* (pp. 295–332). University Of Chicago Press.

Young, A. (1993). Invention and Bounded Learning by Doing. *Journal of political economy*, (pp. 443–472).

7 Annex I: Construction of Engineering and Entrepreneurship Data

7.1 Argentina

The principal source is *Historia de la Ingeniería Argentina* (Centro Argentino de Ingenieros, 1981). At the end of the 19th century, there were three universities that granted the title of civil engineer which was their omnibus term for engineers- Buenos Aires, Cordoba and La Plata as well as a school of mining engineers in San Juan. The CAI documents that from 1870, the year when the first engineers graduated in the country, until 1900, 250 engineers received their diplomas. We do not know the distribution of these degrees across years so we impute uniform graduation rates after which the attrition adjustment leaves 196 or a density of 12.[38]

7.2 Bolivia

In Bolivia, the first engineering school, the Escuela Nacional de Ingenieria in Oruro, began in 1917 and hence Bolivia has 0 locally trained engineers by 1900. As late as 1937, 84% of engineers in the Patiõ Tin mines (accounting for 10 of world production) were foreign(Contreras, 1993).

7.3 Brazil

Telles (1994) *Historia da Engenharia no Brasil, Seculos XVI a XIX* is the principal source. In 1858 the Royal Academy of Artillery, Fortification and Drawing, established in Rio de Janeiro in 1792, dedicated itself to civil engineering for the first time, studying steam engines and railroads, and in 1874 it became independent of the Military and became the Polytechnical School of Rio (today the School of Engineering of the Federal University of Rio de Janeiro). This was the dominant institution for training engineers. Brazil's second engineering school was founded around Mining in Ouro Preto. However, the low motivation for technical teaching of the time the school's isolation, among other social factors, made it difficult to recruit students and it graduated few. From 1894 to 1896 four new schools were started in Saõ Paolo, Pernambuco, Porto Alegre and Salvador. Telles (1994) suggestion that these schools would eventually end the Polytechnical School of Rio's monopoly confirms the dominance of the latter in the production of engineers up to that point. We do not, however, have a long time series on graduates from any program. Telles reports the average annual number of domestic engineering graduates in Brazil as a whole for the period after 1890 at 45 per year, half of them produced in Rio by 1900. To estimate graduation rates for the 1860-1890 period, we rely on evidence from reported stocks. Telles tabulates the number of engineers in Rio as reported in *Almanaque Laemmert*, a periodical dealing with governance, commerce and industry in Rio, for 1854, 1870, 1883 and from the official *Almanak dos Engenheiros* an official publication of the government for the whole country in 1906. In Rio in 1854, there were 6 engineers and in Saõ Paolo, the other principle locus of engineering talent, in 1857, there were 5. We therefore set 11 as our initial stock for the country in 1860. In 1870, the *Almanaque Laemmert* notes that Rio had grown to 28 engineers and by 1883,

[38]A later data point is offered by Almada & Zalduendo (1962), which, when adjusted to be compatible with our data, yields a density of 41.25 in 1925. Given the rapid increase in output of engineers in the beginning decades of the 20th century in most countries, this supports our 1900 estimate.

126 (page 593). Given the rough earlier parity of Rio and Saõ Paolo in 1854-57, we double the Rio numbers figures to get national figures for these periods. While the Almanak may be overstating the stock by including non degreed engineers, the implicit graduation rate leading up to 1883 is roughly 15 per year which is substantially below Telles' documented graduation rate of 45 beginning in 1890. On the other hand, the consolidation of the Ouro Preto School of Mines and the new schools established after 1890 doubled whatever Rio's capacity was and that was likely substantially more in 1890 than prior. Hence, a three-fold increase over the last two decades seems plausible. We interpolate an average value between the known values of 1883-1890. Together, these lead to a total stock in 1900 of 786. If we extrapolate at the same graduation rate, the terminal stock in 1906 is 968 or slightly above the value reported by the official Almanak (941) suggesting that we may, again, be overstating the stock somewhat. Density 12.

Entrepreneurs: Minas Gerais Birchal (1999) based on survey of textile mills from 1870-1890s. Saõ Paolo from citebresser1994 who undertook a detailed survey of the origins of major Saõ Paolo firms and the origins of their founders. The universe, comprising national industrial enterprises with more than 100 employees situated in Greater São Paulo, summed up total 712 enterprises.

7.4 Canada

McInnis (2004) is perhaps the most complete of a thin literature. Substantial engineering curricula had been introduced at King's College (UNB), at McGill College, and the University of Toronto in the 1850s although demand for engineering education gained traction only in the 1870s. McGill offered a full diploma course by 1863 although the first five students graduated only in 1874. Four year courses were implemented in Civil Engineering, Mechanical Engineering, Practical Chemistry and Mining by 1878, Electrical engineering in 1891, Chemical Engineering and Metallurgical Engineering in 1908. The University of Toronto School of Practical Science opened in 1878 and offered the degree of civil engineer in 1885. In 1874, Laval University established an Ecole Polytechnique which emitted its first graduates in 1877. Other smaller programs also emerged at the same time. Also of importance, The Royal Military College in Kingston Ontario, established in 1876, with West Point as a model, explicitly had the dual object of providing scientific training to military officers as well as producing civilian engineers.[39] If we take the discounted sum of the licensed graduates plus half the military graduates [40] by 1900 we reach a total density of about 41. This is relatively low by US standards especially given the number of institutions offering engineering courses, as well as the articulation of the different fields of engineering at a relatively early phase. The development of, for instance, mechanical engineering as a separate course about 20 years after in the US, Electrical Engineering 10-15 years after, but still far ahead of any of the Latin Universities in the sample. Electrical engineering appears more or less at the same time as in the US. It is worth noting, however, that the four principle Canadian Universities emitting graduates lay within a circle of 350 mile radius with Cornell at its center and including many of the principle US universities of the time. Density: 41

[39]http://www.warmuseum.ca/education/online-educational-resources/dispatches/the-royal-military-college-of-canada-1876-to-the-present

[40]our thanks to Marvin McInnis for discussions on this

7.5 Chile

As Serrano (1993) notes in *Universidad y Nación: Chile en el Siglo IX*, training at the *Universidad de Chile* (University of Chile), the principal source of engineers in the 19th century, began in the mid-1850s. Prior to this, there were effectively no schools in Chile and those engineers trained abroad were very few. From 1846-50 there had been 2 fellowships to study abroad with uneven results. Serrano notes (p. 216) that between 1856 and 1879, 100 geographical engineers (surveyors/geographers), 61 mining engineers and 4 civil engineers plus 11 general assayers graduated. This gives us a graduation rate for the first 20 years of our exercise. To anchor the subsequent 20 years, Villalobos et al. (1990) collaborating with Serrano in *Historia de la Ingeniería en Chile*, offers that "in the 19th century there were 130 Chilean engineers and toward 1938, the country had a list of 270 professionals graduating from the University of Chile. They created, in 1930, the Institute of Mining Engineers of Chile " (p. 198). The context may be taken to suggest that we are talking exclusively about mining engineers, although in personal communication, Serrano confirms that it is total graduated engineers. This is consistent with the fact that the implicit graduation rates from the pre -1879 period, 2.3 mining engineers per year, respectively accumulates to only half of the 130 number cited by Villalobos at end century. Clearly, this gap could be made up by a rapid expansion in number of graduates from 1879 on, but as Serrano notes, in 1867 the government expressed concern that the numbers of graduates in physical studies and mathematics was actually decreasing (page 212) so this would have represented a reversal in trend. Geographical engineers translate broadly as surveyors/geographers which are not generally treated as engineers per se and hence, to the degree that they are included in the 130 number, this overstates installed capacity. Density: 17.

Entrepreneurs: Founders of firms using steam power in 1880 Ortega (1990).

7.6 Colombia

As Safford (1976) notes in his *The Ideal of the Practical: Colombia's Struggle to Form and Technical Elite*, the process of establishing a technical class was undermined by recurrent civil wars which often whipsawed the ideological foundations of the schools when they were not closing them, and perennial shortages of funding. The *Universidad Nacional* (National University), founded in 1867, was the dominant source of degreed engineers. It was built on the Colegio Militar (Military College) which operated over two brief periods, 1848-1854, and then in 1861. In the early 1880s, the Congress also authorized the creation of mining schools in Antioquia, Rionegro, Popayan and Ibague but most were aborted by the civil war of 1885. Safford (1976). The exception was the *Escuela Nacional de Mineria* (National Mining School in Antioquia set up in 1887 to 1895, that would eventually close due to a lack of financing, among other factors, and become part of the *Escuela de Ingeniería de la Universidad de Antioquia* (Engineering School of the University of Antioquia). Poveda Ramos (1993) in *Historia Social de la Ciencias en Colombia: Ingeniería e Historia de las Técnicas* summarizes "By the end of the century, there were only three schools of engineering in Colombia: the *Universidad Nacional*, the *Escuela Nacional de Mineria*, and the *Universidad Republicana* (Republican University) in Bogota. The number of students was small, so much so that the National University, the largest of all, the number of students fluctuated from one year to another between 25 and 50."(p.55). The *Universidad Republicana* (now the *Universidad*

Libre Free University) was begun in 1890 but it nearly collapsed financially by 1910 and its contribution to our accumulated stock is likely to be small. Facultad de Ingeniería (2011) tabulates that from 1868-1870 enrollments in the National University averaged 35 per year, yet graduates in the 1871-1875 period average about 4 per year. Though the authors note that their tabulations may not be complete, the virtual absence of graduates from 1876 to 1888 is plausible as from 1876 to 1884 the school was again taken over by the military and oriented away from industry related training. In 1880, despite 56 enrolled, higher mathematics and engineering classes contained only 4 students. (p. 195). In the National School of Mines, from 1887 to 1890 average enrollment was 25 students. Safford notes 63 alumnai of the 1888-1894 period, which is confirmed by Santa-Maria Alvarez (1994) as the number of "egresados" (exiters) of the program. However the same text notes that only five of these had graduated with thesis across the period (in 1893 and 1894) and none again until 1906 (Annex 5 page 103). Poveda Ramos (1993) confirms the lower numbers noting that the first 3 degrees of Mining Engineer were granted in 1893. The two schools together yield an accumulated stock of 75 Engineers by 1900. This is broadly consistent with Safford's finding of "more than 200 Colombian engineers and surveyors "in 1887 derived from the *Anales de Ingeneiría* (Annals of Engineering), the organ of the Colombian Engineering Association Safford (1976) page 219) which, again does not discriminate by whether or not the inscribed had completed a degree, nor separate out surveyors. However, we also know that both the University of Cauca as well as the Republican University in Bogota were generating some unknown quantity of graduates. We round to 100 as number that would incorporate these and missing graduates from Antioquia and the National University. Density: 5. The time series for Antioquia is provided by the Consejo Profesional Nacional de Ingenieria (COPNIA National Professional Engineering Council) that was created in 1937 to inspect and oversee the engineering and related professions in Colombia and certifying them. All working engineers need to be certified and all have graduated from an acredited program.

Entrepreneurs: Data on firms owned by immigrants: Santander: Rincón et al. (2005), Barranquilla: Rodríguez Becerra & Restrepo Restrepo (1982), Antioquia: EAFIT (2013)

7.7 Denmark

The Polyteknisk Laereanstalt was founded in 1829 as the first university level technical school in Copenhagen and was one of the first of its kind in Europe and was heavily influenced by the French Ecole Polytecnique. Harnow (1997) in his study of the impact of engineers in Denmark only focuses on this school, arguing that from 1850 to 1920 it was by far the most important Danish technical institution. He tabulates the number of graduates across the period 1832-69 and then for roughly 10 year periods after. Taking the yearly graduation rate as the average of each period and then applying the usual discounting yields a density of 92.

7.8 Ecuador

The *Escuela Politécnica Nacional* (National Polytechnical School) was founded in 1869 by the President Gabriel García Moreno with the aim of establishing a center for research and training of engineers and scientists at a high level. German Jesuits were brought for the purpose but the school was closed in 1876 for political reasons and was only reopened in 1935. This trajectory is not so different from that of Colombia's School of Mines, although that country had two other universities for more or less three times the population. We can't know the number of graduates of the program, over these seven years, but the density would have to be less that than of Colombia, including that until 1935 there was effectively no local training capacity which is part of what we're trying to capture here. $http : //www.epn.edu.ec/index.php?option = com_contentview = articleid = 1129Itemid = 378$. We assign a value of 2.

7.9 Mexico

The earliest technical training in Mexico was the *Colegio de Mineria* formerly the *Real Seminario de Mineria* (College of Mining, Royal Seminary of Mining) in Mexico city which opened in 1792 and was perhaps the most secular and highest quality technical institution in the hemisphere at the time. Bazant de Saldaña (1993) in her *Historia de la Educación Durante el Porfiriato* has best documented the subsequent evolution. Wars of independence, foreign invasion, and perilous fiscal situations led to a steady decline and by the time it was transformed into the into the *Escuela Nacional de Mineria* (National School of Mines) in 1867 under Benito Juarez, the number of students was so low that the government considered closing it and sending the 8-10 students abroad. Porfirio Diaz would subsequently put great emphasis on engineering as part of his modernization compaign. Despite this, by 1902, still only 18 engineers were graduating per year. Flows from the National School of Mines from 1876-1901 total 327. From 1876 to 1880 (41); 1881-1890 (106); 1891-1901 (180). Most other universities in other areas contributed very few. Allowing for another 16 years prior at the 1877 rate, which likely overstates the case, gives a total stock in 1900 of 336 or a surprisingly low density of 5. Other figures broadly corroborate. The census reports 884 engineers for Mexico city or roughly half the total that it reports for the entire country. Applying that ratio to the stock above gives 159. By comparison, Bazant cites the *Massey Blue Book*, an English language director of Mexico (City) as giving a total of 91 engineers and the *Directorio de Vecinos de la Ciudad de Mexico* as 183, both including some unspecified number of foreigners. The *Association de Ingenieros* (Engineering Association) in 1910 counted 255 members which, again, is not clear on the level of education of its members and may also include both the acceleration in graduation at the turn of the century in many countries. In all, the magnitudes do not suggest that our stocks are importantly underestimated. Density of 5.
Entrepreneurs: Tercer censo industrial de los Etados Unidos Mexicanos, 1940.

7.10 Peru

Although there were institutions teaching technical skills in various parts of the country, modern engineering began in Peru in 1852 two French and one Polish engineer to design and undertake public works of engineering. The need to import talent for these tasks, as was the case elsewhere in Latin America, testifies to the dearth of locally generated qualified human capital. The first school of engineers was discussed in the early 1850s, but only became reality when the Peruvian state in 1876 invited Polish engineer, Edward John Habich, to advise on irrigation, railways and other projects as well as the founding of a school of mines. Lopez Soria (2012) in *Historia de la Universidad Nacional de Ingenieria, los Años Fundamentales, 1876-1909* notes that the resulting School of Civil Construction and Mining Engineers (now the National Engineering University-Universidad National de Ingenieria) opened in 1876 and graduated its first class of 4 in 1880. The school was heavily damaged when used by the invading Chilean forces in 1880 and took several years to rebuild, only graduating one more student by 1882. Lopez Soria (2012) tabulates annual list of graduates going forward, disaggregated by specialty and allowing us to take out surveyors and include only industrial, mining and civil engineers, giving a total net of attrition of 100. This broadly confirms the statement by the *Sociedad de Ingeneiros Del Perù*(Peruvian Engineering Society) (established 1898) of "more than 80" engineers in the country. This gives us a density of 5.

7.11 Portugal

Formal training of non military engineering in Portugal did not begin until the turn of the 20th century with the Instituto de Lisboa (Institute of Lisbon) which started training industrial engineers in 1903 (Heitor et al), and the *Instituto Superior Técnico* (Higher Technical Institute) founded in 1917 Diogo (2007)). Hence, we are unable to generate a stock of graduates as in many of the other cases. Diogo argues, however, that military engineers were responsible for most civil engineering projects and hence military engineers should be counted in this case. The *Associação dos Engenheiros Civis Portuguezes - AECP* (Portuguese Association of Civil Engineers) also did register the majority of those who considered themselves non-military engineers. Though registration in the AECP was not mandatory to be a practicing engineer, it was mandatory in the organization that followed, the *Ordem dos Engenheiros (OE)* (Order of Engineers). In 1870 the AECP reports 150 inscribed; in 1926, 733. We take the average growth rate between the two points and impute the value for 1900. After 1900, we are able to compare the rates between the AECP and the mandatory OE: in 1930, there were 845 members (AECP) and in 1936, 1127 members (OE). Imputing the same growth rate between 1930 and 1936 as previous suggests that the AECP is understating the stock of practicing engineers by roughly 20%. We apply this to the stock value generated using the AECP data for 1900 to yield 579 or a density of 22. This is likely to be an overstatement since we do not know what fraction of these had any higher educational training.

7.12 Spain

We offer two estimates of the stock of Spanish engineers derived from Riera i Tuebols (1993) from 1867 *Industrialization and Technical Education in Spain, 1850-1914* and López et al. (2005) *Estadisticas Históricas de España: Siglos XIX-XX* from 1857. The estimates differ in scope. Riera i Tuebols reports graduates of *escuelas de ingeniería* engineering schools as such, starting with Spain's first, founded in Barcelona in 1867, to train industrial engineers (see also Riera, 2008). He also offers data from mining and civil engineer graduates primarily from institutions in Madrid. Though Riera's tabulations are the most accurate count of certifiably degreed engineers from university programs available, the resulting stock, 892, may be a lower bound. López et al. (2005) casts a broader net, including information from all technical schools (including *Escuelas Nacionales, Escuelas Superiores, Escuelas Especiales, Escuelas Centrales, Escuelas Profesionales and Escuelas Elementales*). Although this compendium is more comprehensive geographically, the estimates include graduates from other technical disciplines potentially miscategorized as engineers as well as including graduates of indeterminate level of training. We treat the resulting estimate of 3,089 as an upper bound. The Riera number is roughly half of the number of engineers and architects combined reported in the 1900 census. The Lopez is about 50% higher, which makes it the only case among our countries where the accumulated estimate is above that reported in the census. Since, as noted, self-reported census definitions are looser than documented degrees conferred, we find this improbable. Density either 12 or 42 respectively and we plot the average of the two. In our regressions, the Spanish influence is accounted for by a dummy so our results are unaffected by these estimates.

7.13 Sweden

The reference here is Ahlström (1993) who tabulates graduates of the two principal engineering programs. The Kungl Tekniska Högskolan (KTH) or Royal Technical University in Stockholm has roots in the Laboratorium Mechanicum founded in 1697, which later became the Mechanical school (1798). The Chalmers Institution in Gothenburg, founded in 1829, provided technical education equal to that of the KTH. Ahlström argues that in the mid 19th century, "...anyone in Sweden who sought an internationally reputable technical education could find it in these institutions." Density is 99.

7.14 United States

7.14.1 National data

We draw on several sources for the US engineering numbers. First, Mann (1918), in his *Study of Engineering Education* done for the Joint Committee on Engineering Education, tabulated graduates from US schools until 1915. As of 1900 this gives a total of 14,679, which gives a density per 100,000 workers of 50. However, as Adkins (1975) in *The Great American Degree Machine: An Economic Analysis of the Human Resource Output of Higher Education* notes, before 1940, the Office of Education made no effort to maintain comparability across years or completeness of coverage of educational institutions. It is not clear how they identified the universe of relevant institutions and, if an institution did not respond to their survey two years in a row, it was dropped from the interview rolls. Hence, Mann's estimates underestimate the true stock by a potentially significant amount. To bring to bear other sources of information, we use more reliable graduation data in select states or periods to calibrate the Census numbers, and then impute engineering stocks for the country in 1900. First, Adkins' tabulations for the US in 1930 yield a stock that is .53 of the census declaration of occupations in engineering at that time. Second, Edelstein (2009) in *The Production of Engineers in New York Colleges and Universities, 1800-1950* offers a full and comprehensive stock accounting for the state of New York for our time period 1900. His tabulations yield a density of 179 which is .67 of the US census number corresponding to New York that year. It is likely that New York's number may have a higher density of fully degreed engineers self-reporting in the census than the country as a whole so this number may be somewhat high. Similarly, Adkins' estimates for the whole country in 1930 may reflect that, in the ensuing 30 years, a higher share of self-declared engineers actually had degrees. Mann's numbers yield a ratio of .39 which we expect to be too low for the reasons outlined above. Hence, we take an intermediate value of .5 as the national ratio of actual graduates to Census declared engineers in 1900 and the data for the South and the North are projections based on this ratio. This yields a density of 84 for the entire country, 160 for the North, and 60 for the South.

7.14.2 County level data

Innovative capacity: As elsewhere we calculate density by engineers per 100.000 male workers. We use OCC1950 variable of IPUMS USA for 1880 census and we aggregate all categories for set up engineers: Engineering, chemical engineers, civil engineers, electrical engineers, industrial engineers, mechanical engineers, metallurgical and metallurgists engineers, mining engineers, and other engineers. We use as proxy of male workers the 40% of population because there are inconsistencies in labor force variable. Patenting is the collected number of patents between 1890 and 1910 like proportion to 1880 population. Number of patents was collected from Akcigit et al. (2013) and include all patents granted by the USPTO.

Sub-national Income in 2005 US Dollars is the household mean income drawn from 2000 USA Census.

Geographical Controls: we include temperature, altitude and rainfall taken from Worldcrim. We use distance to river (distance between the county centroid to the near medium or big size river) derived from HydroSHEDS (USGS 2011). We employ a measure of distance to the coast calculated like distance between centroid and the near coast similar to Gennaioli et al. (2013). We further include a measured of ruggedness of terrain from Nunn Puga (2012).

Growth variables: Population Density in 1880 as a measure of agglomeration is taken from the 1880 census data. As a measure of lagged economic activity, we calculate two measures using manufacturing output, taken from the 1870 NHGIS. Per capita yields a measure of structural transformation, per manufacturing output a measure of productivity. The extreme values and high variance of manufacturing employment suggests some lack of confidence in the 1880 labor allocation data so we report only the first measure. However, the results do not change appreciably using the other. We use slavery as a measure of institutions taken from the 1860 Census as well as Nunn (2008). For railroads, we employ two variables from the Nebraska-Lincoln University railroads data. An identifier variable if the county has railroad or a railroad density variable.

Human capital: Aggregate literacy rates we take from 1880 Census. As with engineers, we measured lawyers and physicians density per 100.000 habitants. We use the OCC1950 variable of IPUMS USA for 1880 census. Lawyers and Physicians categories are used from OCC1950.

Instrument: we compute the distance between the county centroid to the near the 57 1862 Land Grant Colleges.

Entrepreneurs: 5% sample of US census. Fortune 500 founders tabulated in The New American FORTUNE 500 June 2011, A Report by the Partnership for a New American Economy.

7.15 Venezuela

Mendez (2013) in *Historia de la Tecnología en Venezuela* notes that the *Universidad Central de Venezuela (UCV)* (Central University of Venezuela), as it would eventually be known, become the primary source of engineering graduates from 1867 on: 8 from 1867 to 1879 ; 80 from 1880 to 1889; 102 from 1890 to 1899. Other universities that graduated engineers were la *Universidad del Zulia* (University of Zulia) (1 in 1892) and the *Universidad de Valencia* (University of Valencia) (4 between 1892 y 1904); *Colegio Federal de Maracaibo* (Federal College of Maracaibo) 1886 (5) who submitted their these to the UCV for approval. To fill in the 1860-1866 period, we take the average of graduates from *Academia de Matemáticas de Caracas* (Academy of Mathematics of Caracas)from 1831 to 1872 (97 graduates) perhaps half of which were employed in civil or industrial work. Applying our usual discounting gives about 185 engineers. The engineering association gives 196 although this may include foreigners and members of undetermined educational attainment. Density: 11.

8 Annex II: Modeling micro economics of technological adoption:

Numerous models exist for modeling the micro economics of adoption. Comin et al. (2010b); Comin & Hobijn (2010); Comin et al. (2010a) for instance are closely aligned with the opening stylized facts (theirs) about divergence at the intensive margin. Human capital shortfalls are embedded in a scalar that reflects barriers to adoption for the agent that adapts the technology to the idiosyncrasies of the country or for individual producers that find a profitable use for the technology. Howitt & Mayer-Foulkes (2005) further unpack this parameter and investigate the effects that introducing a new technology of scientific inquiry, such as happened in the Second Industrial Revolution, can have in generating convergence clubs of advancing and lagging countries or regions. To briefly sketch their argument, the probability that an entrepreneur innovates is

$$\mu_t = \lambda S_t^{\eta} z_t^{1-\eta} / \bar{A}_{t+1} \tag{4}$$

where λ represents the productivity of the innovation technology; S_t the skill level of the entrepreneur broadly construed; z_t the quantity of material inputs to the innovation process; and η the Cobb-Douglas exponent in the innovation technology. As in Howitt (2000); Aghion et al. (2005), the division by $\bar{A}_{t+1}$ represents a crucial "fishing out" effect where the more advanced the technological frontier, the more difficult it is to innovate. In turn $S_t = \xi A_t$ where ξ is the "effective education time," the product of schooling years and quality, and the multiplication by the local level of technological advance reflects an externality that in more advanced countries, teachers will be better versed in modern techniques, classrooms, curricula etc. are up to date and this will lead to more educational output per unit of effective education time. The resulting equilibrium innovation rate is shown to be

$$\mu_t = \frac{\mu \frac{A_t}{\bar{A}_t}}{1+g} \tag{5}$$

which states that μ_t, the innovation rate, is function of overall competitiveness μ (which is in turn a function of policy distortion, incentives to innovate, overall profits, the incentive to save, and education.) The "normalized productivity, $A_t/\bar{A}_t$ captures increasing absorptive capacity with proximity to the frontier arising from the fishing out and education externalities. Finally, the denominator (1+g) captures the growth rate of the frontier and reflects that local skills are proportional to productivity this period, whereas the skill level required to innovate depends on the global frontier next period. Hence, the faster the growth of the frontier, the larger the effort necessary to maintain a constant innovation rate.[41]

[41] μ is a measure of the country's "competitiveness" in the sense that a higher value of μ means more innovation for any given relative distance from the frontier and world growth rate.

$$\mu = \lambda^{\frac{1}{\eta}} \left[\frac{1-\eta}{1-\phi} \beta \pi \right]^{(\frac{1}{\eta})-1} \xi \tag{6}$$

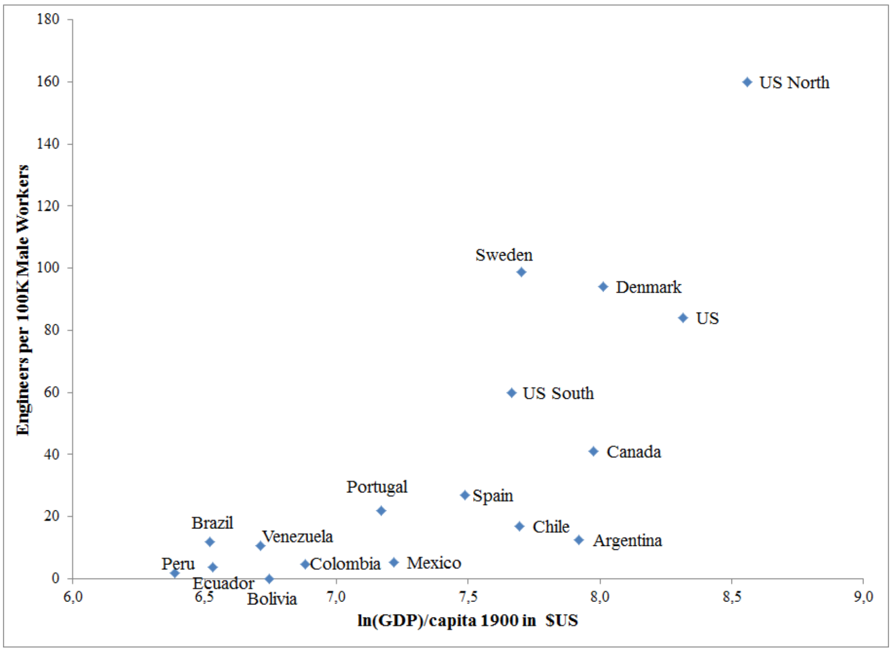
where ϕ is a proxy for distortions and policies that impinge on the incentive to innovate and π is a profit parameter that suggests that in countries where geography, policies and institution make productivity higher, competitiveness rises, even if they do not affect the innovation process directly. Hence, μ is increased by the incentive to innovate, the profitability of innovation; the productivity of the innovation process, λ, the incentive to save β, and the quantity or quality of education ξ.

For our purposes, there are two key results. First, as the global technology frontier advances and becomes more complex, a country needs to increase its skill levels to prevent the erosion of its absorptive capacity and the offsetting of Schumpeterian gains from backwardness. Second, the introduction of a new method of technological change, loosely termed "modern R&D" such as culminated in the late 19th century with the modern R&D laboratory (the rise of institution such as government research agencies, scientific academies, universities with close to industry etc.) gives rise to the possibility of an important and discrete shift in $\lambda' > \lambda$. However, only countries with with a threshold level of skill could undertake this "modern R&D"' and Howitt & Mayer-Foulkes (2005) show that this results in the emergence of three equilibria. Countries with a skilled enough labor force to undertake modern R&D immediately start growing faster. Countries with skills too low to do R&D but not too far behind will have the absorptive capacity to continue to implement foreign technologies, and will follow a growth path parallel to the first country, but with a magnified initial gap in level. Countries with even lower absorptive capacity will grow less than the common growth rate of the first two countries and diverge.[42]

[42]Howitt (2000) offers a similar result of complete stagnation.

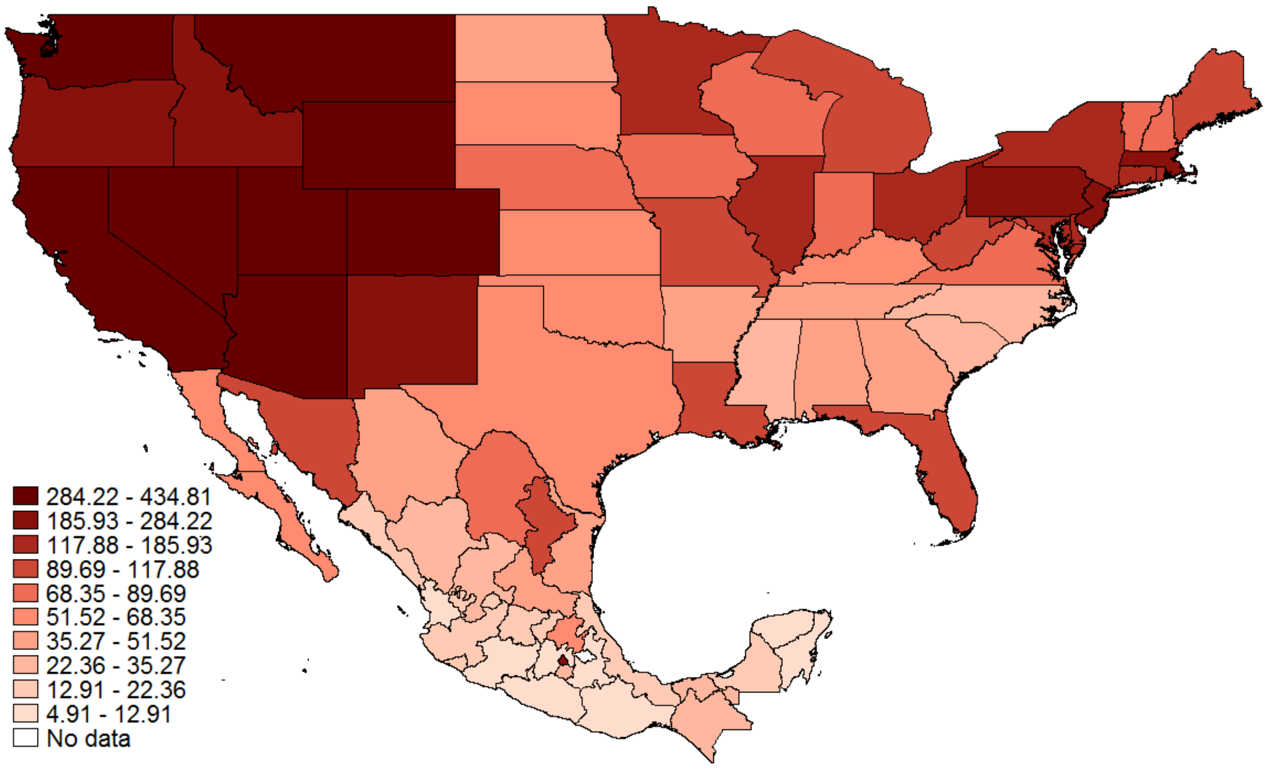
9 Figures and Tables

Figure 1: Income 1900 and Engineering Density 1900



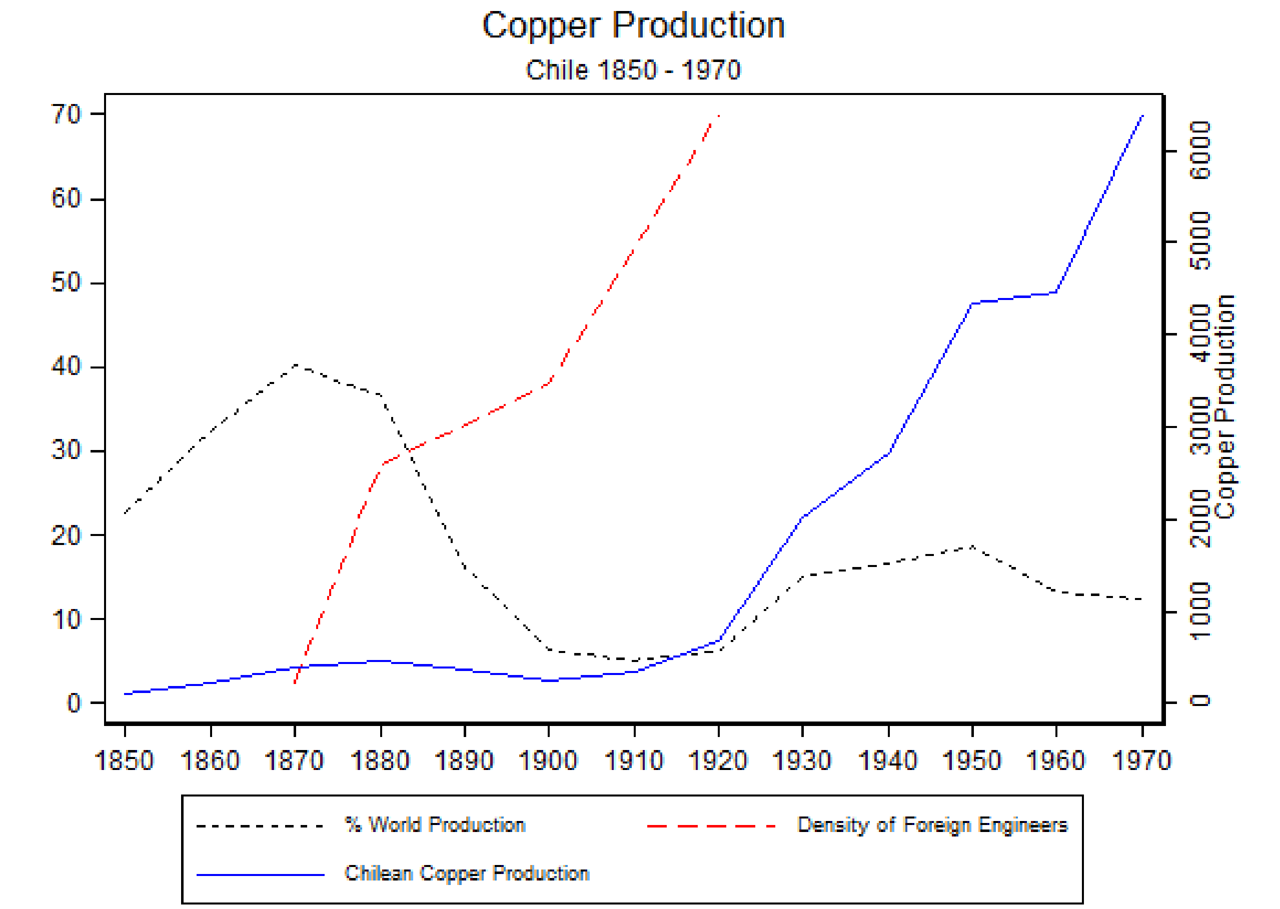
Note: Plot of GDP per capita in 1900 from Maddison. Engineering Density is accumulated graduates of engineering programs per 100,000 male workers around 1900 as described in the Annex.

Figure 2: Sub-national Engineering Density, US and Mexico, in 1900



Note: Engineering Density at the subnational level for North America. Derived from census reported engineers per 100,000 male workers around 1900.

Figure 3: Copper Production in Chile and Foreign Engineers



Note: The figure shows the decline in Chilean production and share of the world market for Copper approaching 1900 and then the sharp recovery with the entrants of foreign mining companies and engineers in 1905. Engineering density per 100,000 male workers calculated from National Censuses available until 1920 when Chile ceased to divide by profession-origin.

Table 1: Summary Statistics (State Level, Americas)

Variable	mean	p50	sd	min	max
Ln Income	9.03	8.92	0.91	7.13	11.18
Engineers	25.34	11.00	31.49	5.00	84.00
Engineers (sub)	88.30	44.81	108.69	0.00	472.59
Population Density (1900)	42.78	4.54	248.42	0.00	3319.27
Population Density (1500)	8.88	2.00	26.13	0.00	392.34
Literacy	41.93	34.00	24.41	11.30	86.70
Literacy (sub)	53.86	46.57	30.97	7.64	98.31
Railroads	3.15	1.80	2.71	0.30	9.30
Railroads (sub)	65.12	48.54	57.46	5.16	309.20
South	0.15	0.00	0.36	0.00	1.00
Slavery	20.67	3.28	25.16	0.00	72.66
Lawyers	218.92	139.22	210.93	1.64	1156.44
Mine Output ($)	.466	.123	1.06	.000075	6.49
Spain	0.81	1.00	0.39	0.00	1.00
Land Suitability	0.56	0.58	0.28	0.00	1.00
River Density	3.28	3.29	1.23	0.00	6.92
Average Temperature	19.97	20.40	5.83	2.38	29.00
Rainfall	1.28	1.10	0.95	0.00	8.13
Altitude	0.66	0.19	0.92	0.00	4.33
Dist. from Coast	0.87	0.91	0.12	0.45	1.00
Ruggedness	126.89	99.33	103.53	0.00	474.34
Malaria	1.11	0.20	1.57	0.00	5.85

Notes: Log Income per capita in 2000 (PPP 2005 US dollars). Engineering density measured by engineers per 100.000 male workers. Engineering density measured by engineers per 100.000 male workers, sub-national. Engineering density measured by engineers per 100.000 male workers, sub-national, scaled by national estimates of engineering stock. Population density is number of individuals per 100 square kilometers in 1900. Pre-colonial population density measures the number of natives per square kilometer in 1492. Literacy share of the population that is literate in 1900. Literacy share of the population that is literate in 1900, sub-national. Railroad density measured as miles of track per 1000 square kilometers. Railroad density measured as miles of track per 1000 square kilometers, sub-national. Colonial Good and Bad Institutions as generated by Bruhn and Gallego (2011); none is excluded category. South is a dummy variable for whether the US state is a Southern state according to the US census. Slavery is measured as a fraction of the population and is taken from Bergad (2008) and Nunn (2008). Lawyer density measured by lawyers per 100.000 individuals. Mining is total mining output in 1860 in hundred thousand dollars. Spain is a dummy for whether the country was a Spanish colony: Argentina, Chile, Mexico and Venezuela. Agriculture Suitability is an index of probability of cultivation given cultivable land, climate and soil composition, from Ramankutty, Foley and McSweeney (2002). Rivers captures the density of rivers as a share of land area derived from HydroSHEDS (USGS 2011). ; Temperature is a yearly average in degrees celsius; Altitude measures the elevation of the capital city of the state in kilometers; and Rainfall captures total yearly rainfall in meters, all are from Bruhn and Gallego (2011). Distance from the Coast from (Gennaioli et al., 2013); Ruggedness of Terrain from Nunn & Puga (2012); Malaria from Kiszewski et al. (2004).

Table 2: Summary Statistics (County Level, US)

variable	**mean**	**p50**	**sd**	**min**	**max**
Income	10.018	10.009	0.223	8.917	11.360
Engineers	0.024	0.000	0.045	0.000	0.299
Patents	0.588	0.308	0.926	0.000	10.000
Dist. to LGC	0.280	0.375	0.722	-5.450	1.811
Rainfall	0.066	0.060	0.048	0.006	0.393
Altitude	0.044	0.028	0.051	0.000	0.346
Ruggedness	0.006	0.003	0.008	0.000	0.057
River Dist.	0.023	0.014	0.150	0.000	3.990
Temperature	-0.006	-0.008	0.067	-0.252	0.208
Dist. to Coast	0.039	0.032	0.032	0.000	0.150
Pop. Density	0.003	0.001	0.043	0.000	2.055
Manuf. output	0.038	0.016	0.063	0.000	0.576
Slavery	0.152	0.018	0.215	0.000	0.925
Railroad	0.419	0.000	0.494	0.000	1.000
Literacy	0.770	0.853	0.206	0.000	1.000
Lawyers	0.001	0.001	0.001	0.000	0.027
Physicians	0.002	0.001	0.002	0.000	0.100

Notes: Log Income per capita in 2000. Engineering density measured by engineers per 100,000 male workers. Patents density measured by patents per 100 habitants. Dist. to LGC is distance to Land Grant College measured by distance between the near LGC and the county centroid. Population density is number of individuals per 100 square kilometers in 1880. Literacy share of the population that is literate in 1880. Railroad is a identifier variable if the county has railroad. Slavery to county level is taken from Nunn (2008). Lawyer density measured by lawyers per 100.000 individuals. Physicians density measured by physicians per 100.000 individuals. Mining is total mining output in 1860 in hundred thousand dollars. Rivers captures the distance between the near river and the county. Rivers taken from HydroSHEDS (USGS 2011). ; Temperature is a yearly average in degrees celsius; Altitude measures the elevation of the capital city of the state in kilometers; and Rainfall captures total yearly rainfall in meters. Dist. to Coast is distance between the coast and the county centroid; Ruggedness of Terrain from Nunn & Puga (2012). Manuf. Output is the manufacturing output per capita in 1880 taken from NHGIS.

Table 3: Summary Regressions: Innovation Capacity (1900) vs Income per capita (2000) (National Level, Americas)

	(1)	(2)	(3)	(4)	(5)
Engineering	28.4**	25.5**	27.0*	15.7	25.0*
	(14.26)	(12.87)	(14.35)	(27.09)	(14.71)
Pop Density		0.03*			0.03**
		(0.01)			(0.01)
Railroads			0.07		0.06
			(0.06)		(0.07)
Literacy				0.02	
				(0.02)	
Constant	8.7***	8.8***	8.5***	8.3***	8.6***
	(0.17)	(0.22)	(0.17)	(0.42)	(0.32)
N	273	225	273	273	225
N Countries	11	9	11	11	9
R^2	0.77	0.76	0.81	0.81	0.79

Notes: Dependent Variable is log subnational income per capita (2000). Engineering density measured by engineers per 100,000 male workers (coef scaled by 1000). Population density is number of individuals per 100 square kilometers in 1900. Railroad density measured as miles of track per 1000 square kilometers. Literacy share of the population that is literate in 1900. Robust and clustered SE in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Innovation Capacity as a Determinant of Income (County Level, US)

	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	IV	IV-Buchinsky
Engineers	1.305***	1.099***	0.682***	0.575***			0.572***	0.491***	6.309**	3.189***
	(0.2)	(0.2)	(0.2)	(0.1)			(0.1)	(0.1)	(2.5)	(0.9)
Patents					0.0452***	0.0406***	0.0383**	0.0363**	0.0440*	0.0346**
					(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Rainfall	0.138	0.150	0.410	0.624	0.411	0.601	0.414	0.710	0.704	0.730
	(0.3)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.8)	(0.5)
Altitude	-0.0377	0.356	-0.0458	-0.697	-0.301	-0.863	-0.333	-0.937	-1.057	-0.869
	(0.4)	(0.8)	(0.8)	(0.8)	(0.8)	(0.7)	(0.8)	(0.8)	(1.1)	(0.9)
Ruggedness	-2.912	-3.537	-1.499	-1.163	-0.471	-0.777	-0.671	-0.517	-0.799	-0.466
	(3.0)	(3.2)	(2.8)	(2.7)	(2.6)	(2.2)	(2.7)	(2.6)	(4.0)	(2.9)
River Dist.	0.371	0.353	0.441	0.418	0.480	0.411	0.419	0.384	0.463	0.442
	(0.5)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.4)	(0.8)	(0.5)
Temperature	-1.009***	-0.433**	-0.134	-0.284	-0.0847	-0.212	-0.160	-0.300	-0.211	-0.304
	(0.2)	(0.2)	(0.2)	(0.6)	(0.2)	(0.6)	(0.2)	(0.6)	(1.0)	(0.7)
Coast Dist.	-1.838***	-1.800***	-1.408***	-0.707	-1.287**	-0.471	-1.285**	-0.475	-0.395	-0.741
	(0.6)	(0.5)	(0.5)	(1.0)	(0.5)	(0.9)	(0.5)	(0.9)	(1.6)	(1.1)
Pop. Density		0.417***	0.408***	0.451***	0.404***	0.448***	0.403***	0.447***	0.430***	0.463***
		(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.06)	(0.04)
Manuf. Output		0.640***	0.546***	0.402***	0.460***	0.295*	0.397***	0.247*	0.279	0.152
		(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.3)	(0.2)
Slavery		-0.104	0.153	0.161**	0.166	0.173**	0.164	0.174**	0.158	0.147*
		(0.07)	(0.1)	(0.07)	(0.1)	(0.07)	(0.1)	(0.07)	(0.1)	(0.08)
Railroad		0.0719***	0.0489***	0.0458***	0.0546***	0.0504***	0.0522***	0.0482***	0.0437***	0.0353***
		(0.02)	(0.01)	(0.009)	(0.01)	(0.009)	(0.01)	(0.009)	(0.01)	(0.01)
Literacy			0.439***	0.549***	0.455***	0.565***	0.436***	0.557***	0.545***	0.540***
			(0.10)	(0.07)	(0.1)	(0.07)	(0.1)	(0.07)	(0.1)	(0.08)
Lawyers			47.66***	49.22***	47.89***	49.41***	38.66***	41.67***	47.58**	41.85***
			(13.7)	(12.3)	(13.6)	(12.3)	(13.4)	(11.8)	(22.9)	(14.3)
Physicians			-14.07	10.18	-15.82	7.955	-13.67	9.246	7.533	8.121
			(12.6)	(10.0)	(12.4)	(10.0)	(12.1)	(10.0)	(17.5)	(12.8)
Constant	10.06***	10.00***	9.597***	9.466***	9.576***	9.479***	9.595***	9.540***	9.390***	9.500***
	(0.03)	(0.04)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.06)	(0.1)	(0.07)
N	2380	1911	1910	1910	1914	1914	1906	1906	1906	1906
R^2	0.188	0.314	0.370	0.472	0.370	0.472	0.376	0.477		
Fixed Effects	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes

Notes: Dependent Variable is log subnational income per capita (2000). Engineering density measured by engineers per 100,000 male workers (coef. scaled by 1000). Patents density measured by patents per 100 inhabitants. Rainfall captures total yearly rainfall in meters; Altitude measures the elevation of the capital city of the state in kilometers; Ruggedness of Terrain from Nunn & Puga (2012); Rivers captures the distance between the near river and the county. Rivers taken from HydroSHEDS (USGS 2011). Temperature is a yearly average in degrees celsius; Dist. to Coast is distance between the coast and the county centroid. Population density is number of individuals per 100 square kilometers in 1880. Manuf. Output is the manufacturing output per capita in 1880 taken from NHGIS. Slavery to county level is taken from Nunn (2008). Railroad is a identifier variable if the county has railroad. Literacy share of the population that is literate in 1880. Lawyer and Physician density measured per 100 individuals.Engineers instrumentd using log distance to nearest Land Grant College measured by distance between the near LGC and the county centroid, estimated by 2SLS and Buchinsky quantile 2SLS. Robust and clustered SE in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Innovative Capacity as a Determinant of Income (Fixed Effect, Subnational)

	(1)	(2)	(3)
Engineering	1.0***	1.1***	0.6***
	(0.33)	(0.28)	(0.17)
Pop Density		0.03**	0.03***
		(0.01)	(0.01)
Literacy			0.01***
			(0.00)
Constant	9.5***	9.4***	8.9***
	(0.41)	(0.38)	(0.36)
N	170	166	166
N Countries	6	6	6
R^2	0.11	0.18	0.37

Notes: Dependent Variable is log subnational income per capita (2000). Full sample is Argentina, Chile, Colombia, Mexico, US and Venezuela. Engineering density measured by engineers per 100,000 male workers (coef. scaled by 1000). Population density is log number of individuals per 100 square kilometers in 1900. Literacy is share of the population that is literate in 1900. Bootstrapped clustered SE in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Mechanisms through which Engineering in 1900 Drives Income in 2000.

	All	New World
Inputs		
R&D/GDP	0.94	0.96
Firm Innovative Capacity	0.94	0.94
Modern Management	0.93	0.93
Outputs		
Patents	0.95	0.98
Technological Adoption	0.84	0.94

Notes: Table reports the correlation between engineering density in 1900 and three inputs and two outputs in the 2000. Inputs: 1. R&D expenditures as a share of GDP. 2. Firm capacity for innovation ranging from pure licensing to pioneering their own new products and processes. "In your country, how do companies obtain technology? [1 = exclusively from licensing or imitating foreign companies; 7 = by conducting formal research and pioneering their own new products and processes]. 3. A globally consistent measure of management quality from Bloom & Van Reenen (2010) and in particular, the sum of the scores on the two the questions dealing with how firms identify new production processes to adopt. On the output side, we have 1. Comin & Hobijn (2010); Comin & Ferrer (2013); Comin et al. (2008)'s measure of technological adoption at the extensive margin, averaging their industrial and sectoral scores and 2. patent applications filed under the Patent Cooperation Treaty (PCT) per million population as tabulated by the World Economic Forum (2008-9)(World Economic Forum et al., 2012).

Table 7: Determinants of Innovative Capacity (County Level, US)

	Engineers		Patents	
	OLS	Buchinsky	OLS	Quantile
Pop. Density	0.02***	0.01***	0.3***	0.2***
	(0.004)	(0.002)	(0.06)	(0.02)
South	-0.02***	-0.001	-0.2***	-0.2***
	(0.004)	(0.002)	(0.05)	(0.02)
Slavery	-0.02***	-0.009**	-0.7***	-0.3***
	(0.005)	(0.004)	(0.07)	(0.05)
River dist.	-0.09	-0.03	-1.7	-0.7
	(0.08)	(0.04)	(1.3)	(0.5)
Temperature	0.09***	0.02	0.4	0.4**
	(0.03)	(0.01)	(0.6)	(0.2)
Rainfall	-0.08*	-0.03	-1.2*	-1.3***
	(0.04)	(0.02)	(0.7)	(0.3)
Altitude	-0.09	-0.05	3.8*	2.4***
	(0.10)	(0.05)	(2.1)	(0.6)
Coast Dist.	-0.06	0.02	-4.5***	-0.7*
	(0.06)	(0.03)	(0.9)	(0.4)
Ruggedness	0.5*	0.2	-16.0***	-9.1***
	(0.3)	(0.1)	(5.3)	(1.9)
N	1912	1912	1907	1907
R^2	0.140		0.231	

Notes: Dependent Variable is innovative capacity measured by engineers per 100,000 male workers and patents per 100000 inhabitants. Pre-colonial population density measures the number of natives per square kilometer in 1492. South a dummy capturing southern US states; slavery as tabulated from the 1860 Census as compiled in Nunn (2008). Rainfall captures total yearly rainfall in meters; Altitude measures the elevation of the capital city of the state in kilometers; Ruggedness of Terrain from Nunn & Puga (2012); Rivers captures the distance between the near river and the county. Rivers taken from HydroSHEDS (USGS 2011). Temperature is a yearly average in degrees celsius; Dist. to Coast is distance between the coast and the county centroid. Population density is number of individuals per 100 square kilometers in 1880.Geographical controls include river density, average temperature, rainfall, altitude, distance from a coast, and ruggedness of terrain. Robust SE in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Determinants of Innovative Capacity (State Level, Americas)

	(1)	(2)
Pre-colonial Density	0.006	0.008
	(0.09)	(0.06)
Spanish Colony		-1.1***
		(0.37)
Spanish Colonized US		2.1***
		(0.42)
Cultivable land	-1.1*	-0.8
	(0.61)	(0.60)
River Density	-0.04	-0.2*
	(0.32)	(0.12)
Temperature	-0.07	-0.09***
	(0.06)	(0.03)
Rainfall	-0.3	-0.2
	(0.29)	(0.19)
Altitude	-0.4	-0.4*
	(0.32)	(0.25)
Dist. to Coast	-0.6	-0.7
	(3.94)	(1.22)
Ruggedness	0.00009	0.0010
	(0.00)	(0.00)
Malaria	0.4*	0.3
	(0.21)	(0.27)
_cons	4.1	5.5***
	(4.31)	(1.41)
N	135	135
N Countries	6	
R^2	0.15	0.48
Fixed Effects	Yes	No

Notes: Dependent Variable is innovative capacity measured by engineers per 100,000 male workers. Sample is Argentina, Chile, Colombia, Mexico, US and Venezuela. Pre-colonial population density measures the number of natives per square kilometer in 1492. Geographical controls include agricultural suitability, river density, average temperature, rainfall, altitude,distance from a coast, ruggedness of terrain and malaria. Bootstrapped clustered SE in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.